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**The Impact of the Fertilizer Sub-Sector Reform Program on the Demand for Fertilizer
in "Office du Niger", Mali**

By

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A Plan B Paper

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

MASTER OF SCIENCE

Department of Agricultural Economics

1998

ABSTRACT**The Impact of the Fertilizer Sub-Sector Reform Program on the Demand for Fertilizer
in “Office du Niger”, Mali****By****Youssouf Cissé**

The “Office du Niger” (ON) is the largest irrigated rice production area in Mali. In the ON, the use of chemical fertilizers is recommended in the cultivation of improved varieties of rice in all production systems.

Given the importance of chemical fertilizer in rice production in the ON, surprisingly little is known about the impact of the fertilizer sub-sector reform program on the demand for fertilizers and the capacity of the ON to support a private-sector fertilizer distribution system. Insights into these questions will ultimately help in assessing the potential for a vibrant and sustainable chemical fertilizer subsector in the ON. The primary objective of this paper is to describe how to carry out a study to assess the impact of the fertilizer reform program on the demand for fertilizer in the Office du Niger. It is planned that data will be collected from both primary and secondary sources in order to implement the proposed models and their extensions. Primary data will be collected from a stratified sample of 30 farms in each rice production system in the ON. Secondary data will be collected by consulting relevant reports written about the ON.

Empirical models based on the conventional linear programming framework will be built to represent a typical household in each rice production system in the ON. The models will be run using two types of price vectors: the input prices at the farm gate in the ON before and after the devaluation of the FCFA currency. In each case, it is possible to derive the aggregate potential demand for fertilizer by varying its price. As the price of fertilizer varies, different levels of input use become optimal and, in consequence, a series of price-quantity relationships is developed. The risk of yield variability in food crops and income variability from crop sales resulting from weather and prices will be incorporated through use of the minimization of total absolute deviation (MOTAD) model as developed by Hazell in 1971.

The results from the analysis should provide insights about the incentives for farmers to use chemical fertilizers and the capacity of the ON to support a private sector fertilizer distribution system.

This piece of work is dedicated to
my mother, *Doussou Coulibaly*,
Who never stood against my ambition to undertake further training,

and
my father, *Abou Cissé*,
who taught me that hard work and patience are the key to success in life.

ACKNOWLEDGEMENTS

I wish to express my thanks and appreciation to my major advisor, Prof. John Staatz, who supervised this plan B paper, providing intellectual stimulation and invaluable guidance. By reviewing the paper with patience he made useful suggestions and constructive criticisms. I am also grateful to Prof. Eric Crawford, Prof. Steve Hanson, Prof. Carl Liedholm for having accepted to be in my guidance committee.

I am grateful to USAID Mali for providing through the PARA project the financial assistance, which enabled me to undertake further training.

I would like to express my thanks and appreciation to many people for their help, intellectual and moral supports during my graduate program.

I would like to express my appreciation to all faculty and staff in the Department of Agricultural Economics, Michigan State University.

Lastly but certainly not the least, I am indebted to all the members of my family for their patience and sacrifice during my long absence for studies in the US. The smiles of my three children , Abdrahamane, Abdoulaye and Ibrahima gave me one more reason not to give up.

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LIST OF ABBREVIATIONS

BNDA	Banque Nationale de Développement Agricole (National Development Bank)
CMDT	Compagnie Maliènne de Développement des Textiles (Malian Company for the Development of textiles)
DNACOOOP	Direction Nationale de l'Action Coopérative (National Direction of Cooperative Action), Mali
DNSI	Direction Nationale de la Statistique et de L'informatique.
FAO	Food and Agricultural Organization
FDV	Fond de Développement Villageois (Village development fund), Mali
IFDC	International Fertilizer Development Center
LP	Linear Programming
MOTAD	Minimization of Total Absolute Deviation
ON	Office du Niger (Niger River irrigated agricultural development agency)
ODR	Operation de Development Rural (Rural Development Agency), Mali
PARA	Programme d'appui à la recherche agronomique
SCAER	Société de Crédit Agricole et d'Equipement Rural (Agricultural credit and input distribution agency), Mali
VCR	Value Cost Ratio

CHAPTER I - INTRODUCTION

1-1 - Problem Statement

Mali is a country located in the Sahelian zone of West Africa. The Malian economy is still dominated by the agricultural sector, which is characterized by its reliance on erratic weather conditions and poor soils. Stoorvogel and Smaling (1990) reported that Malian soils lost 8, 2, and 8 kg/ha of nitrogen (N), phosphorus (P), and potassium (K), respectively, during 1983. The projected annual losses for the year 2000 are 11, 4, 12 kg/ha for N, P, and K. Because of this situation, Malian soils require nitrogen applications, and many require phosphorus, potassium, and sulfur applications to maintain their nutrient balance and soil productivity (Henao *et al.*, 1982).

Indeed, fertilizer use will play a special role in meeting the twin challenges of sustaining food security and preserving the natural resource base. Fertilizer is complementary to the use of seed, water, and plant protection materials capable of shifting the production function and is essential for replenishing the nutrients removed from the soils. The growth in fertilizer use should be sustained by the introduction of policies and technologies to improve the efficiency of fertilizer use so that more output can be obtained from the same or a lower amount of fertilizer nutrients (IFDC, 1995). Only an efficient and environmentally sound fertilizer use can sustain high crop yields and prevent the degradation of the resource base (IFDC, 1995)

On the other hand, if fertilizer use is not managed properly and if fertilizer is used excessively, it can cause harm to the environment through nitrate leaching, eutrophication, and other externalities.

In the "Office du Niger" (henceforth ON), which is the largest Malian irrigated rice production area, the use of inorganic fertilizer (urea and ammonium phosphate) is recommended in the cultivation of improved varieties of rice in the intensive (Niono), semi-intensive (Kokeri), and non fully restored production (Kouroumari) areas. Figure 1 provides the map of the hydraulic systems in the ON area. The intensive system enjoys full water control and involves the use of a relatively high level of fertilizer. The semi-intensive system does not benefit from full water control in all areas of the field. Therefore, farmers in the semi-intensive system use lower doses of fertilizer than in the intensive system. The third system, called the non-restored area, is not maintained on a regular basis, and farmers use a relatively lower dose of inputs. Kamuanga (1982) reported from his study in the ON that 72% of the farmers used less than the recommended level of 100 kg of fertilizer (urea and phosphate), while 18 percent applied it at rates higher than 100 kg per hectare. Application rates reached the recommended level of 50 kg of urea only in one zone (the Sahel), which also had the highest rate of application for ammonium phosphate.

Given the importance of the chemical fertilizer in rice production at the ON, surprisingly little is known about the impact of the fertilizer sub-sector reform program on the demand for fertilizer in the rice production systems at the ON and the capacity of the ON to support a private-sector fertilizer distribution system. Insights into these questions will ultimately help in assessing the potential for a vibrant and sustainable chemical fertilizer subsector in the ON.

Elsewhere in Africa, for example in Senegal, Kelly (1988) reported that the major

SYSTEMES HYDRAULIQUES DU DELTA CENTRAL NIGERIE

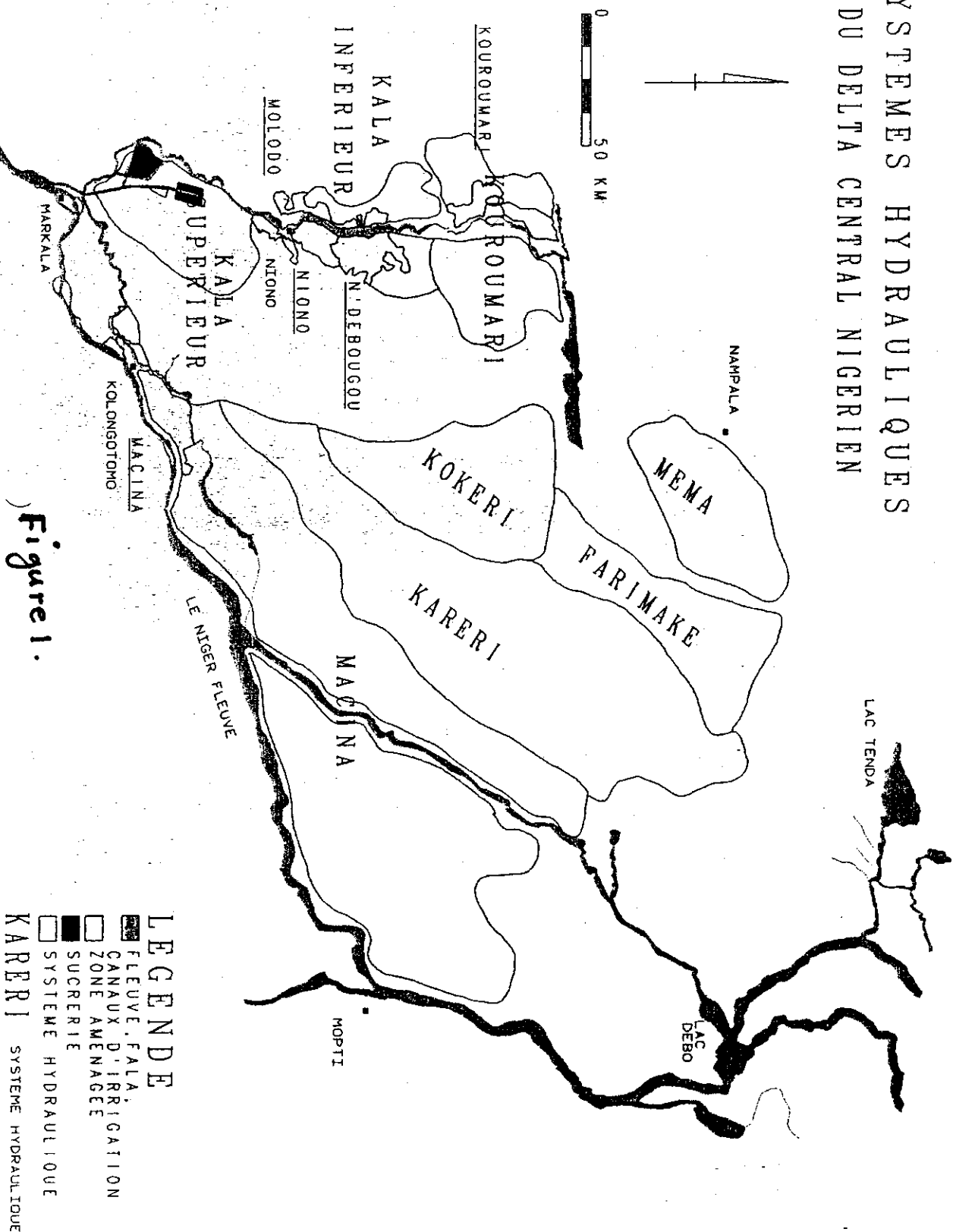


Figure 1.

reasons for the poor performance of the liberalization of the fertilizer market in the 1980s were the high risks and low payoffs of using fertilizer at unsubsidized prices, combined with credit constraints. In contrast, in some parts of sub-Saharan Africa, particularly in well-watered highlands, it appears that constraints to expanded use of fertilizer and improved seeds lie mostly on the supply side (Kelly, 1988). Dione *et al.* (1996) reported that the private sector in West Africa was still unable to satisfactorily fill the gap resulting from the elimination of parastatal enterprises in charge of input delivery before the structural adjustment reforms. The main constraints were as follows:

- 1) Complexity of the input delivery function: Input delivery required
- 2) Satisfactory financial availability, knowledge of the world market and also
- 3) Good technical knowledge of the inputs themselves.
- 4) Small size and poorly organized private sector: These characteristics prevented private sector from benefiting from scale economies.

One of the key questions is which of the above constraints is most binding in the ON?

1-2- Specific Issues

Until 1980 in Mali, the agricultural credit and input distribution agency (SCAER) was the monopoly parastatal in charge of the distribution of farm supplies and the provision of credit to farmers through the Rural Development Operations (ODRs). SCAER was abolished in 1981 by the government and replaced by the National

Agricultural Development Bank (BNDA), which extended credit either directly to farmers through guarantee of group liability of approved village associations or indirectly through ODRs or other Rural Development Agencies, such as the National Direction of Cooperatives (DNACOOOP). Both SCAER and the BNDA operated in relatively stable socio-economic and political environments. Today, however, there are many forces leading to change in the Malian fertilizer subsector. The main forces driving changes are:

i) The removal of subsidies

Fertilizer subsidies in Mali used to be high in the mid-70s (more than 50% of the actual fertilizer costs). The subsidies were intended to reduce the price of fertilizer, but they were substantially reduced in the late 70s and early 80s (to a level of about 15% to 25%) until they were abolished in 1987. Table 1 provides the prices of fertilizer in current and relative terms between 1970 and 1990.

Table 1: Fertilizer Prices in Current and Relative Terms

Year	Urea (CFAF/kg)	Ammonium Phosphate (CFAF/kg)	Price ratio		
			Urea/ Maize	Urea/ Paddy	Ammon. phosph./Paddy
1970/71	30	20	3.0	2.4	1.6
71/72	30	20	3.0	2.4	1.6
72/73	32	20	3.2	2.6	1.6
73/74	32	20	2.0	2.6	1.6
74/75	32	20	2.7	1.6	1.0
75/76	43	28	2.6	2.2	1.4
76/77	46	48	2.6	2.0	2.1
77/78	46	48	2.2	2.0	2.1
78/79	55	70	2.4	2.2	2.6
79/80	60	70	1.9	2.0	2.3
80/81	65	70	2.3	1.7	1.9
81/82	103	108	2.2	2.1	2.2
82/83	103	108	2.1	1.9	2.0
83/84	103	108	2.1	1.7	1.8
84/85	103	108	1.9	1.7	1.8
85/86	105	120	2.5	1.5	1.7
86/87	134	194	—	1.9	2.8
87/88	145	194	—	2.1	2.8
88/89	145	194	—	2.1	2.8
89/90	145	194	—	2.2	2.8

Source: adapted from Sijm (1992).

Table 1 provides the current prices of urea and ammonium phosphate in CFAF/kg in the second and third columns, whereas the relative official prices (fertilizer/cereal) are provided from the fourth to the last column. Since the suppression of SCAER in 1981/82, the prices of fertilizer were no longer fixed by official decree but announced, based on reference prices practiced by the cotton production agency CMDT

(for urea) and the “Opération Haute Vallée” (for ammonium phosphate). It can be seen from Table 1 that in absolute terms, the unit price of urea and ammonium phosphate followed an increasing trend from the 70s through the 90s. However in relative terms, both the prices of urea and ammonium phosphate compared to cereal prices decreased from the 70s to the mid-eighties before the complete removal of the subsidies. This decrease in the relative price of fertilizer in late 70’s and early 80’s was due in part to high cereal prices resulting from drought (e.g., in 1984/85) rather than explicit fertilizer policy. After the removal of the subsidies, the relative prices increased. Then the CFA devaluation took place on January 12, 1994, drawing more attention on the input and output price relationships.

Dione *et al.* (1996) found that the price of inputs registered a 71% increase between the 1993 and 1995 cropping seasons. They reported that many rice producers in Mali responded to this trend by reducing the level of fertilizer use by 11% (Dione *et al.*, 1996). This changing input prices hurt farmers and village associations that could not get access to formal credit because of their high level of indebtedness most. They were forced to rely on the informal source of seasonal credit from traders where the rate of interest ranged from 20% to 50% (Dione *et al.*, 1996).

Table 2 below presents the prices of fertilizer relative to the prices of paddy in each zone in the ON. It can be seen from table 2 that the relative prices were higher in the more intensive areas implying that paddy prices were lower in these areas .

Table 2: Relative Prices of Fertilizer in the ON in 1994/95

Zone	Absolute prices of fertilizer (CFAF/kg)	Relative Prices^(a)
Intensive (Niono)	Urea: 178	1.78
	AP: 172	1.72
Semi-intensive Arpon (Niono)	Urea: 178	1.66
	AP^(b): 172	1.61
Semi-intensive Arpon (Macina)	Urea: 165	1.37
	AP : 186	1.55
Non-Restored area	Urea: 165	1.35
	AP: 178	1.46

^(a) The relative price is the price of fertilizer over that of paddy in each Zone.

^(b) AP = Ammonium Phosphate.

Source: Derived from ON raw data by the author.

Figure 2 presents the prices (CFAF/kg) of paddy and rice along with the prices of urea and ammonium phosphate from 1992 to 1997. In general, there was an increasing trend in the prices of both paddy and rice from 1992 to 1996. But from 1996 to 1997 both paddy and rice prices dropped. The decrease in the prices of rice was more drastic. There was an increasing trend in the prices of both urea and ammonium phosphate. The prices of both fertilizers increased drastically after the currency devaluation in 1994 until 1996. The decreasing trend observed in the prices of both fertilizers from 1996 to 1997 was visibly less pronounced than in the case of paddy and rice implying that fertilizer prices outweighed paddy and rice prices over the same period.

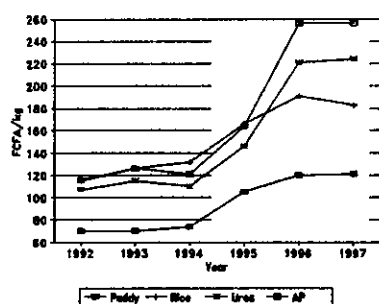


Figure 2 : Annual Prices of Paddy, Rice, Urea, and Ammonium Phosphate (AP) Prices in Mali, 1992-97.

Source: Derived from ON raw data by the author

Figure3

presents the prices of urea and ammonium phosphate relative to those of paddy and milled rice. The prices relative to paddy dropped from 1993 to 1995 implying that paddy prices

outweighed fertilizer prices over this period. But from 1995 to 1996, the inverse trend was observed. The prices relative to paddy dropped slightly from 1996 to 1997. The fertilizer prices relative to those of milled rice increased over the period 1994 to 1997 implying that fertilizer prices outweighed rice prices over that period. Since fertilizer is a critical input in rice production in the ON, an increase in its relative prices raises the issues of input cost and use efficiency.

Indeed, the relative prices on both tables 1 and 2 need to be compared to the marginal physical product or the marginal unit of rice produced from each unit of fertilizer, bringing about an allocative efficiency issue. In other words, one needs to compare the value of the rice produced with an additional unit of fertilizer (MVP of

fertilizer) with the fertilizer price in order to identify the efficiency with which fertilizer is used by farmers, the potential demand for fertilizer and any opportunity for costs reduction. In other words, only if the marginal value product of fertilizer exceeds its unit cost will further purchases of this input be profitable and the most profitable level of fertilizer will be that for which marginal value product of fertilizer (MVPn) equals its unique cost $P(X_n)$. In terms of demand, the graph of MVPn against the use of X_n may be interpreted as a farmer's demand function for this input indicating the quantity that he should purchase at various factor prices.

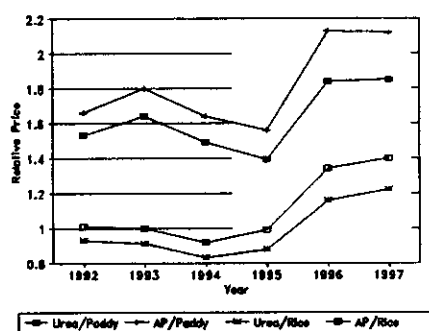


Figure 3 : Relative Prices of Urea and Ammonium Phosphate (AP), Mali, 1992-97.

Source: Derived from ON raw data by the author

ii) The liberalization of the input/output markets:

The Malian rice market was liberalized in 1986 and rice farmers in the ON were allowed for the first time to sell their production in the market. Prior to 1986, they were obliged to sell their entire marketable surplus, at the official price, to the ON rice mills. In addition, the fertilizer market was liberalized in 1994, attracting more attention to the input and output price relationships and stimulating the debate about input demand and supply issues.

iii) The Devaluation of the CFAF currency:

On January 12, 1994, the exchange rate between the CFA franc and the French franc dropped by half, from 1 FF = 50 CFAF to 1 FF= 100 CFAF. The argument for devaluation is that changing the nominal exchange rate will increase incentives for domestic production of tradable goods (exportable goods and import-substitutes) and discourage domestic consumption of those goods (Staatz *et al.*, 1994). This process is supposed to lead to re-establishment of external balance in foreign trade and greater intersectoral balance in the domestic economy.

Sanders *et al.* (1996) argued that the devaluation in 1994 will have a short-run effect in reducing the demand for imports of inorganic fertilizer, but that a long-run effect will be to increase prices of domestically produced food as imported agricultural products become more expensive. However, to the author's knowledge, no empirical studies have been carried out on the impact of input/output market liberalization and the 1994 currency devaluation on the fertilizer market in the ON. Malian economic

policy-makers and researchers, however, need to know the answers to two key questions.

First, how have market reforms affected the demand for and supply of fertilizer in the ON? The answer will depend in part on how these changes have affected the profitability of producing rice and other commodities in the ON. Second, what actions (if any) should be implemented to improve the performance of the inorganic fertilizer subsector in the ON? The relevance of the foregoing questions is at three levels. First, the ON has been the most important rural development agency in Mali with regard to irrigated rice production, processing and marketing. Since the early 80s, the ON has become part of a comprehensive reorganization process under the structural adjustment programs in order to improve its performance, but particularly to increase the self-reliance and socio-economic position of its rice farmers. It is believed that the reforms within and outside the ON open the perspective that the country might become a competitive and self-sufficient producer of rice in the 1990s (Sijm, 1992). Therefore, it becomes important to carry out a study in order to answer some of the questions that policy makers and researchers are concerned about.

Second, a study on demand for inorganic fertilizer can enhance the efficiency of resource planning on the supply of fertilizer and related inputs. The knowledge about the importance of factors affecting demand can enable the private sector to act not only on the planning of supply but also on relaxing the factors that constrain the fertilizer demand at the farmers' level. Finally, policy makers interested in transforming agriculture in general in Africa and specifically in Mali need empirical knowledge not only at the macroeconomic level but also at the microeconomic level in order to see

whether the market reforms are performing well.

This paper outlines an approach to answering research questions about the different rice production systems in the ON:

- (1) What is the level of the demand for fertilizer at the ON given current
And Possible future prices?
- (3) At what level can ON support a private-sector fertilizer distribution
system?

These research questions will be answered against the working hypotheses stated below. We have two working hypotheses related to the demand for fertilizer at the farm level after the market reforms:

- 1) Effective demand for fertilizer still exists across rice production systems
in the ON given current prices
- 2) There exist a production and a fertilizer demand levels at which the ON
can support the private distribution system private sector

The primary objective of this paper is to describe how to carry out a study to assess the impact of the fertilizer sub-sector reform program on the demand for fertilizer in the Office du Niger. The specific objectives of such a study would be:

- (1) To evaluate the potential demand for fertilizer by farmers in the ON rice
production systems,
- (2) To assess the capacity of the ON to support a private sector fertilizer

distribution system.

- (3) To provide from the results of the study insights about the incentives of farmers to use fertilizer and the costs involved in supplying it. This procedure will help evaluate the capacity of the ON to support a private sector fertilizer distribution system and suggest any policy changes needed to overcome problems.**

CHAPTER II - THE SETTING

2-1- Introduction

This chapter reviews the effect of structural adjustment policies on the fertilizer subsector, with particular attention to empirical studies. This discussion helps to understand the conceptual framework and the research problems. Section 2-2 reviews market reform in the ON. Section 2-3 discusses the fertilizer subsidy removal. Section 2-4 discusses studies that focus on the impact of the CFAF devaluation on the agricultural sector.

2-2- Market Reform in the Office du Niger

Market liberalization is implemented through a number of measures including price liberalization, the promotion of the private sector, removal of quantitative and administrative controls, reduction in the role of the state in direct buying and selling of goods, and actions to increase the efficiency of operations which remain with the state. The full process, called structural adjustment, has been implemented in Mali for many years. The adjustment policy towards liberalization and privatization started in Mali in 1981 with the cereal market restructuring program, aimed at raising farmers' incentives to produce more for the market (Dione, 1989). The rice market was liberalized in 1986, and rice farmers in the ON were allowed for the first time to sell their production in the market after deduction for water charges and credit. However, the ON was required to defend a minimum guaranteed producer price of 70 CFAF/kg for paddy. Thus, when the market offered less than 70 CFAF/kg, farmers sold paddy to the ON, adding to the

paddy the ON already collected to reimburse it for water and other inputs, thereby creating a large quantity of paddy to be handled.

Dembélé (1994) reported that the ON was caught in the reform process with three structural constraints, the main one being that the ON administration had no prior marketing expertise and had to learn how to deal with private rice traders. The ON was increasingly unable to fulfill the rice marketing functions as satisfactorily as before. Cisse *et al.* (1993) reported that farmers in all systems were complaining about the late removal of paddy by the ON from the villages, the late payment of the money when paddy was removed, the nonpayment of the rebate related to the bags and the weight differential between paddy weighed in the villages and the same paddy reweighed by the ON at the rice processing factories. But despite all the problems raised by farmers in the early stages of the reforms, farmers preferred to deal with the ON instead with the private channel, which they perceived as full of risk and uncertainty. As reported by many farmers, the uncertain open market price of rice has made the production of vegetables (where this is possible) an important enterprise in complementing incomes (Cisse *et al.*, 1993). However, by 1994, the situation had changed. Diarra (1994) indicated that the producer price offered by the ON (70 CFAF/kg) was not that favorable. By 1994, the average paddy prices have increased since liberalization. It also appeared that the own-mill-sell or the buy-mill-sell activity was more profitable than custom milling activity. Once farmers were free to sell to others, the small, private mills quickly outbid the ON for rice by offering prices higher than 70 CFAF/kg. Diarra (1994) reported that, at market prices of milled rice as low as

CFAF 122 per kg, many private processors were still making money from own paddy processing or buy-mill-sell rice activity. However, major constraints were found to be detrimental to the performance of the own milling activity. Indeed, if the quality of paddy processed happened to be poor, any significant decrease in the market price of milled rice could undermine the profitability of this activity. Storage costs combined with the erratic rice import policies also appeared to be very important factors affecting the farm prices of milled rice, the marketing costs of milled rice, and the profitability of own paddy milling activity.

In the ON, most of the fertilizer consumed was obtained through seasonal credit from the National Bank for Agricultural Development (BNDA) and the Dutch-financed Arpon project, through its lending agency called "Fonds de Developement Villageois" (FDV). Farmers in the ON reported that the price of fertilizers supplied by the FDV was high (5370 CFAF/50kg of urea, that was 107.4 CFAF/kg and 6160 CFAF/50kg of ammonium phosphate, that was 123.2 CFAF/kg), whereas the price offered by the ON for one kilogram of paddy was low (70 CFAF/kg).

Furthermore, the farmers interviewed by Cisse *et al.* in 1993 questioned why the price to be paid for fertilizer was not disclosed at the time of delivery. They suggested a decrease of the price of fertilizer if the price of paddy could not be increased. It was in this socio-economic context that the liberalization of fertilizer market happened, drawing more attention to the input/output price relationships, a critical determinant in farmers' decision-making regarding rice production.

The complete liberalization of the input markets in 1994 stimulated the

participation of private dealers in the supply of fertilizer, enabling more competition and thereby offering more choices to farmers in fertilizer supply. The problem was that in most cases, farmers, who lack technical and functional knowledge about fertilizer, couldn't verify the quality and the right type of fertilizer. Maïga (1993) reported that the FDV undertakes the control of fertilizer quality by simply checking the color and the shape of the granules and by reading the documents provided by traders. However, the FDV refuses to take responsibility for any wrong type of fertilizer delivered to farmers. In addition, among other constraints, inadequate financing of private firms and of fertilizer purchases at the farm level have been identified as major problems following market reforms (Gerner *et al.*, 1996).

Minot (1991) addressed explicitly the impact of a fertilizer subsector reform program in order to provide an understanding of fertilizer use in Cameroon. He reported that privatization there had sharply reduced costs, so that farm-level fertilizer prices rose by only 28% from 1988 to 1990. Minot reported that without any reduction in cost, farm-level fertilizer prices would have doubled over the first two years of the program. However, from the point of view of the farmer, of course, this was still a significant increase. Moreover, with a 50% drop in coffee prices and late payment for coffee, a substantial drop in fertilizer demand has been observed, taking the form of fewer users and smaller quantities bought by users, implying that both the price of coffee and the payment period were factors affecting the consumption of fertilizer. However the computation of the value cost ratios would have shed some more light on the issue of fertilizer demand -related problems.

2-3- Fertilizer Subsidy Removal

The term "subsidy" is defined in the Longman Dictionary of contemporary english as the money paid, especially by the government or an organization, to make prices lower or to make it cheaper to produce goods. As such, input subsidies remain a sensitive issue in the food policy debate, not only in Mali but also in many parts of the world. Gittinger (1982) defines the term subsidy as a transfer payment, that is, a payment made without receiving any good or service in return (except, perhaps, the service involved in making the transfer payment). He distinguished between two types of subsidy: a direct subsidy and an indirect subsidy. A direct subsidy is a payment made by a government to a producer (such as a farmer) and is a direct transfer payment. An indirect subsidy may occur when manipulation of the market produces a price other than that which would have been reached in a perfectly competitive market. The benefit received by a producer or consumer as a result of this difference constitutes an indirect transfer payment through money taken by the government from some people to give to others. The government may deficit finance the transfer. In that case, the resulting deficit imposes costs on others, e.g., through inflation or higher interest rates.

In Mali, some proponents of fertilizer subsidies believe that their removal through the structural adjustment programs will pose major risks to food security (Sijm, 1992). Coulibaly (1993) reported that there are claims in the literature that the removal of fertilizer subsidies have decreased fertilizer consumption in Mali since 1982 and therefore contributed to the expansion of area under cultivation rather than improving

the productivity of existing fields. Opponents to subsidies argue that their use encourages wasteful and misdirected use of resources because the prices no longer reflect real costs (Bumb *et al.*, 1992). Input subsidies in this view therefore are generally considered inefficient as a mean of increasing output and can be eliminated without any harmful economic consequence.

Streeten (1987) reported that low prices of agricultural products are often partly offset by subsidies to inputs such as fertilizers, credit, tractors, pesticides, seeds and the service of infrastructure. In some cases the subsidies are intended to compensate for the protection of high-cost industries, such as fertilizer, farm chemicals and tractors. They are then 'distortions' that compensate for other 'distortions'. Streeten (1987) argued that subsidies to inputs can be useful to encourage farmers to use a new input (that is, to help them learn what the MVP of the input is), or where external economies are important, so that benefits accrue to others, in addition to the farmer using the input. But subsidies also often have some undesirable effects. First, they tend to encourage the inefficient use of subsidized inputs, for example, the waste of subsidized water. Second, they encourage the use of certain types of input, such as fertilizer, but not of the most abundant factor, labor. Consequently, they may encourage substitution of a scarcer factor for a more abundant factor. Third, subsidies may benefit mainly larger or richer farmers at the expense of the poor and small farmers.

The second point cannot be applied to the Malian context, where fertilizer is a complement to labor in crop production in most parts of the country. Indeed, fertilizer increases the yields of both crops and weeds, which leads to higher labor demand. Thus,

subsidized fertilizer may increase demand for labor. The third point was observed in Korea and in Kenya, where subsidies in fact benefited the large and rich farmers and, if accompanied by rationing, can actually deprive the small and poor farmer. Fourth, if different crops, such as cotton, wheat and rice, use the subsidized input, say water, in different proportions, the subsidy will encourage increased production of the crop using most of the input, at the expense of the others, which is an unintended result. Fifth, if the subsidized input is exported at a profit, or smuggled abroad, the price paid by the domestic producer can be higher than it would have been in the absence of the subsidy, or it may cease to be available altogether.

Streeten (1987) reported that an unintended result from input subsidy policy was observed in Bangladesh. He described the event as follows: Bangladesh reduced its initial large fertilizer subsidy after 1979 from 10 per cent of the development budget (and 50 per cent of the fertilizer unit cost) to 2.4 per cent (and 17 per cent of the fertilizer unit cost). This, combined with large increases in irrigation and water control investment, resulted in more fertilizer being available to farmers, and a growth in fertilizer sales of over 10 per cent per year, whereas before there were frequent shortages and high unofficial prices. Renfro (1992) explained that part of the observed growth in fertilizer consumption in Bangladesh was due to the consistently high marginal return of fertilizer to crop production and to the relatively low fertilizer price elasticity of demand.

Roth and Abbot (1990) report similar results from their study in Burkina Faso. Roth and Abbot explained that removing input subsidies would have negligible effect on output, demand, prices, or trade in Burkina Faso, because the marginal value of

fertilizer exceeded the unsubsidized price in all regions. Gittinger (1982) explained that if a farmer is able to purchase fertilizer at a subsidized price, that will reduce his costs and thereby increase his net benefit, but the cost of the fertilizer in the use of the society's real resources remains the same. The resources needed to produce the fertilizer (or import it from abroad) reduce the national income available to the society. Hence, the full cost of the fertilizer must be included for economic analyses in order to remove the distortion from the subsidized price.

The foregoing literature shows how complex the debate is regarding fertilizer subsidy removal on the demand and supply sides and on the level of output. How this policy has affected the irrigated rice production system in terms of efficiency, profitability and demand for fertilizer in rice production needs to be answered. One important lesson we should draw from the debate regarding fertilizer subsidy removal is that the demand for fertilizer will likely exist so long as its use by farmers remains profitable.

2-4- The CFA Franc Devaluation

Sanders *et al.* (1996) argued that the devaluation in 1994 will have a short-run effect in reducing the demand for imports of inorganic fertilizer, but a long-run effect will be to increase prices of domestically produced food as imported agricultural products become more expensive. Staatz *et al.* (1994) raised the issue that "if the aim of the devaluation is to change relative prices of tradables and non-tradables, the first question to ask is whether it has had this effect. Have prices really changed in the economy? If so, what has been the pattern?" A study carried out by Boughton *et al.*

(1994) revealed that the 50% devaluation of the CFA franc resulted in a 40% increase in the cost of imported fertilizers, leading to a reduction of the profitability of intensive maize. Dembélé (1996) reported that a recent studies by IFDC-Africa on restoring and maintaining the productivity of African soils showed that “the primary effect of the withdrawal of fertilizer subsidies and the devaluation of local currencies has been to reduce the value cost ratios (VCR¹) of fertilizer use on rainfed food crops to well below two. Heady and Dillon (1961) defined the marginal productivity of X_i , the i -th input as follows:

$$dY/dX_i = b_i \cdot Y/X_i$$

where Y is production or output and b_i the estimated coefficient with respect to the i -th input X_i . Heady and Dillon (1961) stressed that the most reliable, and perhaps the most useful estimate of marginal productivity is obtained by taking X_i at its geometric mean, i.e. at the value where $\log X_i$ assumes its arithmetic mean. Also Y should be the estimated level of output when each input is held at its geometric mean. The marginal value

¹ The VCR is an efficiency indicator in measuring the economics of input use. For fertilizer use we have:

$$VCR = MVP_r/MC_r \text{ or } VCR = FRC \cdot (\text{product unit price/fertilizer unit price})$$

where FRC is the fertilizer response coefficient. Thus, Value/cost ratio is determined by the fertilizer response coefficient, fertilizer price paid by farmers, crop price received by the farmers, and associated fertilizer costs (such as labor cost and credit costs) borne by the farmers.

productivity of X_i can thus be obtained as follows:

$P_y dY/dX_i = b_i Y/X_i P_y$ where P_y is the price per unit of output Y .

Tessio (1996) found that recent CFAF devaluation increased the price of fertilizer from 143 to 275 CFAF/kg, leading to a sharp decrease of VCR for all food crops in all regions in Togo. He reported also that Togo has embarked on a Structural Adjustment Program (SAP) since 1983. The subsidies on fertilizers were removed gradually until 1987. This removal also contributed to the decrease of the VCRs.

In the ON, many studies treating questions related to the profitability of rice cultivation before and after the devaluation of the local currency have been carried out, but none of them explicitly addressed questions related to efficiency, profitability and potential demand for fertilizer. For example Deme (1993) provided the structure of costs and returns per hectare of paddy production without indicating what proportion of the costs was attributed to fertilizer. In simulating the effect of the currency devaluation, some of the critical factors should have been taken into account. They are:

- i) the frequent variation of the price of products and,
- ii) the ability of farmers to buy fertilizer.

The implementation of scenarios involving the above factors could have provided more insight into the effects of the currency change on the profitability of fertilizer in rice production.

After the CFAF devaluation, Coulibaly *et al.* (1994) suggested other exogenous factors like rainfall and diseases were critical in explaining the level of paddy production.

They argued, for example, that the declining yield in the 1994/95 cropping season in the ON could not be attributed to fertilizer since the quantity used per hectare did not change during the indicated year, implying that the absolute price increase of fertilizer following the devaluation did not discourage farmers from using the same quantity of fertilizer as before. This implication was contrary to the conclusion of their study, that the currency devaluation prevented farmers from increasing the quantity of fertilizer used per hectare of rice. In figure 2, the increasing trend observed in the relative prices of fertilizer in the ON indicated that the relative prices of fertilizer have increased from 1994 to 1997 bringing about the issues of input cost and use efficiency.

The study carried out by Del Villar et al. (1995) was intended to assess the impact of devaluation on the income and strategies of rice farmers at the ON. One of the findings of the study was that there was a differential impact of devaluation on the different types of farmers in the ON. The study found that the return per hectare of rice production has increased but was variable from one farmer to another within a given system and from one system to another. However, which specific type of farmers won or lost from devaluation was not stated in the report. Similarly, issues related to effective or potential effective demand for imported goods like chemical fertilizers were not explicitly addressed. For example, the expected increase of the level of inflation to 30% and the price of fertilizer by 15% were stated in the report as major sources of concern about the profitability of fertilizer and other imported farm inputs. Obviously, this concern calls for an assessment of the impacts of devaluation on the demand and supply of these inputs.

Diagana *et al.* (1995), using a linear programming framework, reported that the price changes brought about by the currency devaluation did not influence the cropping pattern and technology choices by peanut and millet growers in Senegal. Despite this finding, Diagana *et al.* (1995) suggested further analysis involving a multiperiod programming approach taking into account the aspect of risk in the model.

CHAPTER III - CONCEPTUAL APPROACH OF THE DETERMINANTS OF FERTILIZER DEMAND

3-1- Demand for Fertilizer Under Perfect-Market Conditions

Assuming that profit maximization is the ultimate goal of farm business, profit will be maximized where the level of inputs is set such that the marginal value product (MVP) of variable inputs are equated with their marginal factor costs (MFC), given competitive markets, certainty, and no input supply constraints. In other words, profit will be maximum when the marginal physical product of input use is equal to the price ratio of input and crop output ($MPP=PF/PQ$). The magnitude of all these variables, hence the economics of fertilizer use, can be manipulated through fertilizer policy and through biological research that raises the marginal physical product of fertilizer. The difference between the MVP and the acquisition cost of the resource indicates the scope of resource adjustment necessary to attain the economic optimum.

3-2- Demand for Fertilizer Under Imperfect-Market Conditions

As reported by Mudahar (1978), the knowledge about yield response to applied fertilizer forms the analytical basis for the economic analysis of fertilizer use at the farm level, which, in turn, forms the basis for fertilizer policy formulation at the national level. The fertilizer response is determined by a large number of factors, including crop, crop variety, irrigation, soil quality, type of fertilizer material, management, and other agro-climatic factors. Given the fertilizer response function, the optimum level of fertilizer use is determined by economic factors, including constraints and risk associated with

fertilizer use. Given these considerations farmers will use fertilizer only if its use is expected to be profitable.

Given a budget constraint due to cash flow problems (imperfect capital market), the level of fertilizer use may lower than the economic optimum. Under the budget constraint, the level of fertilizer use can be expanded by relaxing these constraints through appropriate credit. In the short run and no budget constraint, the optimum level of fertilizer use can be increased by lowering the input/output price ratio (e.g., through fertilizer subsidy and/ or crop price support policies). Improved roads, by lowering transport costs for both inputs and outputs, also raises farm-level output prices and lowers farm-level input costs, thereby making fertilizer use more profitable.

Mudahar (1978) stressed that in the long run, fertilizer use can be increased by raising its productivity through an upward shift in the response function (that is, increasing MPP). This can be accomplished through developing better fertilizer materials, better management practices, and better crop varieties with higher fertilizer response. Finally, water, being a key complementary input to fertilizer use, can shift the response function through better irrigation facilities and water management.

3-3- Rule of Thumb: the VCR

McIntire (1985) argued that monetary return is the basic determinant of fertilizer demand. In other words, farmers will not use fertilizer if it is not profitable. Logically, profitability of use can be regarded as a prime factor, for farmers' acceptance of a particular input depends upon its profitability. Evidently, the relative level of fertilizer price vis-a-vis agricultural product prices determines the rate of use.

However, the extent to which the price factor determines levels of fertilizer use and ultimately, growth in demand, needs to be examined in the light of a given situation. The price of fertilizer does not affect the demand for it so long as additional returns cover the additional cost. In the areas where the range of profitability of fertilizer use is sufficiently high and yet rates of fertilizer applications are low, implying that farmers are using fertilizer at sub-optimal levels, the price of fertilizer is hardly a disincentive to the farmer in extending fertilizer demand. Possibly, the level of fertilizer demand is significantly affected by the technological change, *i.e.* variations in technical coefficient of output response to fertilizers. This study intends to examine the relevance of changes in product and factor prices on the demand for fertilizers by farmers at the ON in the changing environment.

Mudahar (1985) reported that the profitability of fertilizer use can be determined by evaluating value cost ratios (VCR). The VCR is an efficiency indicator which compares the value of the incremental crop output (MVP) due to the use of fertilizer with the per unit cost of fertilizer used (MFC) (Tessio, 1996). It highlights that both expected revenue and input cost determine the viability of fertilizer use (Demeke *et al.*, 1996).

If it is efficient to use fertilizer up to the point of $MVP = MFC$, then efficiency requires use of fertilizer until $VCR = 1$. However, to motivate farmers to use fertilizer in the risky environment, some higher levels of VCR have been suggested. Tessio (1996) reported, for example, that the minimum VCR required is 2 in order to induce farmers to use fertilizer. For sub-Saharan Africa many authors argue that the minimum

acceptable VCR has to be greater than 2 to motivate farmers to adopt seed-fertilizer technology given the level of risk involved. For Mali, for example, Sijm (1992) reported VCRs for the fertilization of millet ranging from 1.2 to 2.1, and for rice, ranging from 2.2 to 3.8. He suggested that for poor and risk-averse peasants who have to operate under rainfed agricultural conditions and high marketing uncertainties, such as in Mali, a VCR of at least 3.0 might be more useful to encourage farmers to invest in fertilizer. However, Mudahar (1978) argued that when the farmer makes a decision to use fertilizer based on MVP greater than or equal to 2 MFC decision rule, he or she is making an irrational decision because the farmer can increase his profit by using more fertilizer up to a point when the MVP = MFC equality is satisfied (*i.e.*, where VCR = 1). Mudahar pointed out that farmers in Asia, Africa, and Latin America are economic men and women and make rational decisions within their decision environment. In their own calculations, farmers tend to use fertilizer to a point, which roughly equates MVP with MFC, in the absence of budget and fertilizer constraints.

Mudahar provided two possible explanations for the discrepancy between farmers' decision rule of MVP = MFC to determine the level of fertilizer use and the perception that in determining fertilizer use farmers are guided by the decision rule of MVP greater than or equal to 2 MFC. The first explanation is that the alleged decision rule is not a correct representation of farmers' decision-making process of determining optimum fertilizer dose. The second explanation is that the rule is correct but oversimplifies the process of determining optimum fertilizer dose. These explanations were tested by using nitrogen response function for rice under alternative assumptions

and policy regime in Orissa (India) and Arkansas (US). For standard risk-neutral model, the optimum fertilizer dose was determined by assuming (1) $MVP=MC$ decision rule, (2) no yield or price risk, (3) no fertilizer or budget constraint, (4) no credit cost, and (5) no other fertilizer-related costs. Under these assumptions, the derived optimum fertilizer dose is very high and the corresponding MVP/MC ratio was one. In order to test $MVP \geq 2MC$ (or $MVP/MC \geq 2$) decision rule, the optimum level of nitrogen (N) from adjusted risk-neutral model was estimated first. Next, the MVP and MC were estimated from standard risk-neutral model by using N determined by the adjusted risk-neutral model. The corresponding MVP/MC ratio turned out to be 1.39, which was less than 2. Similarly, an estimate of MVP and MC from standard risk-neutral model were made by using the optimum level of N from the adjusted risk-aversion model. The corresponding MVP/MC ratio turned out to be 1.94 for Orissa. For Arkansas this ratio was 1.67. In both cases MVP less than 2MC were observed. However, for Orissa the values of MVP and 2 MC were so close that it was tempting to accept the validity of $MVP \geq 2MC$ decision rule for fertilization. However, it was concluded that since the case of Orissa could also be a mere coincidence, there was a need to estimate these coefficients under different conditions (Crops, varieties, soil types, and environment) to further test the hypothesis. However, Mudahar pointed out that it may not be the best strategy to generalize the $MVP \geq 2MC$ decision rule to determine farmers' fertilizer adoption and use criteria. Rather all the relevant variables need to be incorporated since their importance varies across farms, cropping systems, regions, and policy programs. In any case, we need to bear in our mind that the target VCR may need to

be high enough to motivate farmers to use fertilizer in a risky environment (*e.g.*, VCR = 2). This higher level of VCR is different from the efficient level of fertilizer use with a VCR equated to 1.

In general in the ON, farmers face many constraints affecting their decisions to use fertilizer. The first critical factor affecting the level of fertilizer used for rice production in the ON is the access to seasonal credit from formal sources (FDV and BNDA) and from informal sources (relatives, moneylenders, traders). The second critical factor affecting the level of fertilizer used involves various factors like the price of the fertilizer itself, the price of paddy in the market, the availability of family and hired sources of labor, the size of the rice plot, the quality of the rice plot, the level of the interest rate, and farmers' perception about risk.

Another serious constraint facing the fertilizer delivery operations in the ON zone is the poor condition of the rural roads during the rainy season. This makes difficult, if not impossible, the delivery of fertilizer to farmers at the right time, right place and right quantity. In most cases fertilizers are delivered many months ahead of the right time because of the inaccessibility to farming areas at the rainy season. Then fertilizers are stored in poor conditions before their application. During the storage period, the quality of the fertilizers decreases while at the same time the interest payment increases, aggravating the high default rate in credit reimbursement. For example, Weijenborg (1993) reported that the loan recovery rates (percentage of loans due) by the FDV agents in the ON were only 1% and 5% in February and March 1993, respectively. As a consequence, the amount of overdue loans in 1993 cropping season

accounted for 44% of the total amount of credit disbursed, reducing drastically the total liquidity for lending. Weijenborg also reported that in 1992, the rate of repayment of the loan disbursed by the BNDA in the ON was so low that the BNDA expressed a serious concern about its lending activity in the future. Both the FDV and the BNDA were seeking the best strategy to overcome the problem of low repayment rates and cutting down their operating costs. It becomes clear that any improvement in the logistics and transportation systems and credit arrangements may help improve coordination and productivity.

Another factor, which can be a potential constraint to the demand for fertilizer is that most of the rice production systems in the ON are not fully, restored. This creates a high risk related to fertilizer use and its payoff. Moreover, the low rate of credit reimbursement by most farmers in the ON prevents them from gaining access to fertilizer from the FDV.

3-4- Risk Considerations

The amount of fertilizer that any farmer will use will depend on anticipated yield response, expected product prices, fertilizer costs, capital stock and/or credit availability, the degree of risk and uncertainty that the farmer must take and his ability to absorb such risk (Falusi, 1973).

Given the input prices, returns from fertilizer use vary greatly on account of changes in size of response due to variations in climatic and physical factors. Physical properties of soil, availability of supplementary nutrients, and climatic and rainfall conditions affect the size of response to a considerable extent. Among these, a close

relationship exists between rainfall and crop response to fertilizer use, even in the ON during the pre-irrigation period.

Mudahar (1985) reported that the factors contributing to low fertilizer demand include (1) low fertilizer response, (2) high fertilizer cost, (3) low crop prices, (4) high risk of losing money as a result of the variability in fertilizer response and prices, (5) lack of cash or credit, (6) lack of knowledge, and (7) lack of complementary farm inputs such as fertilizer-responsive crop varieties, water, and insecticides. Gerner *et al.* (1996) found in Africa that in addition to aggregate fertilizer supply constraints, high procurement and distribution cost, timely availability of the right types of fertilizers, foreign exchange constraints, lack of adequate financing of private firms and of fertilizer purchases at the farm-level have been identified as major problems following market reforms. In Ethiopia, Demeke *et al.* (1996) found that there is a relationship between input market and grain market performance. In other words, the performance of the grain marketing system in Ethiopia strongly influences the profitability of fertilizer use by farmers. They concluded that efforts to reduce grain-marketing costs should be viewed as a critical component in the overall strategy to stimulate fertilizer demand and crop productivity.

In the regions where irrigation facilities are inadequate, for example in the semi-intensive and non-restored area in the ON, the amount and distribution of rainfall influences the level of fertilizer use considerably. Moreover, where fertilizer application is spread over two to three of applications, *i.e.* as a basal dose and top dressings, the amount of rainfall has a greater impact on rates of applications. In general, use of fertilizers varies with amount and regularity of rainfall.

In the conditions of irrigated farming, for example in the intensive system in the ON, where availability of water can be regulated as per cropping schedule, yield uncertainty is considerably reduced. Secondly, intensity of cropping increases under irrigated conditions; and fertilizer needs are felt more on account of continued cropping-sequence or multiple cropping. Thus, the response to fertilizer use is higher when irrigation is available. Therefore, the extent of irrigation plays a vital role in determining levels of fertilizer use. Rates of application of fertilizers increase with cultivation of higher yielding varieties, and the extent of adoption of these varieties stimulates growth in fertilizer demand.

The factors affecting the use of fertilizer at the ON have been discussed in section 3-3. These factors are sources of high risk and uncertainty related to the use of fertilizer and its payoff. One of the consequences of this problem is that the recommended levels of fertilizer from agronomic experiments are not applied at the farm level. Most farmers in the ON were feeling insecure after the removal of the guaranteed marketing outlet at official producer prices. Indeed, prices of input and output fluctuate with the changes in supply and demand. Rice yields vary substantially with the variable level of rainfall and irrigation water, the outbreak of weeds, insects and diseases.

The occurrence of the foregoing events results in income variability. However, one of the challenging objectives of any household head in any year in the ON is to obtain a minimum income from rice production to meet the household's financial obligations. Another challenging objective for any household head in the ON in any year is to meet the minimum level of rice self-sufficiency. The quantity of rice needed to

cover the minimum level of self-sufficiency varies across systems in the ON and can reach on average 40 per cent of the total rice production (Cisse *et al.*, 1993). This consideration must also be included in the analysis.

3-5- Financial and Economic Analyses

Financial and economic analyses are complementary in that the financial analysis takes the viewpoint of the individual entrepreneur and the economic analysis that of the society as a whole. Despite the complementarity between the two concepts, three important distinctions must be kept in mind (Gittinger, 1982).

First, in economic analysis taxes and subsidies are treated as transfer payments to or from the government, which acts on behalf of the society as the whole, and are not treated as costs. In financial analysis taxes are treated as a cost and subsidies as a return.

Second, in financial analysis, market prices are normally used. These take into account taxes and subsidies. From these prices come the data used in the economic analysis. In economic analysis, however, some market prices may be changed so that they more accurately reflect social or economic values. These adjusted prices are called "shadow" or "accounting" prices.

Third, in economic analysis, interest on capital is never separated and deducted from the gross return because it is part of the total return to the capital of the society as a whole and because it is that total return, including interest, that economic analysis is designed to estimate. In financial analysis, interest paid to external suppliers of money is deducted to derive the benefit available to the owner of capital. But, interest imputed or

“paid” to the entity from whose point of view the financial analysis is being done is not treated as a cost because the interest is part of the total return to the equity capital contributed by the entity. Hence, it is a part of the financial return that entity receives.

Barry (1994) reported that in most developing countries, it is common to note that resources are not allocated efficiently because either input markets or output markets, or both, function imperfectly, owing to not only market failures, but also to government interventions, through its fiscal and pricing policies. Examples of government interventions are protective tariffs, import bans, pan-territorial and pan-seasonal prices. With such interventions, market prices may differ from social opportunity costs and government-induced prices may lead to suboptimal resource allocation. In this respect, private profitability may differ from social profitability, which is the true measure of the efficiency of resource allocation because inputs and output are valued at their opportunity costs or shadow prices.

Assuming that the domestic market prices of agricultural inputs and products were distorted before the CFAF devaluation in 1994 means that these prices did not reflect their scarcity value (social opportunity cost) because of government intervention. The economic analysis uses prices from which all market distortions or taxes have been removed. All subsidies and taxes are considered as transfer payments between groups of producers or consumers in the same country. Furthermore, if any inputs or products are imported, then not only must taxes and subsidies be removed in the valuation of these goods but also an adjustment be made for the rate of exchange.

Stryker *et al.* (1987) found that the Malian local currency was overvalued by 33-

37 percent during 1981-1985 period. The method employed consisted of correcting the level of the official exchange rate (E_0) by adding a term that adjusts it to the rate that would need to prevail in the market for foreign exchange if there were no current account deficit.

For small deviations, this equilibrium rate of exchange E' can be approximated

$$\text{by: } E' = E_0 + E_0 (\text{DEF} / (e_m \text{EXP} + e_d \text{IMP}))$$

Where E_0 is the official exchange rate, DEF is the current account deficit, IMP is the existing level of imports, EXP is the existing level of exports, e_m is the elasticity of supply of foreign exchange, and e_d is the elasticity of demand for foreign exchange. The values of these elasticities were roughly estimated as $e_m = 1.0$ and $e_d = 2.0$. Stryker *et al.* (1987) argued that if the distortions in domestic prices resulting from price controls and from trade taxes and controls were accounted for, the exchange rate would almost certainly be even more overvalued because of the high tariffs and the system of import controls. Salinger and Stryker (1991) argued that in Mali, like in all CFAF countries, for several years, the equilibrium exchange rate has been above the observed or official exchange rate because of unsustainable current account deficits and trade policy distortions which resulted in an excess demand of foreign exchange and led to extra borrowing and excessive drawing down of foreign exchange reserves. The corresponding overvalued exchange rate made imports, such as agricultural inputs, cheaper (*i.e.*, less domestic currency paid out for imports) and the price of exports as well as the domestic prices of non-tradables, particularly labor, more expensive (*i.e.*, less domestic currency earned by exports). In other words, Malians have paid a premium on traded goods over what

they paid for non-traded. A rate of about 50 percent overvaluation of the CFAF has been reported by Salinger and Stryker (1991) whenever the deficit was more important, accounting for about 44 percent of the overvaluation. Thus, because the CFAF currency was overvalued before the 1994 devaluation, it would be necessary to use an adjusted rate to convert the price of goods traded in foreign currency into a domestic equivalent in undertaking an economic analysis for years prior to 1994.

Economic analysis corrects the distortion in order to undertake any evaluation on the basis of the opportunity cost to the country as a whole of the resources invested in the activities. For non-tradable goods such as labor, their social value is found by estimating their social opportunity cost (*i.e.*, the net income foregone because the factor is not employed in its best alternative use). In contrast, for tradable goods such as fertilizers or paddy, the appropriate social value should be based on world prices (expressed in domestic currency) because these prices represent the society's choice to permit consumers and producers to either import or produce those goods domestically.

CHAPTER 4 - EMPIRICAL MODEL

4-1- Introduction

This chapter presents the analytical method that will be used in the proposed study to the effective demand of fertilizer in the ON areas. The chapter consists of six sections, and is organized as follows. The introductory section is followed by a section that is devoted to a critical review of methods employed by researchers for estimation of consumption of fertilizers. This section provides a justification for the selection of the mathematical programming approach. The third subsection provides a review of the conventional mathematical programming approach followed by section four, which covers the parametric programming technique. Section five discusses the models to be implemented in the study area. This section includes the expected results, the method of aggregation of the potential demand for fertilizer, and the method of calculation of the import parity prices for fertilizer. Chapter 4 ends with a section describing the modification of the basic model to incorporate risk.

4-2- Review of Methods Employed for Estimation of Consumption of Fertilizers

Maharaja (1975) grouped the procedures researchers have used to estimate fertilizer consumption into three types:

- (1) Need-based approach
- (2) Area-crop-coverage approach; and
- (3) Regression approach.

The essence of the need-based approach is to plan for needed expansion in agricultural production. Fertilizer requirements are calculated by using specific input-output ratios in order to achieve the required or desired quantity of additional production.

The essence of the area-crop coverage approach is to determine fertilizer requirements by considering probable trends in cropping patterns and expected coverage of area under fertilizers at recommended doses.

The broad framework of the regression approach is the prediction of fertilizer demand based on time-series data and by accounting for the influence of one or more variables on fertilizer consumption. In the regression approach, the estimation method varies from trend fitting to multiple regression analysis based on econometric models.

The need-based approach virtually ignores the profiles of demand viewed from the farmer's angle. Such estimates are based on a priori assumptions; for neither are they based on considerations of agro-climatic influences on growth of demand nor are they assessed in the context of factors influencing farmers' ability and willingness to use fertilizers at different levels and in different proportions. It is always possible to deduce from simple arithmetical exercises the quantity of fertilizers that should be used at specified average levels to achieve certain levels of output. However, such estimates

ignore the basic economic realities at the farm level.

The area-crop approach assumes rates of application of fertilizers at near-optimum doses or at recommended doses. The estimates arrived at by this approach overlook current trends in the rates of application of fertilizers on different crops and the rates in the future that are likely to be adopted due to various dynamic factors. The errors from this method, often in the direction of over-estimation, can be costly.

Econometric models identifying factors affecting fertilizer demand and quantifying their significance for estimating demand at macro-level could provide more realistic picture. Yet these econometric models can be inadequate on account of collinearity problems among explanatory variables, causing the impossibility of separating the effects of one component from another. The results from econometric analysis may be sensitive to practical data availability and variable construction problems. Indeed the analysis requires adequate time-series or cross-sectional data for all the relevant variables. Statistical problems aside, econometric analysis of historical data to predict future responses is not without its difficulties. For example, in predicting the outcome of a specific program proposal, econometric models are likely to be inadequate as a predictive device if the new program provides a new set of institutional restraints for, which there is no historical counterpart to use in estimating response. Staatz (1997, personal communication) reported that one of the biggest limitations of the econometric approach in the setting of countries like Mali where there have been large changes in the rules governing the markets is that parameters estimated using historical time series may be very poor predictors of future behavior in the new market

structure. A mathematical programming approach can overcome this problem by directly simulating the current situation.

Indeed a mathematical programming based on the macro-economic and micro-economic environments and followed by a sensitivity analysis or parametric programming can produce better results. The programming approach has the advantage of being able to derive optimal production and consumption plans, etc. to satisfy a multiplicity of objectives, of taking into account the role of price, and of specifying in considerable detail the constraints under which production, income generation, and policy making are taking place (Sadoulet and De Janvry, 1995). In recent years, programming models have been used extensively to address many types of policy questions, including input demand analysis. The basic approach has been to validate the model for a base period, and then use it to simulate adjustments and responses of economic agents to policy changes (McCarl and Spreen, 1980).

In deriving demand estimates by parametric programming procedures, a series of related problems are solved in which the price of the factor of interest is varied from a minimum to a maximum level. As the price of the factor varies, different levels of input use become optimal and, in consequence, a series of price-quantity relationships is developed. Flinn (1969) argued that the synthetic demand function derived by the price-quantity relationship procedure is of a stepped nature because of the linear nature of the production data, and the finite number of production alternatives and resource restrictions considered. Therefore, the demand 'curve' derived by using linear programming differs from the smooth curves of conventional theory. Flinn (1969)

concluded that the derived demand curves, at best, can only be regarded as short run estimates due to uncertainty about future prices, technologies and institutional constraints which may be imposed on the system. Even in the short run, farm managers' decisions may vary substantially from the actions predicted by the linear programming models of the farm firm. In particular, different subjective estimates of managers in relation to crop yield and prices, and different attitudes may result in farmers' actual decisions differing, somewhat markedly, from those indicated as optimal. In this study, the basic model will be modified to incorporate the risk component. This procedure is discussed in subsection 4-5-5. The next section provides more details about the conventional programming model, followed by section 4-4, which discusses sensitivity analysis or parametric programming.

4-3- Mathematical Programming

Rae (1977) described mathematical programming as a planning tool used to determine the best plan or course of action among which:

- (a) there are many alternatives for the plan;
- (b) a specific or numerical objective exists;
- (c) the means or resources available for obtaining the objective are limited.

The strength of mathematical programming lies in its ability to handle a large number of interrelated variables and thus to cope with peasant farming systems that are characterized by a high degree of interdependence between production and consumption, consumption and investment, investment and resource availability, and social and cultural constraints (Low, 1974). Beneke and Winterboer (1973) stressed

that the great advantage of programming is that it allows one to test a wide range of alternative adjustments and to analyze their consequences thoroughly with a small input of managerial time. The question "what would happen if...?" can be posed repeatedly and answered rigorously and quickly once the model is built. In a typical programming analysis, the magnitudes of the marginal value productivities of fixed resources are obtained as by-products of the conventional programming solution. The elements in the Z-C row of the disposal activity columns represent the marginal value products of these resources and are regarded as the measure of the ceiling that should be set in acquiring extra resources.

The conventional programming model can be formalized as follows:

$$\text{Max } Z = C'X \quad (1)$$

$$\text{subject to } AX \leq B \quad (2)$$

$$\text{and } X \geq 0 \quad (3)$$

where: Z = the value to be maximized

C = n by 1 vector of prices

X = n by 1 vector of activity levels

A = m by n matrix of input-output coefficients

B = m by 1 vector of variable factors or other restrictions.

In a programming model, activities can be grouped into (at least) five categories.

These are:

- (1) production activities;**
- (2) buying activities,**
- (3) selling activities;**
- (4) storage activities; and (5)**
- (5) transfer activities: these activities provide a vehicle whereby the service or output of one activity may be transferred in the model to another activity.**

The number of activities depends on the availability of data and on the objective of the study. It is important to note that large and complex models are costly to develop in terms of both time and money; and it is not always certain that the benefits to be derived from using a more sophisticated model (in terms of greater precision of the planning decisions derived from it) are sufficient to justify the cost. Furthermore, the solution of the programming analysis rests on the validity of the following assumptions (Barnard and Nix, 1973):

- 1) all the enterprises under consideration must be linearly additive, excluding the possibility of interaction in the amount of resources used per unit of output, whether or not enterprises are produced alone or in various proportions.**
- 2) resources used (such as land, labor and capital) and the commodities produced are infinitely divisible.**
- 3) a limit exists to the number of alternative enterprises and resources, which need to be considered.**

- 4) it is usually assumed that resource supplies, input-output coefficients, and prices are known with certainty. This assumption of single valued expectations may seem unrealistic for the farming situations in Mali.
- 5) the large element of fixed resources usually incorporated in the linear programming matrix means that relatively short-term situations are being studied. When solutions are not widely different from the current farm organization, they may represent the farmer's problems adequately. When, however, they differ widely, several years may be required to attain the suggested organization, as is true of longer-term planning in general. In such circumstances, it may be preferable to use a technique in which a dynamic element is incorporated.

Despite the limitations of the programming technique, its advantages outweigh the limitations. Examples of the use of mathematical programming for farm planning are many, including applications to planning peasant farms (*e.g.*, Clayton, 1964; Heyer, 1971; Traore, 1979; Niang, 1980; Ogunbile, 1980; Etuk, 1982; Kamuanga, 1982; Maïga, 1983, Cisse, 1987, Camara, 1988, Ngwira, 1994).

Bernard and Nix (1973) outlined the main techniques developed to deal with some of the conceptual criticisms of linear programming. These techniques and the inadequacies of 'ordinary' linear programming which are tackled by each of them are presented below.

Table 3: Other Computer Programming Techniques

Techniques	Shortcoming of Linear programming tackled by each technique
Integer Programming	
Separable Programming	Structural
Monte Carlo Method	Structural; Objectives
Parametric Programming	Structural and Uncertainty - but only to a very limited extent
Dynamic	Dynamics; Objectives – to a limited extent
Linear Programming	
Dynamic Programming	Dynamic Primarily; Structural and Uncertainty also
Quadratic Programming	Objective and Uncertainty
Stochastic Programming	Objectives and Uncertainty
Game theory	Objective and Uncertainty

Source: Adapted from Barnard and Nix (1973)

On the table above, structural refers to the assumptions of linearity and continuity in a linear programming model. The latter means that 'integer', or indivisible unit, cannot be dealt with in a fully acceptable manner. In addition, a linear programming optimal plan may not suit the longer-term aims of the farmer. All these

problems of longer-term planning require a 'dynamic' treatment rather than the 'static' approach of linear programming. As discussed in point 4 above, linear programming is 'deterministic', that is, it assumes single values for net revenues, constraints and resource requirements, as though perfect knowledge existed. Since an important aspect of a farmer's objectives relates to his attitude to risk and uncertainty, Bernard and Nix (1973) stressed that linear programming only maximizes within the limits imposed and with the data given; thus allowances can be made for personal preferences and, to some extent, for risk

Kamuanga (1982) used a one-period linear programming model to evaluate the profitability from the introduction of five improved practices or intensification techniques in the ON in 1982 under the current paddy price level of 60 Malian francs/kg². The results of the study indicated that across all LP runs, there was a strong indication that the ON should concentrate the intensification program on small and medium sized farms. Since then, the ON has been subject to many changes which have been described in chapter II. Therefore, it becomes necessary to re-evaluate the profitability of rice production and to compare and contrast the outcomes with previous results. It is expected that such analysis will provide farmers, researchers, and policy makers with more insight into the resource use efficiency, profitability and fertilizer demand issues after the market reforms.

² 2 MF = 1 CFAF

4-4- Parametric Programming

Parametric programming is a modification of the conventional model to allow the implementation of variable price programming and variable resource programming. It is a technique that allows a series of optimum plans to be estimated, for differing levels of any parameter of the problem (Rae, 1977). Such parameters may be product prices, variable factor costs, crop yields, supplies of fixed factors, or the requirement per unit of any crop for any fixed factor. In short, parametric programming enables us to know how optimum farm plans change as prices, input/output coefficients, or resource endowments vary.

Ogunfowora (1972) has conceptualized a programming problem with a parametric objective function as follows:

$$\max Z_a = \sum_{j=1}^n c_j X_j$$

where: Z = $Z(X_1, X_2, \dots, X_j, X_m)$

Z_a = the objective function
to be maximized for a given price level within the
acceptable price range;

b_i = the level of the i th
resource available.

Assuming that:

1) C_j' and C_j'' = the lower and upper limits of the price of the j th activity and $C_j' \leq C_j \leq C_j''$;

2) Θ = constant increment in the price of the j th activity;

3) K = the number of optimum solutions within the price range;

We can write:

$$(C_j' - C_j'')/\Theta = k$$

$$C_j'' - C_j' = \Theta K$$

This approach is useful because it enables a model builder to determine the number of optimal solutions and the levels of increment in price of the j th activity within an acceptable framework.

For variable price programming, the objective function is parameterized with respect to the price of the activity of interest. Optimum plans are then derived for each price level. The variable resource programming is analogous to the variable price programming. In this case it is the resource levels that are parameterized.

Parametric programming can be used to derive product supply and factor demand functions (Rae, 1977). For a given type of farm input, the farmer's demand function for this input can be derived by plotting the quantities that should be purchased against the various levels of prices. The stepped appearance of the graph

obtained from this procedure is a result of the use of a linearly segmented production-possibility boundary by the linear programming method, and can be considered as an approximation to the smooth demand functions of economic theory (Rae, 1977). The basic principle is the profit maximization principle introduced in section 3-1: if a farmer considers X_n to be a variable input and wishes to determine whether it would be profitable for him to add to, or reduce, his present use of this factor, he will need to compare the marginal value product (MVP_n) given his present supply of X_n , with the price per unit of this factor, $P(X_n)$. Only if MVP_n exceeds $P(X_n)$ will further purchases of this input be profitable, and the most profitable level of X_n will be that for which MVP_n equals $P(X_n)$. Thus the graph of MVP_n against the use of X_n may be interpreted as a farmer's demand function for this input since it indicates the quantity that he should purchase at various factor prices.

By programming a number of 'representative' holdings in an irrigation area, for example, demand functions for irrigation water can be derived for each holding (Flinn, 1969). Given knowledge of the supply situation with respect to irrigation water, a pricing policy can be formulated so that the total regional demand for this resource can be equated with the regional supply. Alternatively, by programming a number of representative holdings, supply curves could be generated by varying the price of the product of interest. We could then determine total regional output of that product at various price. This information would help in the making of pricing decisions (Martin, 1988).

Kottke (1967) concluded from his examination of the anatomy of a step supply

function that it is a valid approximation of agricultural supply behavior, particularly at the firm level. However, in terms of demand, Yaron (1967) from his empirical analysis of the demand for water by Israeli agriculture, found that the shape of the demand function for water was highly dependent on the sociopolitical economic mix, which determined the framework within which it is derived. Therefore, Yaron deduced that the more comprehensive and realistic was the agricultural development program or projection available as a background for the derivation of the agricultural demand function for water, the more realistic its estimate. The implication of this finding is that the derived demand and supply curves should be interpreted with a minimum dose of good sense. The results from these types of analysis are highly specific to the area under study. These limitations apply to the empirical model to be implemented in this proposed study and the results, which may be derived.

4-5- Empirical Model, Expected Results, and Modification of the Basic Model

4-5-1- Empirical Model for the Study Area

First, an empirical model based on the conventional programming framework will be built to represent a typical household in each rice production system. The structure of the farm model is as follows:

The objective function is maximized subject to the following constraints:

- five land constraints,
- nine monthly labor constraints from May to January,
- ten constraints on the average yield permitted,

- one minimum subsistence and income requirement constraint,
- one fertilizer supply constraint. Fertilizers include urea and ammonium phosphate and are considered separately in the model.
- one seed supply constraint related to rice seeds used on ON plots.
- one organic manure supply constraint: although organic fertilizer requires no outlay of cash, collecting, transporting and applying organic fertilizer are extremely labor-intensive. Organic manure includes human and animal manure, decomposed grasses and rice straws and household waste products.
- one animal feed supply constraint,
- nine capital constraints and /or transfer rows.

Activities:

Fourteen groups of activities are defined: rice production on ON and outside ON plots; horticulture (onion, tomato, garlic, pepper), root crop production (sweet potatoes); cereals production (millet and sorghum in mixture, maize as sole crop); feed buying activity; labor hiring activity (labor hired in the household, labor hired out of the household); exchange labor (through village level associations and among individual farmers for land preparation, weeding and tillage; off-farm employment (in the village and/or in the city); equipment hiring (oxen traction team for a work day for land preparation); capital transfer from May to January to meet farm expenditures; selling and buying activities of rice, vegetable crops, cereals; consumption activity of rice

(cultivated outside ON plots), cereals, and sweet potatoes; input supply of rice seeds, fertilizers (urea and ammonium phosphate), organic manure and feeds for draft cattle; borrowing activities from BNDA, FDV and informal sources. None of the activities discussed can be operated at negative levels.

Rice, vegetable crops and cereals are the major crops grown in the ON and will be considered as the main production activities, with a unit of one hectare (ha) in the model. Double cropping of rice will not be included in the model because the period considered for the proposed study starts from May and ends in January, which corresponds to the beginning of this off-season activity and the end of the proposed survey or study.

Like rice, vegetable crops are cultivated in every zone in the ON. Table 4 gives an idea about the relative importance of vegetable crops (including sweet potatoes) in terms the percentage of households involved in this activity.

Table 4: Relative Importance of Vegetable Crop Production (Percent of households)

Vegetable	Niono ARPON	Sahel Non-restored Area	Molodo Non-restored Area	Kokry ARPON
Onion	51%		99%	59%
Sweet Potato	34%	20%	13%	16%
Pepper	25%	7%	33%	16%
Tomato	18%	13%	25%	24%
Garlic	47%	13%	5%	

Source: Adapted from IER'S 1989/90 Survey.

For any fertilizer procurement activity, the farm gate price per kilogram and the quantity of that fertilizer as applied by farmers per hectare are considered in the model. In other words, the quantity of any type of fertilizer is the average quantity of that type of fertilizer used to cultivate one hectare of rice on ON plots. It is assumed in the model that the farmer can borrow money from BNDA, FDV and from an informal source (moneylenders and friends) at an interest rate (in cash or in kind) to buy fertilizers and other supplies, to hire labor at the going wage rate, and to hire equipment when the need arises at any time from May to January. Table 5 below gives an idea about how the fertilizer buying activity will be accounted for in the LP matrix.

Table 5: Incorporation of Fertilizer Buying Activity

Resources	Activities	Rice (ha)	Buying Urea (kg)	Buying Ammonium Phosphate (kg)	Signs
Fertilizer Buying			-	-	
Urea		+	-1		Equal 0
Ammonium Phosphate		+		-1	Equal 0

Source: From the author

NB: The plus (+) signs on the table correspond to positive required levels of fertilizer per hectare of rice. The minus (-) signs are the unit prices of fertilizer. The fertilizer acquired is transferred to the equality constraints via the -1 signs.

It is also assumed in the model that money earned from off-farm employment may have a positive impact on the use of fertilizers and the level of rice production on

ON plot, via provision of liquidity to buy inputs. In other words, off-farm employment provides cash to the household, which may be used to purchase fertilizer if its use is profitable.

For rice and vegetable crop output marketing, the selling activity in the model converts physical output into cash via sale. The consumption activity transfers rice, root crops and cereals outputs from the farm storage to meet minimum consumption requirements. The consumption activity is built into the program to make sure that rice, other cereals, vegetables and sweet potatoes consumption habits are respected and that the subsistence requirements in term of calories are met. The activity unit is 1 kilogram.

Resources Available:

Land: The model includes five types of land that are:

- 1) Rice lands inside ON, where improved varieties of rice are the only crops grown with irrigation water. This type of land is commonly known as "Casiers" and is under the supervision of the ON authority.
- 2) Rice lands outside ON, where only traditional varieties of rice are cultivated. This type of land, called "Hors casier", is not under the supervision of the ON authority. However, the "Hors casier" can also enjoy irrigation water from the ON as long as the water fees are paid by farmers. No fertilizer is applied on these lands because of the cultivation of traditional varieties of rice and the poor degree of water control.

- 3) **Lands for vegetable crops production:** Horticulture is practiced on this type of land, which is outside the rice plot and can enjoy irrigation water subject to the payment of water fees.
- 4) **Lands for coarse grain (millet, sorghum, maize) production:** This type of land is located some distance from rice and vegetable crops production areas. Lands for coarse grains production don't enjoy irrigation water from the ON. Crops produced on these lands are totally rainfed.
- 5) **Lands for root crops production:** This type of land is similar to land for coarse grain production.

Labor: The model includes four types of labor including family labor, hired labor, exchange labor, and off-farm employment. The total farm workdays of eight hours per day available on an average household in each system will be calculated by converting all categories of labor in each month to a person-day equivalent. Norman's weighting formula will be used to convert family workers into adult man-day equivalent. Small child (under ten years old), large child (above ten years old), female adult, will be converted to adult man-day equivalent (before totaling) by using Norman (1973) weighting formula of 0.00, 0.50, 0.75 respectively. In Mali, it has been noticed above 60 years, some people still do some very useful work. Hence the weighting rate of 0.50 will acquired is transferred to the equality constraints via the -1 sign.

It is also assumed in the model that money earned from off-farm employment in the household labor available.

Consumption Requirements:

Farmers in the ON grow traditional varieties of rice, coarse grains and root crops essentially for their own subsistence requirements. Improved varieties of rice are grown for sale on ON plots. Vegetable crops are essentially grown for market, although part of them is consumed to meet household subsistence needs. A typical household in the ON can be considered a production unit for profit maximization on one side and a consumption unit on the other. Elsewhere in Africa, for example in Nigeria, D.W. Norman (1973) has shown in a study of small farmers that profit maximization and food security were not in conflict. While the provision of adequate food for the family was given top priority, it was found that the pattern of resource allocation was consistent with profit maximization. Martin (1988) assumed in Senegal that besides the profit motive the other important component of the farmer's objective function is the food security objective. This objective pushes him/her to grow food crops for home consumption and to select crops for sale in order to guarantee a minimum income whatever the state of nature. Both actions may run counter to the profit maximization objective. Therefore, the farmer often has to make trade-offs among conflicting objectives. Thus Martin (1988) imposed several constraints on his model to reflect the priority given to food security by Senegalese's farmers. In the ON case in particular, the heads of households have the social responsibility of ensuring that the food needs of all members of the household are satisfied. Therefore, an attempt to introduce realism into the model will be made by maximizing the objective function within the framework of consumption patterns. In other words, besides the selling activities, consumption

activities will be built into the model to make sure that subsistence crops consumption habits are met. That is, subsistence crops are consumed and are expected to fulfill the minimum level of calorie requirements for individuals in the typical household in each system. The average size of household in the ON areas is 10 persons (Cisse et al., 1993). An average household in the ON must consume 2124 kg of cereals per year to meet the minimum requirement of 2300 calories per person per day. Further discussion of food security issue in the ON is provided in section 4-5-5.

Operating Capital:

Operating capital includes all production expenses on fertilizers, hired labor and cost for draft cattle maintenance and rice seed costs. It is assumed that farmers in all systems have access to the same lending sources.

Derivation of the Input/output Coefficients:

The input-output coefficients (a_{ij} 's) express the amount of input i needed for one unit of activity j . For land, the coefficient is one for all corresponding enterprises. For labor, the average coefficients per hectare will be used. In other words, the ratio obtained by dividing the total number of man-days spent on an enterprise within a particular month by the total area of land in hectares allocated to the enterprise in question, is the input-output coefficient.

Production coefficients will be derived by dividing the total output in kilograms by the total area in hectares planted with the specific crop or crops combination like millet and sorghum in mixture. Operating capital includes expenditures on fertilizers,

hired labor, draft cattle maintenance and rice seed costs. Fertilizers used per hectare of rice times the price per kilogram of each type of fertilizer will be entered in the model. The cost of hired labor will be captured in each month at the going wage rate. Expenditures on rice seeds and feeds will be entered in the model under the months during which they occur.

4-5-2- Expected Results

The basic model will be run using two types of price vectors: price of rice and fertilizer after the CFAF currency devaluation in January 1994. The aggregate demand for fertilizer that needs to be satisfied by the private channel for input delivery will be calculated following a method described in subsection 4-5-3.

In the analysis, it will be assumed that the 1994 CFAF devaluation removed all the distortions from this currency to reflect its social value. Therefore, no adjustment will be needed to realigned the official exchange rate prevailing in Mali after the devaluation.

It is expected from the analysis that we will get an estimate of the aggregate demand for rice production that needs to be satisfied by the private channel for input delivery.

In order to assess if the ON can support a private fertilizers distribution system, the levels of aggregate potential demand for fertilizers will be estimated from the model by using the import parity price of fertilizer at different places at the ON.

4-5-3- Aggregate Potential Demand

Classically the demand schedule for a given input in a competitive market is

derived through horizontal summation of the demand schedules of the individuals producers in the region being studied (Flinn, 1969). Aggregation can be performed in this manner providing two conditions are met. First, the various producers in the region must confront the same factor prices. Second, only the price of the input of interest is varied; all other prices are assumed to remain constant.

The evaluation of the aggregate potential demand for fertilizer in the ON is based on the optimal levels of fertilizer and the total number of farms. The first step is to calculate the consumption of fertilizer by multiplying the optimal fertilizer levels using different input-output price vectors by the number of farms in each of three rice production systems. The second step is to evaluate total fertilizer consumption at different price levels in the ON by adding consumption from all the production systems. More explicitly, the total demand schedule for fertilizers at the ON can be derived as the aggregate of the demand schedules for the representative households defining the population. The aggregate demand schedule in the ON can be specified as:

$$D = \sum_{i=1}^t f_i n_i$$

where: **D** is the aggregate demand for the ON area;

n_i is the number of households in the *i*th stratum;

f_i is the optimal fertilizer input for the *i*th representative household when the price of fertilizer is *p_f*; and

t is the total number of strata specified for the ON.

The result of such an aggregation is a single set of fertilizer quantity- price data in which each of the representative households strata exerts an influence proportional to the total quantity of fertilizers used by households of that stratum.

In principle, given a set of fertilizer and rice product prices, fertilizer use can be extended to the level where marginal return equals marginal cost. These levels of fertilizer application are commonly known as “ optimum levels” of use. The aggregate likely levels of consumption, if all the farmers fertilize their entire crop area by optimum levels of fertilizer use, represents upper limit of the effective demand. However, in practice, these optimum rates of application are discounted by farmers on account of uncertainties of returns due to several climatic, social, economic and availability factors; and the level of effective demand is largely determined by the impact of these factors on farmers’ decisions to use fertilizers in the context of prevailing situation.

The derived demand curves, at best, can only be regarded as short run estimates

due to uncertainty about future prices, technologies and institutional constraints which may be imposed on the system. Even in the short run, farm managers' decisions may vary substantially from the actions predicted by the linear programming models of the farm firm. In particular, different subjective estimates of managers in relation to crop yields and prices, and different attitudes to risk may result in farmers' actual decisions differing, somewhat markedly, from those indicated as optimal. Therefore, our basic model will be modified to incorporate the risk component. This procedure is discussed in subsection 4-5-5. The following subsection describes the cost structure in transporting fertilizer.

4-5-4- Import Parity Prices for Fertilizer

In order to check whether or not ON can support a private fertilizer distribution system, we need to estimate the potential effective demand for fertilizer at the ON by using or plugging into the model the import parity price of fertilizer at the ON. The calculation of the import parity price of fertilizer might also reveal possible areas of improvement in the marketing margin resulting from fertilizer import. The marketing margin is the difference between import or ex-factory price and the retail farm price. It consists of wholesalers' commissions, retailers' commissions, transportation costs, storage costs, insurance, interest on stocks and facilities, and other overhead costs. It is possible to determine the share of each of the components, which comprise the marketing margin, and to determine the factors responsible for a high marketing margin. The retail price of fertilizer can be lowered by reducing the marketing margin through an increase in marketing efficiency. It will also be possible to derive the

nominal protection coefficient (NPC) and the nominal effective protection coefficients (NEPC) from the import parity prices of fertilizer. From the standpoint of farm incentives, it is important to determine the extent to which farmers in the ON are still protected after the devaluation. Protection implies that domestic producers of a commodity i can be inefficient relative to foreign producers.

The nominal protection coefficient (NPC) is equal to the ratio of the domestic price of a commodity i to its border price using the official exchange rate (Sadoulet *et al.*, 1995):

$$NPC_i = P_{id}/P_{ib}$$

Thus,

- if NPC_i is greater than 1, producers are protected and consumers taxed,
- if NPC_i is less than 1, producers are taxed and consumers subsidized, and
- if NPC_i is equal 1, the structure of protection is neutral.

The effective protection coefficient (EPC) can be estimated for a commodity I (i.e. rice) at the farm level to capture the net effect of distortions such as input subsidies (Sadoulet *et al.*, 1995). The nominal EPC is: $NEPC_i = V_{aid}/V_{aib}$ where V_{ai} is the value added (or return) on primary factors in the production of I measured at domestic price (d) and at borders price (b) using the official exchange rate, hence the term nominal.

If $NEPC_i > 1$ or > 0 , domestic producers of i are directly protected. The return on their resources is higher than it would be if border prices prevailed, creating incentives to increase the production of this commodity.

If $NEPC_i < 1$, domestic producers of i are disprotected, price distortion give them disincentives in the production of i and they can remain in the production of i only if

they are more efficient than foreign producers.

If NEPC $i=1$, the structure of prices is neutral on incentives.

Two types of fertilizers are used by rice farmers in the ON: urea and ammonium phosphate. Urea is imported from outside the continent. Ammonium phosphate is imported from Senegal's chemical industry (ICS) or from Hydrochem-CI in Côte D'Ivoire. While the bulk of Mali's imported fertilizer goes through the Dakar-Bamako region route by train, or the Abidjan-Ségou-region route by truck, a small portion comes from Nigeria and Niger. The main cost items in importing fertilizer are international and domestic transportation costs, handling and insurance costs. More explicitly, the calculation of the import parity price of fertilizer includes the following cost items:

- 1) The FOB price at the export point, plus freight and insurance, plus unloading at import dock, corresponding to the HANDLING price,
- 2) The HANDLING price plus tariffs, minus subsidies, plus port charges, transport and marketing to the relevant market or project boundary correspond to the import price at central market or project boundary (IPPCM or IPPPB). Tariffs and subsidies are excluded in economic analysis.
- 3) The IPPCM or IPPPB plus the local transport, storage costs, etc, between the market and the farm gate, corresponding to the import parity price at the farm gate.

In this study, the main central market or project boundary is Niono, which represents the point of entry to the intensive system (Retail zone), semi-intensive system

(Arpon zones located next to and far away from Niono) and non-restored area far from Niono.

4-5-5- Modification Of the Basic Model to Incorporate Risk Component

As said earlier, farmers in the ON are facing the risk of income variability resulting from weather and price variabilities. Assuming that farmers in the ON are facing the same market price conditions, the main difference among them is weather and the degree of water control. Indeed, improved varieties of rice cultivation in the semi-intensive system and non-restored area are more affected by the distribution and level of rainfall than are those in the intensive system, where water is relatively well controlled.

When linear programming is used in a decision support role, risk can sometimes be assessed outside the formal framework of the model and the farm plan indicated as optimal may be adjusted in a subjective way (Dent *et al.*, 1986). It is also possible to incorporate risk formally into the planning framework using linear or quadratic programming methods. If a quadratic risk programming study is to be undertaken, then it is necessary to estimate both the expected gross margins for each activity and also the variance of these returns. In addition, estimates must be made of the covariances between all activity returns; that is, the extent to which the returns for different activities vary together. The objective function in the quadratic risk programming is specified in non-linear quadratic form, accommodating the variance and covariance of the C_j values. The solution is then in terms of a plot of the expected values of Z , denoted $E(Z)$, against its variance $V(Z)$ (which is taken as a measure of the risk faced). Choice of

the optimal solution then depends on matching the feasible set of $[E(Z), V(Z)]$ values against the farmer's preferences so as to choose the pair, which gives him or her the greatest utility.

Quadratic risk programming is demanding of both data and computing resources. Indeed, the considerable data requirements, exacerbated by a lack of widely available trouble-free solution algorithms, have so far restricted the application of quadratic risk programming as a practical decision aid in solving applied management problems (Dent *et al.*, 1986). Because of this, a variety of linear approaches to accommodate risk have been developed. Such modifications include simplex linear risk programming, minimization of total absolute deviations (MOTAD) programming and a variety of extensions of MOTAD. In particular, MOTAD has the attraction of being a linear approximation to quadratic risk programming (Hazell, 1971).

The income variability will be taken into account in the semi-intensive system and non-restored area by developing a MOTAD model accommodating the constraint of risk via the incorporation of possible states of nature and their probability of occurrence. The conventional MOTAD model as developed by Hazell in 1971 is as follows:

$$\text{if} \quad 1) \text{ Minimize: } sA = \sum_{i=1}^n (Y_i^+ + Y_i^-)$$

such that for each year,

$$(2) \sum_{j=1}^n (C_{jt} - G_j) X_j - Y_t^+ + Y_t^- = 0$$

$$\sum_{j=1}^n G_j X_j = E$$

$$\sum_{j=1}^n A_{ij} X_j \leq B_i$$

where;

sA = total absolute deviations of farm income over all years

s = the number of years over which income is sampled,

A = the mean annual absolute deviation of farm income,

X_j = the level of the j th activity or enterprise,

C_{jt} = the gross margin (i.e., gross return over operating costs)

for the j th activity in year t ,

G_j = the annual gross margin for the j th activity,

$C_{jt} - G_j$ = the gross margin deviation for the j th activity in year t ,

E = expected net income set equal to some specified level,

A_{ij} = the input-output coefficient showing the units of the i th input required by the j th activity,

b_i = the quantity of each resource,

Y_t^+ = an accounting enterprise in the LP matrix entering the MOTAD solution when the total income deviations for a

particular year t are positive,

Y_t^- = an accounting enterprise in the LP matrix entering the MOTAD solution when the total income deviations for a particular year t are negative, with

$$Y_t^- \text{ or } Y_t^+ = \left| \sum_{j=1}^n (C_j - G_j) X_j \right|$$

By means of equality constraints, the value of expected net income (E) is set at specified increments, from zero up to the linear programming profit maximizing level to develop a series of solutions. Plotting expected total gross margin against total minimum absolute deviation yields the efficiency frontier. Each solution is efficient in the sense that no other enterprise mix will result in less income variation at the specified level of income.

In the semi-intensive and non-restored area in the ON, the farm household wants to obtain a minimum income from rice and vegetable crops production to cover part of its expenses. To include this objective in the structure of the LP model, additional rows are needed. These rows contain the deviations from the mean income of rice (produced on ON plot) and vegetable crops. The mean income for each crop is calculated by weighting the income from one hectare of that crop associated with each state of nature such that for each year,

annual rainfall data from which it is possible to determine a relatively good, average and

bad years in the regional context. It is assumed that income per hectare is one of the uncertain variables since both the yield and the price of rice and vegetable crops may fluctuate. Table 6 below illustrates the way the minimum income constraints will be included in the model.

Table 6: Incorporation of the Minimum Level of Income.

Income	Level	Relationship	Activities				
			Rice (ha)	Vegetable crops (ha)	Z1	Z2	Z3
Expected Total Gross Margin(TGM)	+	Equal	\bar{X}	\bar{X}			
Year1 GM tie	+	Greater than or Equal	+	+	1		
Year2 GM tie	+	Greater than or Equal	+	+		1	
Year3 GM tie	+	Greater than or Equal	+	+			1
C Min					1	1	1

Source: From the author.

On Table 6 above, the expected total gross margin (from rice produced on ON plot and vegetable crops) will be set at a specific level by means of an equality constraint. The three gross margin tie rows are introduced for three representative types of years (Good, average, and bad) based on the levels of rainfall received. Also for each year, a shortfall activity (reflecting the amount by which the gross margin fails to reach its expected level) is added. Shortfall activities are labeled Z1 to Z3. Each of the gross

margin ties stipulate that the total gross margin plus shortfall for the year be not less than the specified level of total gross margin. The average of the gross margins for the three-year types is the expected gross margin in the expected TGM row. Since the expected gross margin for any activity is the mean (\bar{X}) across all individual years, the sum of deviations above this mean will equal the sum of deviations below it (Dent, 1986).

Hence, minimizing the sum of shortfalls minimizes the sum of deviations both above and below the expected gross margin. The C row on the table states the objective of the head of household as minimization of the sum of shortfalls, that is, of the sum of negative deviations from the expected total gross margin. The choice of this objective function ensures that the sum of the shortfall will be as small as possible, that is, that the most stable plan in terms of total gross margin will be selected.

The farm household wants to produce on average a large share of the coarse grains (millet, sorghum, maize, rice) and root crops to cover its needs. To include these considerations in the analysis, additional rows will be introduced in the LP matrix in a way similar to that for the constraint on the level of income. These rows contain the deviations from the mean during the worst possible states of nature for the yields of food crops produced for home consumption. The mean yield is calculated by weighting the yield associated with each state of nature (good, average and bad years) by the probability of occurrence of that state of nature. It is assumed that the yields of food crops are the uncertain variables. The yields are expressed in thousand calories to allow for the same unit across all crops. Table 6 below illustrates the way the minimum level of foods production for self-sufficiency will be accounted for. On the table, the Zs are

shortfall activities.

It was estimated (DNSI, 1988-89) that the per capita consumption of cereals per year in Mali is 203.81 kg, rounded to 204 kg. This figure was lower than the consumption norm of 212.4 kg reported by Steffen in 1995, implying that some other sources were needed to cover the shortfalls. The shortfalls could be covered up from food aid or by buying cereals from the market bringing about the issue of food security discussed by Sadoulet and De Janvry in 1995. The definition of food security provided by Sadoulet and De Janvry was as follows: Food security means access by all people at all time to food sufficient for a healthy life.

It is clear from the above definition that if food security cannot be obtained through domestic or own production the gap should be cover up from market or from outside the country. Thus assuming that an average person in the ON must consume 212.4 kg of cereals per year to meet the minimum requirement of 2300 calories per person per day, an average household of 10 persons must consume in minimum 2124 kg per year. Since households in the ON are more likely to fall into transitory food insecurity because of many sources of risk (e.g. fluctuation in income, production and prices) during average and bad years, food security must be tackled with the broad concept of food security in covering up the shortfalls (Z2 and Z3) defined in table 7 below. The level of expected yield during the average and bad years can be varied within an acceptable range in order to analyze the magnitude of the shortfall in each scenario. Such analysis can reveal the need to rely on other possible sources (i.e. market, food aid) that may help covering the shortfalls in a risky situation.

Table 7: Incorporation Of the Minimum Level Of Food Crops Self-Sufficiency.

Expected Yield	Level	Relation s	Activities								
			Mil let	X	X	X	X	Vegetable s	Z1	Z2	Z3
Expected Yield	+	E	\overline{X}	\overline{X}	\overline{X}	\overline{X}	\overline{X}	\overline{X}			
Year 1 tie	+	G or E	+	+	+	+	+	+	1		
Year 2 tie	+	G or E	+	+	+	+	+	+		1	
Year 3 tie	+	G or E	+	+	+	+	+	+			1
C Min									1	1	1

Source: From the author

NB: The plus (+) signs on the table correspond to positive levels of yield. G and E stand for "Greater" and "equal", respectively

CHAPTER 5 - DATA NEEDS AND PROPOSED DATA

COLLECTION STRATEGY

5-1- Data Needs

In each rice production system in the ON, we need to collect data in order to derive enterprise budgets and the input/output coefficients for each enterprise under consideration. Enterprise budgets constitute the key building blocks of the LP model. Detailed information needs to be collected on the sampled households' labor force, labor hired in mandays and wages, off-farm employment, the various inputs including fertilizers and their respective costs, the market prices of crops, the sources and amount of credit and the rates of interest charged. We also need data to derive the import parity prices of fertilizer. The type of the needed data in deriving the import parity prices for fertilizer or any commodity has been described in section 4-5-4. These data will come both from primary and secondary sources.

Data requirements for both the conventional LP model and the MOTAD model are the same with respect to Input-output coefficients and expected costs and returns. However, a time series of gross margins (gross returns over operating costs) and crop yields are required for each enterprise to develop the income and yield deviations for the MOTAD LP matrix. The determination of the distributions of gross margins over many years involves the determination of the distributions of several random variables. The

most analytical approach to specifying revenue distributions is to begin with the underlying distributions of the uncertain components such as yield and price (Dillon and Hardaker, 1977). Usually, only means, variances, and covariances are required so that assessment need not be too demanding.

Let GM = rice enterprise gross margin in CFAF/ha

Y = rice yield in kg/ha

P = rice price in CFAF/kg

VC = variable costs of rice in CFAF/ha.

Let assume that VC is known with certainty. So that they do not influence the variance of the gross margin GM which given approximately by:

$$V(GM) = \{E(P)E(Y)V(Y)\} + \{E(Y)E(P)V(P)\} + \{2E(P)E(Y)\text{Cov}(Y,P)\}$$

$V(GM)$, $V(Y)$ and $V(P)$ are variances of gross margin, yield and price respectively

$\text{Cov}(Y,P)$ is the covariance between the yield and the price.

$E(P)$, $E(Y)$ are the expected price and yield, respectively.

The expected gross margin is derived as follows:

$$E(GM) = E(Y)E(P) + \text{Cov}(Y,P) - VC$$

Even after having gone through the problem of estimating revenue distributions for several enterprises, the analyst is still left with the difficulty of establishing the appropriate correlations between enterprises returns. Dillon and Hardaker (1977) reported that one of the solutions to this problem requires knowledge of at least one formula for the parameters of a conditional distribution for one variate of a bivariate normal distribution. If X_1 and X_2 are jointly normally distributed with means $E(X_1)$

and $E(X_2)$; standard deviations SD_1 and SD_2 ; and correlation $Corr_{12}$; the conditional distribution of X_1 , given $X_2=X_2^*$, is characterized by mean and variance

$$E(X_1|X_2=X_2^*) = E(X_1) + Corr_{12}(SD_1/SD_2)[X_2^*-E(X_2)]$$

$$V(X_1|X_2=X_2^*) = Corr_1^*Corr_1(1-Corr_{21}^*Corr_{12})$$

Attention should be given to the above possible correlation relationships when two or more enterprise gross margins in this proposed study are found to be correlated through years. Appendix A presents the linear programming tableau including the consumption activity while appendix B provides the programming matrix including the possible correlation between rice enterprise and the other enterprises in the ON area.

5-2- Data Collection Strategy

The data used in this study will be obtained from both primary and secondary sources. Secondary data will be collected by consulting relevant reports written about the ON. Primary data will be collected through a survey method by means of questionnaires and personal interview. Data from the survey will be used to undertake the costs and returns analysis and to implement the programming exercises. The collection of the field data will be done by trained enumerators under the supervision of the researcher. The collection of secondary data, the implementation of the reconnaissance survey and the implementation of the interviews will be carried out by the researcher with the help of ON extension workers.

5-3- Sampling Procedure and Sample Size

In deriving demand estimates by linear programming, it will be prohibitively expensive and time-consuming to estimate the demand schedules for each farm household in a region and then to derive the regional demand function by summing the individual firm functions. An alternative is to select a sample of representative farms in order to guide planning on individual farms. Barnard and Nix (1973) suggested that in areas where there is reasonable homogeneity in at least some of the major resources – particularly with respect to natural factors, such as soil type, topography and climate – linear programming can be used to obtain solutions to ‘modal’ or ‘representative’ farm situations. In this way some of the benefits of comprehensive computer planning can be made available to a greater number of farmers in an area than would be the case with the individual programming of farms. Since farms are likely to display considerable

variation around a particular modal situation (when account is taken of both quantitative and qualitative aspects of farm resources), more than one model is required if differences in factors such as farm size, the number of workers and the availability of building are to be accommodated. Therefore, we need a sample of representative farm households, each supposed to be characteristic of a larger group of farm in the region. Each representative farm demand curve is weighted by the number of farms in its stratum, and the weighted demand curves are then summed to derive the regional estimate.

Stovall (1966) discussed three sources of error that may bias the demand schedule estimated from a linear programming model and a sample of representative households:

- (i) specification error;
- (ii) sampling error; and
- (iii) aggregation error.

Specification error arises when the programming model fails to accurately describe the conditions faced, the derived objectives, and the resulting decisions being made by the firm.

Sampling error arises when the distribution of the variables of interest within the sample differs from the distribution of those variables within the population. That is, when a sample is taken from a population, it will not be possible to know precisely the value of any population parameter, such as the mean or proportion. Any point estimate will be in error. The problem of reducing and measuring sampling error are tackled by

statistical procedures and sampling theory is sufficiently developed so that sampling rates can be set so as to hold sampling error to a desired level.

Frick and Andrews (1967) have defined aggregation error as ".the difference between the area supply (demand) function as developed from the summation of linear programming solutions for each individual farm in the area and the summation from a small number of typical or benchmark farms." In other words, aggregation bias occurs when the results obtained by scaling up solutions from one or more representative farms are different from the results that would be obtained if it were possible to solve for each individual farm in the target population and add the results (Upton and Dixon, 1994).

Aggregation error or bias is brought about by the use of averages or other measures of central tendency in synthesizing a model unit from survey data. According to Collinson (1972), aggregation bias is the same phenomenon noted in supply response work; in this case interfarm differences in timing create different peak requirements on particular farms, which are damaged when averaged – and peaks on one farm are offset by relatively slack periods on another, so that the whole labor profile is flattened. An alternative to straightforward averaging is the construction of the model from components, each of which is sampled, perhaps independently, for the population under investigation (Collinson, 1972). Such construction reduces the aggregation effect and highlights the decisions required on the inclusion of specialized activities, which are situations. In this way some of the benefits of comprehensive computer planning can be made available to a greater number of farmers in an area than would be the case with sequence, and rates of work for each operation. Improving the simulation of the profile

requires attention to the timing of crop operations. Construction reduces the aggregation bias by enumerating timing, the center date for each discrete operation, as a component. The steps involved in a profile construction is described by thoroughly described by Collinson (1972).

The necessary conditions for selecting representative farms to minimize aggregation error within a given budget are still undefined in a general sense. However, Miller (1967) has demonstrated that two criteria are useful to control aggregation error in an empirical situation. Miller recommended that:

- (1) farms be grouped on the basis of what is the most limiting resource in the production process; and
- (2) that farms with similar patterns of product response to price change be grouped together.

Upton and Dixon (1994) reported that some bias can be avoided by careful grouping of the population of farms prior to selecting the representative cases. They suggested that farms that produce similar products in similar climatic zones be grouped together as a first step, and then use the statistical technique of cluster analysis to identify sub-categories based on resource ratios. Furthermore, they reported that when the models are of representative farms and results are to be scaled up to describe behavior of a population of farms, it becomes important to take some accounts of aggregate effects on prices by linking MP models to market models in a recursive fashion or by separate estimation of price changes and consequent use of the prices for the farm model. Selected input and output prices in

representative models can be varied parametrically to derive demand and supply schedules, which can then be scaled up across categories as appropriate. Given other information about the supply of farm inputs or the demand for outputs, market equilibria can be deduced.

Thus, for this proposed study, a sample of a representative group of farm households within each rice production system can help reduce the problem of aggregation error and serve the purpose of this study. The techniques of sampling based on field experiences in conceptualizing and implementing policy- relevant studies have been thoroughly discussed by Tefft *et al.* (1990).

The other important source of error is non-sampling errors. This type of error is unconnected with the kind of sampling procedure used and tend to be greater than sampling errors (Liedholm, 1998, personal communication) . Indeed such errors could just as well arise if a complete census of the population were taken. In any particular survey, the potential for non-sampling error exists at a number of places. Newbold (1991) provided some examples as follows:

1. The population actually sampled is not the relevant one.
2. Survey subjects may give inaccurate or dishonest answers.
3. Non-response.

(4)-Data entry or processing errors

In addition to the three sources of errors provided by Newbold, other types of non-sampling errors arises during data transcription and data entry stages. There is the possibility of an error connected with enumerator errors. Tefft *et al.* (1990)

argued that minimizing non-sampling errors during the data processing stage demands consideration of several other aspects, such as the design of questionnaires, hiring knowledgeable computer personnel, planning the type of analysis to be completed, and selecting hardware and software that satisfy researcher needs throughout the implementation of any project.

There is no general procedure for identifying and analyzing non-sampling errors (Newbold, 1991). The main prescription is that the investigator take care in such matters as a) identifying the relevant population, b) designing the questionnaire, and c) dealing with non-response in order to minimize their significance. Tefft et al. (1990) argued that minimizing non-sampling errors depends on well-defined concepts, adequate operational definitions, accurate translations, and simple and easily understandable questionnaire formats. In addition, researchers must carefully train enumerators and supervisors, provide them with explicit instructions and sufficient logistical support, obtain the cooperation of village leaders and respondents, and initiate data verification and analysis early in the study.

In regard to sample size, Yang (1965) warned that: "...in no circumstances should the research worker choose a sample larger than his financial and personal resources..". Moreover, Yang stressed that when 20 farms are selected from the same stratum for cross-tabulation, the addition of more farms will not seriously change the results..., that roughly 20 farms should be included in each of

the classes in order to make reliable comparisons." Yet for this study, 30 farmers will be selected in each system in order to anticipate the possible lack of cooperation of some farmers and other problems associated with farm management investigations. Resources, activities, and constraints pertinent to the ON area will be collected in a survey of 90 households during a cropping season. Linear programming models will then be developed to present the major household types in the ON area. Parametric solutions will be obtained for those resources limiting in the initial optimal plan for each model, as the scarce resources influence the MVP and hence the demand for fertilizer. The variability of income and yield risks farmers faced will be taken into account by developing risk-programming models for the study area.

Appendix A:**Programing Matrix Including the Different Activities in the ON area**

Linear Programming Tables

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CORN		SOYBEANS		WHEAT		BARLEY		RICE		CATTLE		PORK		BEEF		LAMB		CHICKEN		EGGS		MILK	
Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm	Off Farm	On Farm
October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September
1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987

[illegible]

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Year	2000	2001	2002	2003	2004	2005	2006
Value	-	-	-	-	-	-	-

APPENDIX B:

**Programming Matrix Including the Possible Correaltion Realtionships between Rice
and other Enterprises in the ON area.**

Programming Matrix: Possible Correlations between Rice and Other Enterprises in the ON Area

[illegible]

BIBLIOGRAPHY

- Barry, A.W., 1994. Comparative Advantage, Trade Flows And Prospects For Regional Agricultural Market Integration In West Africa: The case Of Cote D'Ivoire And Mali. Unpublished Dissertation for the Degree of PhD .Michigan State University.**
- Beneke, R. and Winterboer., 1973. Linear programming application to agriculture, Ames, Iowa State University press**
- Barnard, C. S. and Nix, J. S.,1973. Farm Planning and Control, Cambridge University Press, Cambridge, London. New York. Melbourne.**
- Boughton, D. et al, 1994. Analyzing the Impact of Structural Adjustment on Commodity Subsectors. Currency Devaluation and the Maize Subsector in Mali**
- Bumb, B.L. and Teboh, J.F., 1992. The Policy Environment and Fertilizer Sector Development in Mali. An Assessment.**
- Camara, A.,1988. Economic Analysis of Traditional and Improved Farming Systems and Optimal Farm Plans for Peasants in the OHV Zone, Mali. Unpublished Masters Thesis, Texas Tech. University, 1988.**
- Cisse, Y. et al, 1993. Etude Recherche Développement à l'Office du Niger. Rapport d'étude non publie, Ministere Du Development Rural et de L'environnement, institut D'economie Rurale.**
- Cisse, Y., 1987. Resource Use and Productivities. A Comparative Study of**

- Intensive and Non-Intensive Farming Systems in "Mali-Sud"**
Rural Development project. Unpublished M.sc.Thesis,
Ahmadu Bello University, Zaria (Nigeria).
- Clayton, E.S., 1964. Agrarian Development in Peasant Economics.**
Some Lessons from Kenya. Pergamon Press.
- Collinson, M.P. Farm Management in Peasant Agriculture.**
New York, Praeger, 1972.
- Coulibaly, O., 1993. Farm Level Potential Impact of Soil Fertilization**
and Water Retention Techniques on Sorghum Based Cropping
Systems in Mali.
- Coulibaly, B.S., Sanogo, O., Mariko, D., 1994. Coûts de Production du**
Paddy à l'Office du Niger. Atelier Régional sur l'impact de la
Dévaluation du FCFA sur les Revenus et la Sécurité Alimentaire
en Afrique de l'Ouest.
- Del, V. et al, 1995. Les Premiers Effets de la Dévaluation sur les Filières Riz**
Irrigué au Sahel. Le Cas du Mali. IER-CIRAD. Ministère de la
Coopération. République Française.
- Dembele, N.N., 1996. "Implication of Market Reform for Fertility**
Technology Development and Implementation in Sub-Saharan
Africa with Special Reference to the Soil Fertility Management
Initiative in Burkina Faso." Unpublished study report,
International Development Center -Africa

(IFDC-Africa). Soil Fertility Management Unit (SFMU), Burkina Faso.

Dembele, N.N., 1994. Economic Analysis of Trader's Response to Cereals

Market Reforms in Mali. Unpublished Dissertation for the Degree of Ph.D.,

Michigan State University. Department of Agricultural Economics.

Deme, M., 1993. La Filière Riz au Mali. Situation- Problèmes-Perspectives

Rapport Principal.

Demeke, M., Said, A., and Jayne, T.S., 1996." Relationship Between Input

Markets and Grain Market Performance in Ethiopia.

".Paper Presented at the Grain Market Research Project

Discussion Forum.", Sodere, Ethiopia. Ministry of Economic

Development and Cooperation

Dent, J.B., 1986. Farm Planning with Linear Programming: Concepts

& Practice.

Dillon, J.L. And Hardaker R. Agricultural Decision Analysis (1977),

Iowa State University Press, Ames.

Diarra, S.B, 1994. The Role of Small Rice Mills in the Rice Subsector of the

Office du Niger, Mali. Unpublished Master thesis.

Michigan State University. Department of Agricultural Economics.

Dione, J., 1989. Informing Food Security Policy in Mali. Interactions

Between Technology, Institutions and Market Reforms.

Unpublished Dissertation for a Degree of Ph.D. Michigan State University.

Department of Agricultural Economics.

- Dione, J., et al., 1996. " Adjustment Structurel, Politiques Economiques et Sécurité Alimentaire Au Sahel. " Contribution au Forum International du 20ème Anniversaire de l'Institut Du Sahel."**
- Dione, J., et al., 1996. " Contraintes à l'Investissement pour la Productivité et la Compétitivité des Systèmes Agricoles et Alimentaires en Afrique de l'Ouest: Question Trans-Filières et Trans-Nationales."**
- DNSI: Direction Nationale De la Statistic Et De L'Informatique. Enquete Budget Consommation, 1988-1989.**
- Diagana, N.B., 1995. " Devaluation du Franc CFA et Décisions de Production Agricole. Une Analyse des Impact de la Dévaluation du Franc CFA sur les Choix de Culture et de Technologies de Production par les Ménages Ruraux du Bassin Arachidier du Sénégal."**
- Communication Préparée pour l'Atelier Régional CILSS/PRISAS sur le Thème ".Impact de la Dévaluation du Franc Cfa sur les Revenues et la Sécurité Alimentaire en Afrique de l'Ouest." Tenu à Bamako, Mali.**
- Etuk, E.G. ,1982. A Comparative Study of Optimal Farm Plans for Small Farms with Traditional and New Technology in Zaria Area of Northern Nigeria. Department of Agricultural Econmics and Rural Sociology, Ahmadu Bello University.**
- Falusi, A., 1973. Economics of Fertilizer Distribution And Use in Nigeria. A Thesis Presented to the Faculty of the Graduate Scholl of Cornell**

University for the Degree of Doctor of Philosophy.

Flinn, J.C., 1969. "The Demand For Irrigation Water In An Intensive Irrigation Area." University of New England.

Frick, G.E and Andrews, R.A." Aggregation Bias and Four Methods of Summing Farm Supply Functions. " Journal of Farm Economics, 1967.

Gerner, H., Jager, de. M., Tboh, F.J,Bumb., and Dembele, 1996. "Economic Policies and Fertilizer Market Development." In Restoring and Maintaining the Productivity of West African Soils.

Gittinger, J.P., 1982. *Economic Analysis Of Agricultural Projects. Second Edition.* The Johns Hopkins University Press, Baltimore And London.

Hazell, P.R., 1971. " A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." American Journal of Agricultural Economics, vol. 53, No.1.

Heady, E.O. and Dillon, J. L. (1961). Agricultural Production Functions. Iowa State University Press, Ames, Iowa.

Henao, J. et al, 1982. Fertilizer Policy Research Program for Tropical Africa. Agronomic Potential of Fertilizer Use in Mali.

Heyer, J., 1971. " A Linear Programming Analysis of Constraints on Peasant Farms in Kenya. " Food Research Institute Studies in Agricultural Economics, Trade and Development, vol. X, No.1.

IER (Institut D'Economie Rurale). Enquêtes 1989/90.

IFDC_ International Fertilizer Development Center,

"1995 Global Fertilizer Perspective 1980-2000.

The Challenges in Structural Transformation."

Kamuanga, M., 1982. Farm Level Study of the Rice Production System at the Office du Niger in Mali. An Economic Analysis. A Dissertation for the Degree of Ph.D., Michigan State University. Department of Agricultural Economics.

Kelly, A.V., 1988. Factors Affecting the Demand for fertilizer in Senegal's Peanut Basin. A Dissertation for the Degree of Ph.D. Michigan State University. Department of Agricultural Economics.

Kottke, M." The Anatomy of a Step Supply Function." Journal of Farm Economics, 1967.

Longman Dictionary of contemporary English, New Edition, Longman Group UK Limited 1987 (Secon Edition). Page 1055.

Low, A.R., 1974. " Linear Programming as a Tool in Innovation Selection for Farms in S.E. Ghana, in Planning in Low Income Countries." A Symposium Development Study No.14, Reading. Factors Affecting Demand And Estimation of Future Demand. Baroda (India.)

Martin, F., 1988. Food Security And Comparative Advantage In Senegal: A Micro-Micro Approach. Dissertation for the Degree of Ph.D. Michigan State University. Department of Agricultural Economics.

Maïga, S.A., 1993." Revue Bibliographique et Description Sommaire de Mécanismes de Fonctionnement du Marché des Engrais."

Ministere Du Developement Rurale et de L'environnement.

Maïga, S.A., 1983. Optimum Farm Plans in Irrigated Agriculture. A case Study of the Niger River Development Project Office du Niger in the Republic of Mali. Unpublished M.SC. Thesis, Ahmadu Bello University, Zaria, Nigeria.

Maharaja, M.H., 1975. Demand For Fertilizer. An Analysis of Factors Affecting Demand and Estimation of Future Demand. Printed by Nutan Printery, Baroda and 3A Associates Baroda.

McCarl ,B.A. and Spreen T.H., 1980." Price Endogenous Mathematical Programming Models as a Tool for Sector Analysis." American Journal Of agricultural Economics. 62(1) pp 87-102.

McIntire, J., 1985." Constraints to Fertilizer Use in Sub-Saharan Africa. Management of Nitrogen and Phosphorus Fertilizers in Sub-Saharan Africa proceeding of a Symposium, Held in Lome, Togo March, 1985.

Minot, N.W., 1992. Distributional Effects of Currency Devaluation on Households in Rwanda. An Application of Willingness to Paym Welfare Measure. Unpublished Dissertation for the Degree of Ph.D. Michigan State University. Department of Agricultural Economics.

Miller, T.A." Aggregation Error In Representative Farm Linear Programmin Supply Estimates." Unpublished Ph.D. Thesis, Iowa State University., Ames, 1967.

Mudahar, S.M., 1978." Needed Information and Economic Analysis for

Fertilizer Policy Formulation." Indian Journal of Agricultural Economics, vol.XXXIII, 33(3).

Mudahar, S.M. " Fertilizer Problems and Policies In Sub-Saharan Africa in Management of Nitrogen and Phosphorus Fertilizers In Sub-Saharan Afria." Proceedings of a Symposium, Held in Lome, Togo, March 25-28, 1985. Edited by A.UZO MOKWUNYE and Paul L.G.VLEK IFDC, Muscle Shoals, Alabama, USA.

Ngwira, A.N., 1994. The Role Of Dimba Land And Small Scale Irrigation InSmallholder Farmers' Food Security I Target Motad Mathematical Programming.Dissertation for the Degree of Ph.D. Michigan State University. Department of Agricultural Economics.

Niang, A., 1980. A Linear Programming Model of a Representative Sahelian Farm. The Cases of the Cotton Zone in Mali and Peanut zone in Sénégal. Ph.D.Thesis, Purdue University.

Norman, D.W., 1973. " Economic Analysis of Agricultural Production and Labor Utilization Among the Hausa in the North of Nigeria," African Rural Employment Paper No.4, Department of Agricultural Economics, Michigan State University.

Newbold, P., 1991. Statistics for Business and Economics. Third edition by Prentice-Hall, Inc.

Ogunfowora, O., 1972. Derived Demand, Product Supply and Farm Policy in the North Central State of Nigeria. npublished Ph.D. Thesis, Agric. Econs.,

Iowa State University, Ames, Iowa.

Ogungbile, A.O., 1980. An Evaluation of Improved Sole-Crop Production Technology or Small Farms in Northern Nigeria under Different Farm Power Sources. A Multi-Period Linear Programming Approach. Unpublished Ph.D. Thesis, Iowa State University. University of Ibadan. Ibadan, Nigeria.

Roth, M. J. and Abott, P.C., 1990." Agricultural Price Policy, Food Aid and Input Subsidy Reforms in Burkina Faso." Journal of Agricultural Economics vol. 41, no.3, sept.

Rae, A.N., 1977. Crop Management Economics. St.Martin's Press, Inc. New York.

Renfro, R.Z.H., 1992." Fertilizer Price and Subsidy Policies In Bangladesh." World Development, Vol. 20, No.3

Sadoulet, E., De Janvry, A., 1995. *Quantitative Development Policy Analysis*. The Johns Hopkins University Press, Baltimore And London.

Salinger, B.Lynn., 1991. " Exchange Rate Policy And Implications For Agricultural Market Integration In West Africa." Paper Prepared for the U.S. Agency for International Development under Subcontrat to the Harvard Institute for International Development.

Sanders.J.H et al, 1996. *The Economics of Agricultural Technology in Semiarid Sub-Saharan Africa*. The Johns Hopkins University Press, Baltimore and London.

Sijm. J, 1992. Food Security and Policy Interactions in Mali.

Tinbergen Institute, Erasmus University, Rotterdam.

Staatz, M.J., 1994. " Use of Simple Price Analyses for Analyzing the Impact of the Cfa Franc Devaluation. " Institut Du Sahel, Michigan State University.

Staatz, M.J., 1989. " The Role of Market Conditions in Influencing the Adoption of New Agricultural Technologies in Mali." Report to USAID/Mali Prepared under Food Security in Africa Cooperative Agreement Department of Agricultural Economics. Michigan State University.

Staatz, M.J, et al., 1994." Monitoring and Analysis of the Effects of the Devaluation of the Cfa Franc on Food Security and Economic Growth in West Africa." Agency for International Development. Michigan State University.

Steffen, N.P., 1995. The role and Limits of the Grain Market In Assuring Household Food Security In NorthEastern Mali: Implications For Policy.Dissertation for the Degree of ph.D Michigan State University.

Stoorvogel, J.J. and E.M.A. Smaling, 1990. " Assessment of Soil Nutrient Depletion in Sub-Saharan Africa, 1983-2000."Wageningen, The Netherlands, DLO Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO), Report 28.

Stovall, J.G., " Sources of Error in Aggregate Supply Estimates."

- Journal of Farm Economics, 1966.**
- Streeten, P., 1987. What Price Food Agricultural Price Policies in Developing Countries. St. Martin's Press, New York.**
- Stryker, J.D., Dethier, J.J., Peprah, L., Breen, D., levin, E.L., Wohl, J.B., 1987."Incentive System And Economic Policy Reform In Mali." Associate For International Resources And Development, Inc.287 Alewife Brook Parkway, Somerville, MA. 02144.**
- Tefft, J.F., Weber, T.M and Staatz, M.J., 1990. Research Methods in the MSU Food Security In Africa Project. Conceptualizing and mplementingPolicy Relevant Studies.**
- Tessio, K.E.M., 1996. " Regional Variation in Efficiency of Fertilizer Use: The Case of Food Crops Producers in Togo." Economics of Agro-Chemicals Symposium, Wageningen Agricultural University, the Netherlands.**
- Traore, B., 1979. Introduction of New Technology and Optimal Farm Plans. A Linear Programming Analysis of the Household Economy in the Subsector of Sirakorola, O.A.C.V., Zone Mali**
- Upton, M., and Dixon, J.M, 1994. Methods of Micro-level Analysis for Agricultural Programmes and Policies. A Guideline for Policy Analysts Food And Agriculture Organization of the United Nations. Rome, 1994.**
- Weijenberg, S.,1993. " Rapport de la Mission d'Appui au Fond De Développement Villageois", Office Du Niger, Mali.**

**Yang, W.Y, 1965. " Method Management Investigations." Agricultural
Development Paper No. 80, Rome , FAO.**

**Yaron, D. ." Empirical Analysis of the Demand for Water by Israeli
Agriculture." Journal of Farm Economics, 1967.**