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ECONOMIC AND TECHNICAL ASPECTS OF FERTILIZER PRODUCTION AND USE IN WEST AFRICA

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FOREWORD

The African Rural Economy Program was established in 1976 as an activity of Michigan State University's Department of Agricultural Economics. The African Rural Economy Program is a successor to the African Rural Employment Research Network which functioned over the 1971-76 period.

The primary mission of the African Rural Economy Program is to further comparative analysis of the development process in Africa with emphasis on both micro and macro level research on the rural economy. The research program is carried out by faculty and students in the Department of Agricultural Economics in cooperation with researchers in African universities and government agencies. Specific examples of on-going research are, "Poor Rural Households, Income Distribution and Technical Change in Sierra Leone and Nigeria," "Rural and Urban Small-Scale Industry in West Africa," "Dynamics of Female Participation in the Economic Development Process in West Africa," and "The Economics of Small Farmer Production and Marketing Systems in the Sahelian Zone of West Africa".

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PREFACE

This paper was prepared under a United States Agency for International Development contract (AID/afr-C-1260) with Michigan State University with the cooperation and assistance of the International Fertilizer Development Center of Florence, Alabama. Numerous individuals have assisted with various aspects of this study. Particular thanks goes to the technical and support staff of IFDC, especially Kham T. Pham, John Allgood, Fred Klem, Terry Frederick and Richard Booth. Substantial constributions and helpful comments were also made by Warren Vincent, E.P. Whiteside, R.L. Cook, Carl Eicher, Godwill Lekwa and Patrick Sutton of Michigan State University. Francis LeBeau provided a valuable outside perspective that considerably improved an earlier draft. A special thanks reserved only for secretaries who have to do everything by yesterday goes to Jill Malefyt. Errors and omissions, of course, are those of the authors.

LIST OF ABBREVIATIONS

ABU	Ahmadu Bello University (Nigeria)
CFDT	Compagnie Française pour le Développement des Fibres Textiles
FED	Fond Européen de Développement
FONADER	Fond National pour le Développement Rurale
IBRD	International Bank for Reconstruction and Development
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Center
IITA	International Institute of Tropical Agriculture
IRAT	Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières
OMVS	Organisation pour la Mise en Valeur du Fleuve Sénégal
ONCAD	Office National de Cooperation et d'Assistance au Developpement
ONDR	Office National pour le Développement Rural (Chad)
ORSTOM	Office de la Recherche Scientifique et Technique Outre-Mer
SAFGRAD	Semi-Arid Food Grains Research and Development
SCAER	Société de Credit Agricole et d'Equipement Rural
SIES	Société Industrielle d'Engrais au Sénégal
SIVENG	Société Ivoirienne d'Engrais
SOCAME	Société Camerounaise d'Engrais
SODEFITEX	Société de Développement des Fibres Textiles
SONADER	Société Nationale de Développement Rurale
SSEPC	Société Sénégalaise d'Engrais et des Produits Chimiques
STRC	The Scientific, Technical and Research Commission of the Organization of African Unity
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
WARDA	West African Rice Development Association

RECOMMENDATIONS AND SUMMARY

The purpose of this paper is to examine the role of fertilizer in increasing agricultural production in West Africa and to assist USAID develop a strategy for the production and expanded use of fertilizer in the region. The following recommendations cover a broad spectrum of agricultural development issues as they relate to fertilizer production and use. They are arranged logically rather than by order of priority.

A. Recommended Strategy

1. Support national and regional farming systems research oriented toward:
   a. developing high yielding varieties of food crops and nitrogen fixing legumes. There is an urgent need for a major increase in research on symbiotic and non-symbiotic nitrogen fixation as well as on intercropping and rotation systems.
   b. soil fertility as it relates to the farm level testing of high yielding crop varieties in practical farming systems in specific areas.
   c. identifying production constraints facing the farm firm and evaluating the effect of new technologies in overcoming these constraints.
   d. the association between livestock and crop production systems.
2. Support the design, implementation and evaluation of extension programs aimed at increasing the participation of smaller and poorer farmers in agricultural development. An important component of such programs should be to provide resource-poor farmers with profitable packages of improved inputs and the necessary supporting services. Donors should recognize that extension programs aimed at resource-poor farmers

constitute a high risk investment but are one of the few ways of reaching such farmers while having an impact on the distribution of income in rural areas.

3. Before participating in agricultural production projects, donors should encourage favorable input-output price relationships and crop prices adequate to render the improved technology profitable on an unsubsidized, untaxed basis. This does not preclude the use of moderate fertilizer subsidies for stimulating adoption or use of fertilizer. However, it does preclude the use of high subsidies to induce farmers to adopt uneconomic technologies.

4. Finance investment in infrastructure aimed at strengthening linkages between the rural-agricultural and the urban-industrial sectors. These include feeder road development, improved maintenance for national road systems, more efficient input and output marketing institutions and improved storage.

5. Develop and field test farm level storage technologies capable of preserving food grains for a two to three year period. This is especially critical for the more humid areas and should include a study of the economic feasibility and effectiveness of traditional storage technologies in West Africa as well as factors affecting farmers' decisions to store grain.

6. Identify and evaluate fertilizer raw material deposits throughout the region. Phosphate rock deposits in Upper Volta, Mauritania, Niger, Benin and Liberia need to be characterized for possible future use in fertilizer production. Prospecting for phosphate rock deposits in Chad also appears justified at this time.

7. Conduct field trials of various phosphatic materials produced from

local phosphate deposits where their characterization is favorable. Except for the Tilemsi Valley deposits in Mali, unexploited phosphate rock deposits in the region need to be field tested for direct application before feasibility studies on mining and grinding operations proceed. However, in those countries with low levels of use of phosphatic fertilizers it may be substantially cheaper to combine field testing with a brief feasibility study.

8. Establish a phosphate rock mining and grinding facility for the Tilemsi Valley deposits in Mali.

9. Establish and evaluate a pilot bulk blending facility of the type suggested by the West Africa Fertilizer Study somewhere in West Africa. Questions raised about the cost and the special transportation problems suggest caution in proceeding on a wider front at this time. USAID should approach this project on an experimental basis and ensure complete documentation and costing of all aspects. Bobo-Dioulasso would be a logical location for a plant to serve both Upper Volta and Mali if cooperation between the two countries appears feasible. Otherwise, a pilot plant at Sikasso would be preferable, both because of the higher level of use of phosphatic fertilizers in Mali, and the possibility of supplying Upper Volta at least for a few years.

10. Finance an empirical study of the impact of crop and input pricing policies on agricultural output, national income, foreign exchange balances, returns to labor, and income distribution both between urban and rural areas and within the agricultural sector itself. This study should include one country with a relatively high level of fertilizer use and one with a lower but still significant level of fertilizer use. Senegal or Ivory Coast and Mali or Sierra Leone would

be likely choices.

11. Finance a series of regional conferences dealing with various aspects of the fertilizer sub-sector. At this time, input and output pricing policies, plant breeding, micro-biological, and soil fertility adaptive research appear to be particularly relevant topics.

12. Encourage regional cooperation in agricultural research, fertilizer production, marketing, and distribution, and in input and output pricing policies. The payoff to research, economies in production of fertilizer, and the effectiveness of national pricing policies can all be increased substantially by greater integration of national policies.

13. Encourage coordination of donor efforts relating to fertilizer production and use in the region. IBRD, UNIDO, the international research centers and organizations, USAID and other bilateral donors all are currently involved in one aspect or another of the fertilizer sub-sector. Getting them all together to rationalize their efforts would no doubt go a long way toward dealing more constructively with some of the problems discussed in this report and avoid a great deal of working at cross-purposes or duplication of effort.

B. Summary of Findings

1. Projected Food Deficit for West Africa[1]

Between 1961-65 and 1975 aggregate food production in West Africa increased by 26 percent (79)[2] while population grew by 34 percent, reach-

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[1]West Africa includes Cameroon, Chad and all Sub-Saharan countries to the west, including Mauritania.

[2]The numbers in parentheses are reference numbers.

ing 140 million in 1975 (28). Over this period urban and rural populations increased 85 percent and 22 percent, respectively. This suggests that increases in food production have come primarily from an increase in the size of the agricultural labor force rather than an increase in the agricultural productivity of the rural population. Under current trends of growth of population, urbanization, income, and agricultural productivity, the region's annual deficit in food staple production is expected to amount to 5.5 to 6.4 million tons of cereal equivalent by 1985. Only increases in agricultural productivity considerably higher than recent trends can reduce the size of the expected food staple deficit.

2. Policies Constraining Food Production in West Africa

Stagnant agricultural productivity may be more a symptom than a cause of lagging food production. Weak linkages between the agricultural and the industrial sectors and between the rural and the urban sectors in most of the countries of the region deter farmers from increasing agricultural productivity. Heavy taxes on cash export crops; cheap food and other policies that favor urban as opposed to rural areas; restrictions on the internal and international movement of foodstuffs; the lack of availability of essential agricultural inputs; and the lack of an industrial sector responsive to the needs of the agricultural sector for appropriate technology to overcome seasonal labor bottlenecks on small farms; all retard the evolution of a dynamic, responsive agricultural sector. Once these and similar constraints are removed there is little doubt that farmer interest in fertilizer and other output expanding technologies will increase.

3. The Role of Fertilizer in Increasing Agricultural Productivity

Present fertilizer consumption in West Africa is small. Regional consumption averages less than two kilos of nutrients per hectare, and ranges as high as nine kilos per hectare in Liberia. Though the scope for increasing fertilizer use is potentially very large, it is important to remember that fertilizer is only one input in the overall agricultural development, food production chain. Its effectiveness in increasing yields and agricultural productivity is directly related to the availability of complementary inputs such as fertilizer responsive varieties, adequate rainfall or water control, insecticides, and appropriate cultural practices. To be economically viable, fertilizer requires institutional support in the form of favorable producer prices, effective and timely input delivery, and adequate transportation and marketing infrastructure. In addition, fertilizer subsidies, agricultural extension, and credit can facilitate and expand the use of fertilizer. But without favorable agronomic, economic and institutional underpinnings, stimulating the use of fertilizer in these ways does not promote dynamic, self-sustaining growth in agricultural production.

4. The Need for Research

Research required to develop, adapt and test fertilizer responsive varieties of both food and cash crops, and to develop technologies which improve the availability and efficient use of plant nutrients takes years to bring to fruition. Creating an indigenous capacity to conduct such research will take even longer. The development of an indigenous research capacity and of relevant crop production technologies for West Africa should have top priority for donors. Indeed, agricultural research can provide aid donors with a vehicle for effectively assisting the rural poor apart from national government policies and market forces. In this respect much more research attention needs to be given to labor bottlenecks, cropping systems, intercropping, and symbiotic nitrogen fixation than has been the case heretofore.

5. Crop Response to Fertilizer in West Africa

In general, fertilizer response data indicates that varieties which respond well to fertilizer under controlled, usually sole crop conditions, exist for rice and maize. The farm level response appears to be considerably lower, particularly for sorghum and millet though few hard data exist. Crop response to phosphate rock found in several of the countries is, in some cases, very good; but more controlled experiments are necessary to establish the economic potential of specific deposits for use in direct application.

6. Labor Constraints as They Relate to Fertilizer Use

At the farm level, available labor during critical periods rather than land seems to be the major constraint on agricultural output. With a few exceptions, fertilizer is likely to be adopted much more quickly where its use increases returns to this scarce factor. Available data supports the general conclusion that high yielding technologies have a much greater proportional impact on yields than on returns per unit of labor employed, since they usually require large amounts of additional labor. This emphasizes the need to focus on returns to labor at critical periods as well as on yields in research on new crop technologies. This is especially true for technologies intended to benefit resource poor farmers.

7. Influence of Credit and Extension on Fertilizer Use

Empirical evidence indicates that both extension and credit are important factors affecting fertilizer adoption and use. In West Africa, however, credit and extension programs generally are oriented toward the wealthier, more progressive rural farmers. In addition, credit programs not reinforced by marketing monopolies tend to have very poor repayment rates. This suggests, on a practical level, that more creative approaches to agricultural credit are needed to ensure the economic use of credit for food crops. Similarly, extension services need to concentrate more on stimulating resource poor farmers to adopt and use fertilizer and improved practices if these farmers are not to become the "people left behind" in rural areas.

8. Marketing Constraints

There is evidence that both input and output marketing constraints are holding down fertilizer consumption. Fertilizer availability is a critical problem in Nigeria and Ghana and in many rural areas throughout the region. Where its availability has been assured, consumption has sometimes skyrocketed. At the same time, a poor farm-to-market transportation network and public sector interference in food crop marketing channels has frequently had the effect of reducing effective demand for locally produced cereals. There appears to be a good case for less, rather than more, regulation of private commercial traders coupled with policies designed to encourage, rather than restrict, competition in grain trade. In addition, improving farm level storage technology should stimulate the use of fertilizer by encouraging specialization and production for exchange.

9. Pricing Policies

Cheap food pricing and trade policies discourage the adoption of productivity increasing technologies such as fertilizer. Fertilizer subsidies have been used to partially compensate for some of these policies but, except in the case of export crops, the use of subsidies appears to reflect political expediency rather than economic wisdom. West African farmers have demonstrated the ability to generate substantial agricultural surpluses over and above their own needs when adequate incentives exist.

10. Fertilizer Subsidies

Some level of subsidy on fertilizer used on export crops can be justified in almost every country in the region. Export taxes or marketing margins over and above marketing costs effectively reduce the farm value of output. Fertilizer subsidies partially offset the distorting impact of such policies. Since marketing board and other taxes rarely exceed 25% of the export value of output, subsidies in excess of this general magnitude must be justified primarily as an investment in innovation diffusion. This can be done if available technology renders the use of fertilizer without subsidies sufficiently economic to return investment costs. Clearly this becomes less likely the higher the subsidy and the longer the period over which they are provided. In measuring the effective level of subsidy all costs associated with handling and distributing fertilizer to the farm level should be included in fertilizer costs, with subsidies measured as a proportion of the farm delivered cost of fertilizer. Only where fertilizer supplies are adequate to satisfy demand at subsidized prices do fertilizer subsidies achieve the economic objectives for which they are intended. Even then, the magnitude of their impact on agricultural output in West Africa will generally be small because of the very low fertilizer consumption base to which they apply.

11. Demand for Fertilizer

The use of fertilizer in most West African countries is far below its potential under an improved set of agricultural and rural development policies. For this reason projecting fertilizer demand is particularly hazardous. For this study total nutrient consumption is projected to grow at 12 percent per year up to 1985, a continuation of the growth rate prevailing over the past eleven years. By 1985 this would lead to consumption of about 210,000 tons of nitrogen, and about 140,000 and 130,000 tons of P_2O_5 and K_2O, respectively, for the region as a whole. Under more favorable policies than have existed heretofore, actual demand could be much higher.

12. Fertilizer Raw Materials

The region has numerous phosphate rock deposits. Commercial production occurs from two deposits--Senegal and Togo. Hydrocarbons for nitrogen production are available only in Nigeria. More than adequate supplies of potash have been available from neighboring People's Republic of the Congo. However, recent reports indicate this production may be discontinued.

13. Present Production

No basic production of nitrogen fertilizer (ammonia) or potash exists in the region. Chemical processing plants in Senegal, Ivory Coast, and Cameroon incorporate imported ammonia into fertilizers (ammonium sulfate, diammonium phosphate, and/or NPK grades). Facilities in those countries and in Nigeria process phosphate rock into soluble phosphate fertilizers (single or triple superphosphate, diammonium phosphate, and/or NPK grades).

14. Planned Production

By 1985 a 1,000 mt per day ammonia plant, the lowest cost technology currently available, would be approaching full capacity in serving the regional market. Nigeria is planning such a plant. Plans to construct a small ammonia-urea complex based upon refinery intermediates in Senegal should be closely examined. The economies of scale and potentially low hydrogen and fuel costs available for the planned Nigerian plant would not exist in Senegal. Furthermore, Senegal will probably be able to use no more than 50% of the proposed plant's N capacity by 1985. It would have to export the rest to neighboring countries. This would leave West Africa with about 100,000 mt of ammonia fertilizer to export to more distant markets outside the region.

Senegal and Togo are planning expansion or initiation of processed phosphate production utilizing a portion of their phosphate rock presently produced. By 1985 capacity for processed phosphates is expected to be about 350,000 mt of P_2O_5 in excess of consumption in the region.

15. Other Fertilizer Production Possibilities

Considerable potential exists for fertilizer blending operations utilizing imports of high analysis intermediates. Currently, Nigeria, Ghana, Mali and Chad have sufficient demand to justify construction of bulk blending plants using the technology suggested in IFDC's West Africa Fertilizer Study. However, this labor intensive technology has never been used in West Africa and needs to be tried on a pilot basis before going ahead in all countries.

In spite of ample production of P_2O_5 in West Africa, there is scope for additional small-scale phosphate rock mining and grinding operations to meet local demand, especially in the land-locked countries. The most promising opportunity is in Mali. Longer ranged potential exists in Niger, Benin, Upper Volta and Liberia. Except for the Mali deposit, however, these deposits need to be characterized and field tested before their technical usefulness for direct application can be established.

I. INTRODUCTION

Population in West Africa[1] has nearly doubled during the past 25 years. Projections to 1985 indicate a sustained rapid rate of growth of about 2.8% per annum with almost half of the absolute increase occurring in towns. By 1985 the urbanization level in two countries, Ghana and the Ivory Coast, will approach 50%. For the region as a whole, it will rise from 22% in 1975 to 28% in 1985 (28).

Food grain imports into the region have increased in response to the growth in urban population. Between 1963 and 1970, as the region's rural population grew by 14%, its urban population grew by 53% and grain imports rose to about 1.5 million tons, an increase of 75% over roughly the same period (28).

As the proportion of the population actively engaged in food production has declined, so also has per capita food production. Though food crop production per rural resident did not decline, it failed to grow in line with the increase in urban population and incomes (79). This reflects both the stagnant, subsistence character of much of the region's agriculture and the paucity of governmental policies supportive of more intensive agricultural development. The general absence of favorable producer prices and supporting infrastructure, in particular, has weakened linkages between urban food consuming areas and rural food producing areas. Fortunately, the recent drought has drawn attention to these problems and has stimulated a search for a longer run solution to the problem of low productivity in agriculture. This paper concerns the production and use of fertilizer as it relates to such a solution. Its purpose

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[1]West Africa as discussed in this report includes Cameroon, Chad and all sub-Saharan countries to the west, including Mauritania.

is to assist potential donors develop a fertilizer funding strategy for West Africa.

A. Projected Food Deficits

Based on current labor productivity, per capita consumption and urbanization trends, Table I.1 gives estimates of production, consumption and the expected deficit for major food staples in the region for 1985. The major influence on the size of the deficit is the increasing rate of urbanization as a smaller proportion of the population engages in food production in the face of stagnant agricultural productivity. The IBRD study from which most of these data were drawn suggests that the effect of income on the size of the aggregate deficit is likely to be marginal due to substitution among grains. Though urban consumers consume more wheat and rice at the expense of coarse grains, available consumption data suggest that overall consumption of food staples declines as a result of the more diversified diet available in urban areas. The study suggests that a ceiling in average intake of basic staples may have been reached or may be reached by 1985, and warns against projecting an over-rapid growth in demand for food staples due to increases in income. For this reason Table I.1 includes estimates based on no income effect as well as a set based on income elasticities of 0 for roots and tubers, 0.2 for rice and coarse grains, 0.7 for wheat and an optimistic 4.7 per cent annual growth in GNP.

Based on current trends, the gap between food staple production and consumption in the 17 countries of the region covered by the present study would widen from 1.2 million tons in 1970 to 5.5 - 6.4 million tons in 1985. This would amount to 16 - 18% of 1985 total regional consumption of food staples. Only an increase of about 15% in food production per agricultural laborer and a willingness to substitute local cereals for

TABLE I.1
PRODUCTION, CONSUMPTION AND IMPORTS OF FOOD STAPLES FOR 21 COUNTRIES IN WEST AFRICA, 1970-1985[1]
(MILLION METRIC TONS)

	1970 Base[2] Period	1985 Projections	
		Without Income Effect	With Income Effect
Production[3]			
Wheat	--	--	--
Rice	1.4	1.9	1.9
Coarse grains	11.4	15.5	15.5
Roots and tubers[4]	10.5	13.9	13.9
Total	23.3	31.3	31.3
Consumption			
Wheat	0.7	1.1	1.3
Rice	1.8	2.8	2.8
Coarse grains	11.6	17.4	18.1
Roots and tubers	10.5	15.8	15.8[5]
Total	24.6	37.1	38.0
Deficit (imports)			
Wheat	0.6	1.1	1.3
Rice	0.6	0.9	0.9
Coarse grains	0.1	1.9	2.6
Roots and tubers	--	1.9	1.9[5]
Total	1.3	5.8	6.7
Deficit for seventeen countries			
Cereals	1.2	3.8	N.A.
Roots and tubers	--	1.7	N.A.
Total	1.2	5.5	6.4[5]

[1]Most of the data in this table were taken from the IBRD, Western Africa Food Grain Study (28), pp. 19,20 and Appendix Tables 2.2. The definition of West Africa used in that study differs from that used in this report in that it includes Gabon, The Peoples Republic of the Congo, Central African Empire, and Equitorial Guinea. Details of production and consumption by commodity was not available on a country basis though aggregate grain and root crop deficits were. These are detailed in the last line of the table for the 17 countries covered by the present study.

[2]Estimated base period figures, not actual totals. Estimates were chosen to reflect a "normal" level of production after allowing for unusual climate conditions which prevailed in the region between 1966 and 1974.

[3]Production figures are quoted net of milled waste and are estimated at 78 percent of gross production.

[4]Quoted in approximate "grain equivalent", i.e. net weight/3.

[5]Our estimates. These figures were not estimated by the IBRD study.

wheat and rice could keep the gap from rising above the base period by 1985. Clearly, achieving an increase in productivity of this magnitude will be very difficult without a very large expansion in the use of fertilizer.

B. The Role of Fertilizer

Expanding the use of fertilizer will not necessarily increase agricultural productivity. It is but one component of an agricultural transformation strategy. Unless a sufficient number of components are brought to bear at the same time, fertilizer is not likely to be an economic source of increased food supplies. Furthermore, other improvements in the food production-storage-processing chain can greatly reduce the amount of fertilizer needed for a given increase in output.

Availability of high yielding varieties and the production technology to support their adoption by farmers are key factors affecting the efficiency and effectiveness of fertilizer. In one study of Asian rice producers, David (13) found that modern varieties and associated cultural practices (including irrigation) explained from 1/3 to 2/3 of the variation in fertilizer use in various areas. Furthermore, her data indicate that the elasticity of production with respect to fertilizer is about twice as large in the long run as in the short run due to the adoption of inputs and cultural practices complimentary to the use of fertilizer.

Pest control and improved storage also can stretch available fertilizer supplies. Cotton yields, for example, scarcely respond to fertilizer alone but make dramatic gains when spraying and fertilizer are combined. Somewhat the same applies to coffee and cocoa. For food crops, storage losses may be substantial. Reducing these losses can have a favorable impact on available food supplies.

Lack of available markets and an efficient transportation network commonly limit food crop production in West Africa. The effective isolation of many rural areas results in a very inelastic local demand for food crops and often pushes farm prices far below official prices established by government. In many such areas farmers would be more than willing to expand acreage and output without the use of fertilizer if they could find markets at offical minimum prices.

And finally government policies relating to pricing and taxing, legislation concerning food distribution and the cost of transportation, licensing of transporters, availability of credit, use of the agricultural extension service and other areas impact agricultural production independently of available technology. Favorable policies in these areas can induce increased output by encouraging a fuller utilization of available land and labor resources.

Eventually, of course, the agricultural sector will require large amounts of fertilizer if agricultural productivity is to keep pace with population growth and urbanization. Increasing both fertilizer use and efficiency ultimately must be an important component of government policy. Some ideas on when and how this can be done are discussed in this report.

II. SOME FERTILIZER RELATED CONCEPTUAL ISSUES

A. Macro Economic Framework and its Relationship to Fertilizer Consumption and Self-Sustaining Development

An important issue relating to rural development and the production and use of fertilizer in West Africa is the area's very heavy orientation toward the production of cash export crops and importation of consumer goods--increasingly, foodstuffs. There is a clear need to begin restructuring the region's economies so as to maximize internal linkages between the rural-agricultural and urban-industrial sectors by producing more for local consumption using local resources. A continued heavy reliance on cash export crops no doubt would stimultae greater consumption of fertilizer in the short run since most fertilizer is used on export crops. Policies aimed at promoting internal economic integration, on the other hand, would place heavier reliance on incentives for production of local food crops and crops required as inputs to local industries; on developing an appropriate technology to overcome production and processing constraints; and on marketing and transportation infrastructure to deliver the inputs and store and market the output. In food deficit countries such as Senegal, Ghana, and Ivory Coast, resources would shift to the production of less responsive food crops which probably would retard fertilizer consumption. This reduced emphasis on fertilizer would probably carry into the longer run as well, as technology based more on the local resource base--such as efficient nitrogen fixing crop varieties--becomes available.

In countries self-sufficient in food production, the short-run depressing effect on fertilizer consumption would be accompanied by reduced farmer incomes as well--unless production resources shift to new agricultural enterprises, new markets are opened, or new uses are found for existing agricultural output. Much greater attention would need to be given to creating and expanding industrial sector-agricultural sector linkages within the national economy.

The choice is one of orientation and degree rather than a sharp shift in economic structure. For many countries, surpluses available from cash export crop production are simply too great to forego, though a closer examination may reveal that the rural sector benefits very little from them. Current weak price, infrastructure, and technology linkages between the agricultural sector and the urban-industrial sector may offer little hope for the latter to absorb much additional production in the short run even as food imports continue to rise in food deficit countries. Export demand and crop production on the other hand, provide a "vent for surplus" which allows fuller employment of available domestic resources and greater national income until such time as these linkages can be strengthened.

Over the longer run this shift in emphasis becomes increasingly important. An agricultural sector producing for local industries which are based on indigenous consumption patterns and the indigenous resource base maximizes dynamic linkages between the urban and rural sectors and between the producer and consumer good sectors. As these linkages expand, economies become more stable and more independent of external forces over which they have no control.

Promoting internal economic integration does not rule out partial reliance on export markets. But an export capability based first and foremost on commodities which have a local use is much more likely to have favorable spillover effects. These include greater flexibility of trade, a base for indigenous technological improvement and, more importantly, linkages to the domestic economy which allow domestic consumers to benefit from price decreases in the same way as foreign consumers. Thus, increasingly, the tradeoffs in income affect various categories of domestic producers and consumers, rather than domestic producers and consumers versus foreign producers and consumers. Eventually the expanded linkages generate self-sustaining growth which carries the rural sector along with the urban sector toward higher levels of consumption.

B. The Need for an Expanded Social Cost-Benefit Framework for Analyzing Fertilizer Related Issues

Fertilizer policy needs to be considered from a truly national point of view. The ultimate objective of fertilizer policy is presumably not so much to increase crop yields as to increase the amount of real consumption a country can derive from its resource base. This may indeed require an increase in crop yields. But any increase in agricultural output resulting from the use of fertilizer must be measured against all the costs incurred in obtaining that output, not just the cost of fertilizer. This requires consideration of alternative uses for all the resources employed and how those uses affect various members of the economy. This is the normal domain of social cost-benefit analysis.

The need to examine how resource allocation decisions affect various members of the economy takes on special importance where policy makers are attempting to substantially alter the distribution of income. USAID policy specifically singles out the rural poor as the target of its efforts. Conventional social cost-benefit analysis normally uses opportunity cost based shadow prices to value inputs and output. Since these are computed by adjusting existing prices for various "market imperfections," they still embody the distribution relations reflected in the structure of prices arising from the existing distribution of income and income producing resources. They simply provide a more efficient way of allocating resources to satisfy, rather than change, the existing distribution of income. Only explicit political intervention in the form of weights to be given to consumption by various members of the economy can change this orientation. It is important in this respect to consider the effect of the use of agricultural surpluses on desired rural development objectives as much as the size of the surpluses generated. Until output expansion programs--whether they be fertilizer subsidies, pricing policies or investments in infrastructure--explicitly consider who benefits from the expanded output, they have a high probability of failing to achieve their objective of helping the rural poor.

The argument here is not that programs which increase agricultural output and incomes will have no impact on the standard of living in rural areas. Rather, it is that the rural sector can benefit a great deal more than at present from the investible surpluses that it generates. This will happen when benefits begin to be measured, not so much in terms of the increased production or income which results, but rather in terms of any increase in consumption accruing or likely to accrue to the rural population. In addition to increases in income this would include investments which promote linkages between production and consumption, between urban and rural areas, and between the modern and traditional sectors. Particularly, more attention needs to be given to the effective utilization of agricultural surpluses for financing investments which improve agricultural productivity and the quality of rural life rather than increase the public sector payroll or finance prestige projects.[1] Elaborate public

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[1]One of the most pernicious uses of agricultural surpluses throughout West Africa has been to finance an increase in the salaries and size of

buildings and large international airports would not be likely investment choices for most rural people. They would more likely choose to use agricultural surpluses to finance integrated capital goods, intermediate, and final product industries, developing and using labor intensive technologies not available from the developed countries, and producing agricultural implements, farm level processing equipment, shoes, clothing, building materials, durable bicycles and basic consumer goods for the rural sector. In this way, the industrial sector becomes linked to the agricultural sector and the consumer goods sector to the capital goods sector just as the urban sector needs to be linked to the rural sector. By looking only at crop production and output, donors skirt these apparently unrelated issues of economic structure. As a result they are accepting a small return on their rural development investment dollars and only kidding themselves as to the eventual impact of their assistance on the standard of living of the rural poor.

C. The Use of Fertilizer Value-Cost Ratios

Fertilizer value/cost ratios are used by agricultural technicians to evaluate the attractiveness to farmers of a given application of fertilizer. The value/cost ratio is a ratio of the value of incremental output resulting from the use of fertilizer over the cost of the fertilizer required to produce that incremental output. As such it incorporates fertilizer responsiveness and crop and fertilizer prices into a single least common denominator. The ratio uses actual farm level prices in valuing both fertilizer and crop output. As a general rule of thumb, technicians seem to

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the public sector labor force. Indeed, there appears to be a pronounced tendancy for both to adjust themselves to available public revenue in a sort of surplus consuming version of Parkinson's Law. With a few exceptions, where agricultural surpluses are not used to finance an expanded bureaucratic structure, they are used to finance investments having a much more direct impact on urban than rural consumption patterns.

agree that this ratio must be around 2:1 before farmers will use large amounts of fertilizer and 3:1 or greater before farmers will adopt fertilizer for the first time.

The economic basis of the value:cost ratio is simple. Use of fertilizer requires additional labor for fertilizer application, increased weeding, and harvesting the added output. Available evidence cited in Chapter IV indicates that labor requirements increase about one-half as much as output for most crops, the largest increase being for labor in harvesting. Interest, risk, and costs associated with purchasing and using fertilizer also must be recovered by farmers before fertilizer becomes attractive to them. In very rough terms the added labor, capital and risk costs associated with the use of fertilizer appear to be about equal to the cost of the fertilizer itself. This yields a break even ratio of around 2:1. This does not mean that the farmer or the country has earned two dollars in income for every dollar spent on fertilizer. The inputs associated with the use of fertilizer cost farmers something in terms of output foregone, either by not using traditional technologies, or by diverting cash and other resources away from other uses. Only to the extent that the value: cost ratio rises above 2:1 does a farmer increase his income from using fertilizer.

Obviously, acceptable value/cost ratios will vary between farmers and crops. Even for specific crops they fall on a continuum rather than at single points. Furthermore, there is a tendency for minimum acceptable ratios to decline as both individual farmers and agriculture in general develop, labor productivity increases and risk is reduced. Nonetheless, as a rough approximation, the value/cost ratio provides a useful measure for evaluating farmer response to annual changes in subsidy and pricing policies.

Being primarily a measure of farmer responsiveness, the fertilizer value/cost ratio is insufficient for evaluating the impact of fertilizer subsidies and crop prices from an aggregate income point of view. This point cannot be overemphasized. High levels of subsidy may indeed reduce the cost of fertilizer so that its use becomes profitable to farmers. But if farmers generate only two or three dollars of additional output per dollar they spend on fertilizer, then where subsidies exceed 50% of the farm delivered cost of fertilizer they may well be producing insufficient output to cover the real cost of fertilizer to the country. A country may be getting only one dollar of added output for every two dollars of foreign exchange spent on fertilizer. This is the real danger of the very high subsidies currently prevailing in Ghana and Nigeria.

III. A REVIEW OF AGRONOMIC RESEARCH RELATING TO FERTILIZER

A. Soil Surveys

Systematic soil surveys have been made for 1) Upper Volta, 2) Benin, 3) large sections of southern Ivory Coast, 4) southern Niger, 5) northern Ghana, 6) northern Nigeria, and 7) the central agricultural region of Chad. Reconnaissance surveys have been completed for significant portions of Cameroon, Chad, Togo, Ivory Coast, Senegal, and about 2/3 of Nigeria. Figure III.1 gives an indication of the detail of the surveys.

Most soils of West Africa are deficient in P_2O_5. The acid soils with high levels of clay tend to adsorb phosphate. Sandy soils have lower phosphate adsorption capacity and fertilizer phosphate is readily available to plants. Generally, soils of West Africa have adequate levels of K_2O to sustain crop production under the modified shifting cultivation practiced in the region. However, continuous intensified crop production will require potassium fertilization. Cotton, groundnuts and maize will likely benefit from K_2O fertilization before other non-plantation crops.

B. Fertilizer Response Studies

It is important to distinguish the economic crop response to fertilizer from the technical response. In economic terms a "good" response is one which renders the use of fertilizer economic or profitable for the economy as a whole. To be economic the response must suffice to pay for the cost of the fertilizer and related inputs to the economy and still leave a surplus. Economic response is determined by the technical crop response to fertilizer and the unsubsidized and untaxed prices of fertilizer and the crop produced. Theoretically, any positive response to fertilizer can

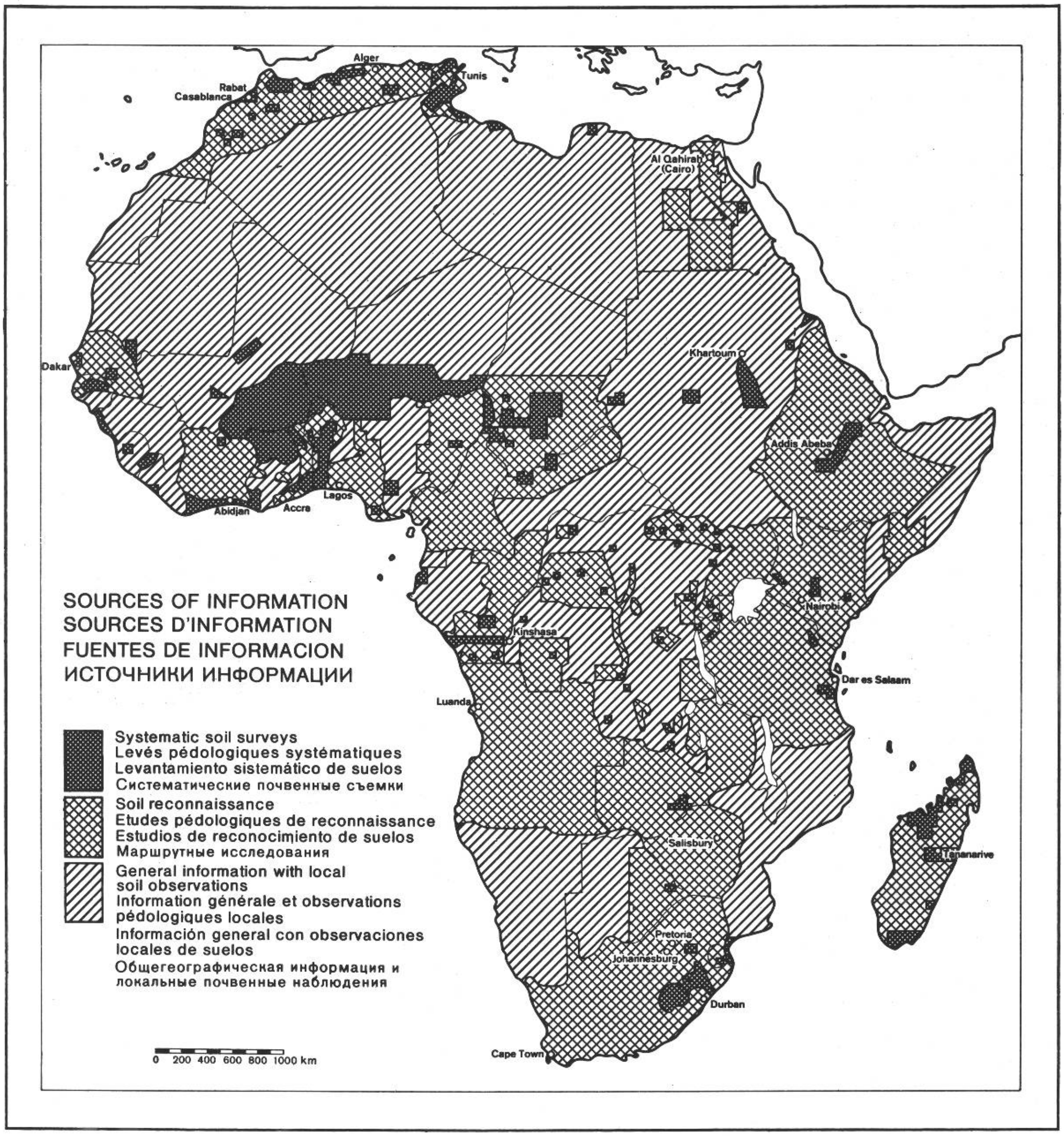

Figure III-1. An Indication of the Detail of Soil Surveys in Africa (Soil Map of the World, VI-2, FAO/UNESCO, 1973).

be economic, provided the value of the output is sufficiently high. At the same time, even very large technical responses will be uneconomic if crop and fertilizer prices are unfavorable.

As a rule of thumb, agronomists consider 10 kilos of grain per kilo of nutrient applied to be a good response to fertilizer. From an economic point of view this seems appropriate for West Africa, given the real cost of fertilizer and producer prices for food grains which prevailed throughout most of the region in 1976. Where the yield increase was this high the use of fertilizer would have been economic on most crops, even on millet in Chad which was selling for 22 FCFA per kilo.

Table III.1 summarizes fertilizer response data from a variety of sources, mostly FAO fertilizer trials and fertilizer demonstrations. The results are highly variable and no doubt incorporate substantial differences in rainfall and other environmental factors. Some trials and demonstrations do achieve yields of 10 kilos of grain per kilo of nutrient or better, especially those using 20-40 kilos of nitrogen per hectare on rice and maize. Response of these two crops to P_2O_5 is generally slightly less than 10 kilos of grain at an application rate of 20 kilos of nutrient per hectare. But for millet and sorghum, the bulk of the region's cereal consumption, trial or demonstration results of this magnitude are the exception rather than the rule. Results for groundnuts are highly variable, the better response generally coming from P_2O_5 demonstrations in Senegal. None of these crops respond well to K_2O.

Data analyzed in the West Africa Fertilizer Study (31, 32, 33) for some of the Sahelian countries, indicate responses to nitrogen for millet and sorghum in the upper part of the range of Table III.1, ranging between 7 and 11 kilos of grain per kilo of nutrient. Montgomery (40) shows good

TABLE III.1
GENERAL NATURE OF CROP RESPONSE TO FERTILIZER NUTRIENTS
FROM TRIALS AND DEMONSTRATIONS IN WEST AFRICA

Crop	Applied Nutrient		Yield Response
	Nutrient	Rate, kg/Ha	Kg crop/Kg Nutrient
Fertilizer Trials[a]			
Maize	N	40	6 - 14
	P_2O_5	20	5 - 12
	K_2O	20	1 - 7
Millet and sorghum	N	20	5 - 10
	P_2O_5	20	4 - 8
	K_2O	20	0 - 6
Rice	N	45	10 - 20
	P_2O_5	20	8 - 15
	K_2O	20	5 - 10
Groundnut	N	10 - 25	2 - 40
	P_2O_5	20	4 - 8
	K_2O	20	3 - 4
Fertilizer Demonstration[b]			
Maize	N	20	10 - 20
	P_2O_5	20	2 - 8
	K_2O	20	2 - 5
Millet and sorghum	N	20	6 - 14
	P_2O_5	20	6 - 15
	K_2O	20	4 - 7
Rice	N	20 - 40	10 - 20
	P_2O_5	20	4 - 12
	P_2O_5	20	2 - 4
Groundnut	N	10 - 20	2 - 12
	P_2O_5	20 - 40	9 - 17
	K_2O	20	2 - 4

[a]Summary from various FAO Fertilizer Program Reports and country Research Station Reports.

[b]Summary from various FAO Fertilizer Program Reports.

response of both cereals to all three nutrients using experiment station data from Senegal, Mali and Upper Volta. His analysis further reveals a significant positive interaction effect between nitrogen and P_2O_5. Falusi (15) cites trial and demonstration plot data for Nigeria indicating a response of 11-14 kgs of maize per kilo of nitrogen. The same data series shows a yield response of 16 to 36 kilos of yams per kilo of nutrient for composite NPK fertilizers.

Few data exist on the actual farm level response to fertilizer. What data are available suggest that the response of millet and sorghum to fertilizer is about half that of experiment station results. For rice, farm level response is generally much closer to experimental results but highly variable (40). This variability for rice appears to arise both from an inability to distinguish between upland and other varieties in aggregating results, and from large variations in soil moisture at the farm level. The lower response from sorghum and millet appears to arise primarily from differences in cultural practices relating to intercropping. New fertilizer responsive varieties have been developed largely on the basis of pure stands though little sorghum and millet is actually grown this way in West Africa. Clearly, much more attention needs to be given to quantifying the farm level response of improved varieties to fertilizers in the context of prevailing cropping systems. This information will greatly assist plant breeders to develop more suitable technology for West African farming systems.

C. Crop Response to Phosphate Rock (PR)

The response of groundnuts and cereals to various sources of phosphate rock from West Africa are shown in Appendix A. In general the data show that cereal and groundnut yields are increased by applications of ground PR from Togo, Mali, Niger and Senegal. Application of phosphate rock at rates of 40-160 kgs of P_2O_5/ha generally gives significant yield increases on phosphorus deficient soil for 3 to 5 years. Where direct comparisons were made, Taiba (Senegal) and Tilemsi (Mali) PR gave similar crop responses. Where phosphate rock materials have been compared with dicalcium phosphate or triple super phosphate, the PR's are from 50-90% as effective as the processed fertilizers. As would be expected, the response to soluble P_2O_5 is better than PR in areas of low rainfall, though neither is very good.

Crop responses to P_2O_5 vary among locations, PR source and rainfall; but in many trials, responses to PR were 10-40 kgs of groundnuts and grain for each kg of P_2O_5 applied as PR. In general rock phosphates seem to be most effective when applied as basal fertilizers under a medium to good rainfall regime (37).

These conclusions about the value of selected phosphate rock deposits as a source of P_2O_5 are tentative. Additional experiments are needed in which better documentation of experimental conditions is recorded. But defining areas of profitable use and the relative value of specific sources of phosphate rock in comparison to processed phosphates should have a high priority. Phosphate rock is the one indigenous source of fertilizer widely available throughout the region.

D. Other Agricultural Research

1. The Research Network

Agricultural research on food crops in the Francophone countries has been conducted principally by the French Research Institute for Tropical Agronomy (IRAT). Since the mid 1960's, USAID has assisted both Francophone and Anglophone countries through the JP-26, millet and sorghum research project. The International Institute of Tropical Agriculture (IITA) has responsibility for research on food crops in the humid areas of West Africa, and the West African Rice Development Association (WARDA) deals with rice in the region. U.K. agronomic research assistance in the region apparently has been concentrated in Nigeria at ABU/Zaria.

In the future, The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) will play an important role in the arid regions of West Africa through funding by USAID and UNDP. IITA will be working closely with ICRISAT, while continuing its efforts in the humid areas. Both these institutes will be closely linked with national research stations, especially in Nigeria, Upper Volta and Senegal, through USAID's Semi-Arid Food Grains Research and Development project. Their research programs will continue to be orientated toward major food crops, including the development of improved varieties, soil and water management, cropping systems, and increasingly, farming systems.

The strongest food crop research programs have been conducted in Nigeria, Senegal, Ghana, Ivory Coast, Sierra Leone and Cameroon. Improved varieties of major food crops have been identified and developed. Beneficial effects of soil tillage, additions of organic matter, correct planting dates, plant populations, proper weeding, and fertilizer response have all been demonstrated on research stations in these countries. Although much additional experimental research is needed--especially as it relates to farming systems--there is an even greater need to extend the known beneficial practices to the farm level and to identify those factors which restrict their adoption. At the same time, much more attention must be given to documenting the conditions--soil, moisture, planting dates, etc.--

under which farm level trials are conducted.

2. Soils Research

Soil tillage has been studied more than the other practices mentioned above, particularly in the Francophone countries. A large number of trials conducted in Senegal showed that plowing (animal or tractor) increased yields of millet, sorghum, maize, and rainfed rice in 85% to 100% of the trials conducted. The yield increases were 20% to 25% for millet and sorghum, 30% for miaze, and 75% to 100% for rice. In Niger, plowing gave erratic results with groundnuts (yield increases from 0% to 20%), but millet yields were increased by 25% to 50%. In these trials, fertilizers gave a 13% increase in groundnut yields without plowing and 6% with plowing. Fertilizer increased millet yields by 55% to 75% without plowing and 35% to 65% with plowing (1).

Increasing the organic matter content in soils of the tropics can reduce the requirements of chemical fertilizers as well as improve certain soil properties. Many experiments on research stations in West Africa have demonstrated this. The greatest remaining need in this area is to encourage green manuring and incorporation of animal and crop residues into the soil. The reason such efforts have not had much effect to date include the cost of growing a crop to incorporate into soil, other uses for residues, and lack of draft power and equipment to incorporate residue. For the time being, emphasis on alleviating these constraints appears to be more important than additional research on the effects of organic matter additions to the soil.

3. Nitrogen Fixation and Crop and Soil Management

One area of research that has received surprisingly little attention in relation to its potential payoff in West Africa is that of symbiotic and non-symbiotic nitrogen fixation. With the prospect of rapidly rising costs for energy and the very limited availability of raw materials for nitrogen fertilizer production outside of Nigeria, the time for a major increase in this kind of research is clearly at hand. Also the high proportion of cereals which are intercropped with legumes immediately suggests symbiotic nitrogen fixation as potentially a very important vehicle for delivering low cost nitrogen to subsistance farmers.

Potential symbiotic nitrogen fixation by pulses and other legume crops are 40 to 500 kg of nitrogen per hectare (Appendix B). This nitrogen may be utilized by the legume, a non-legume grown in association with it, or by a subsequent crop. Obtaining proper nodulation for the legume to realize its potential for fixing nitrogen appears to be a problem in tropical soils, as does the lack of strains of micro-organisms with which such legumes can efficiently interact. Also harvesting and removing the crop after maturity can virtually eliminate any net gain in nitrogen as nitrogen fixed on the roots may be translocated to the plant tops or to the grain. However, the tremendous variability in the ability of individual crops to fix nitrogen suggests that the potential for making important plant breeding and microbiological breakthroughs in this area is substantial.

Non-symbiotic nitrogen fixation potentially can also be very important, especially for rice. Some important tropical grasses have been found to have considerable nitrogenous activity in their rhizospheres. Assays of pennisetum purpurem plants in the field suggested that nitrogen fixation supplied about two-thirds of the plants' nitrogen. Rice also appears to stimulate nitrogenous activity. Nitrogen-fixing blue-green algae are commonly found in rice fields in Japan. In Asia, the small fern Azolla is estimated to fix up to 120 kgs of N per hectare per season (12).

E. Concluding Comments

Experiment station results with high yielding varieties have been generally good in the region, especially with maize and rice. But sorghum and millet yields on farms appear to be much lower than experiment station results. Work on upland rice has been inadequate in relation to its importance to the region (10). Furthermore, extending the new varieties and the supporting technology to the farm level has not been very successful, partly because much of the technology developed does not appear to fit well into existing farming systems and cropping patterns.

The amount of agricultural research relating to the use of fertilizer which needs to be done in West Africa is vast. With only one or two exceptions, none of the countries in the region can, by themselves, make the kind of investment that is needed even if such research is restricted to food crops. While research on cash crops needs to push ahead, the recent shift in emphasis toward food crops is necessary and long overdue. Continued efforts in developing high yielding varieties are needed; but as these become more widely available efforts will have to shift toward yield maintenance research on pests and disease. Much more attention needs to be given to crop and soil management research and farm level fertilizer trials which identify and develop new technologies complimentary to existing cropping systems. In this respect, a very sharp increase in the amount of resources going into research on intercropping, crop rotation and nitrogen fixation should have the highest priority. And finally, well planned trials on crop response to P_2O_5 from indigenous phosphate rock sources which appear to have economic potential need to be undertaken.

IV. FARM-LEVEL ECONOMIC ISSUES RELATING TO FERTILIZER

A. Labor Constraints on Agricultural Output and Their Relation to Fertilizer Use

According to FAO data, 80 percent of the increase in food grain output in West Africa between 1948-52 and 1972-74 arose from increases in area planted (28). This points to the availability of idle land throughout most of the region and suggests that farmers are probably more concerned with returns to available cash and labor resources than returns to land. Areas of exception certainly do exist such as the groundnut basin in Senegal, the Mossi plateau in Upper Volta, and parts of the coastal countries. But as a general rule, available labor at critical periods is the most serious constraint on increasing agricultural output in West Africa at this time.

Even where available cash or capital is a constraint on farm incomes, it frequently is expressed in terms of the inability of farmers to hire sufficient labor rather than the inability to purchase modern inputs. In both the tree crop belt of southern Nigeria and the savanna belt to the north, farmers spend several times more cash on hiring labor than the amount spent on fertilizers and materials (16, 43). The same holds true in Sierra Leone (62). Only hiring tractors for plowing approaches hired labor in importance as a cash expenditure for farming operations. Labor is hired mainly for land preparation and weeding, but also for harvesting. Of the three, weeding is more normally the most serious constraint. This is indicated by labor flow studies which show higher total hours worked in the months corresponding to the weeding period than in other months (43,62).

The division of labor between farm and non-farm activities plays a role in determining the level of agricultural output in West Africa.

Norman (42) found that farmers could increase their incomes by 28 percent with only 4 percent more annual labor by allowing labor inputs during some nonpeak months to rise to the level attained during the peak season. He did not examine the nature of the non-farm activities which occupy farmers during these periods, an area that requires further study. Yet it does seem likely that more favorable pricing policies would mobilize additional labor for agricultural production either by reducing leisure, inducing a reorganization in the farming system, or reducing non-farm allocations.

In areas where labor is the main constraint on agricultural output, fertilizer becomes attractive to farmers only to the extent that it increases returns to labor rather than returns to land. These two do not always go together. Norman et al. (45, 47) found that input packages for sorghum and cotton increased yields by 101 percent and 105 percent, respectively. But the return per unit of labor employed rose only 5 percent for sorghum and 17 percent for cotton. Obviously, much of the return attributed to the input package would have been available through an expansion of acreage using traditional methods as well. A similar situation prevailed in Sierra Leone in 1974-75 where an improved rice production package increased yields 38 percent as against a 65 percent increase in labor inputs (52). In this situation, returns per unit of family labor were actually lower, although more hours were employed during slack labor periods while water control no doubt reduced risk considerably.

Another study by Norman (46) and several cited by Falusi (15) indicate only marginal increases in the labor requirements associated with the use of fertilizer on yams, rice and maize (10-20 hours per acre). The conflict between these and the previous studies cited point to a basic lack of knowledge about fertilizer-labor relationships. They do suggest, however, that both yield increases and labor requirements associated with the use of fertilizer need to be examined carefully before the suitability of a technical package for land extensive areas can be determined.

B. The Role of Intercropping

Intercropping is a very important aspect of West African agriculture. In some areas, 90% of the fields contain more than one crop. Intercropping has two principal functions: reduce risk and increase incomes. Though many experiment station trials show that yields per acre for individual crops are lower when crops are planted in mixtures, on an income per acre basis, total return under farm conditions usually is higher. Intercropping is less common and almost always less intensive with cash crops.

Intercropping reduces risk by allowing farmers to plant earlier and harvest later on the same plot of land. Should the rains come late, the late crop does well, and vice versa. In cereals-legumes mixtures, cereals do well in wet years and legumes do well in dry years. Intercropping enables farmers to increase utilization of environmental factors such as sunlight, water, and soil nutrients, not to mention nitrogen fixed by soil organisms attaching themselves to leguminous plants. It increases crop density and thereby reduces weed growth and protects the soil against erosion. At the same time, there is evidence that though a greater variety of insects and pests are likely to be present in intercropped fields, crop damage is likely to be less acute than with a sole crop (44).

Intercropping does not seem to be induced by land scarcity, though labor inputs per acre have been found to be higher. Norman (44) found no relationship between the degree of intercropping practiced and relative availabilities of land and labor. He did find that both the value of output and total labor input per acre for intercropped fields was on the average 50 percent higher than for sole crops. But return per hour of labor expended during the June-July labor bottleneck was almost 15 percent higher for the intercropped fields. Thus total returns per family member were higher as farmers were able to expand the number of hours in agricultural employment.

The central role played by intercropping in West Africa suggests that biological research, especially as it relates to developing fertilizer responsive varieties of food crops, should be carried out in the context of common crop combinations rather than sole crop stands. Length of growing season, nutrient requirements, and physical plant characteristics may well be quite different for varieties grown in mixtures than for varieties grown as sole crops.

C. Diffusion of Innovations Relating to Fertilizer

Although pockets of relatively high rates of fertilizer application exist in West Africa, such as in the groundnut basin of Senegal and on mechanized rice farms in northern Ghana, the vast majority of farmers use no chemical fertilizer at all. Consumption of nutrients per hectare of arable land averages between 2 and 4 kgs in Senegal, Ivory Coast, Cameroon and Ghana, and 0.5 kgs in Nigeria for the five major fertilizer using countires. A breakdown by nutrient and country, along with per capita consumption, is included in Appendix C, Table C.1. It appears that more than 65 percent of total nutrients are applied on export crops, though accurate estimates are not available.

The value of manure as fertilizer is generally recognized throughout the region. Manure from animals kept in family compounds is usually applied to small vegetable gardens inside or immediately next to the compounds. Manure from other animals is normally applied to food crop fields adjacent to the compound. The most common method of application is to bed the cattle down on the parcel to receive the manure, perhaps over an extended period of time. In many areas, farmers pay herders to do this. No doubt, much of the available nitrogen is lost in this way as the manure is exposed to the sun over the dry season. But without considerable investment of labor, it is difficult to see how the practice can be much improved upon. In any case, available supplies of manure appear to be rather fully utilized and do not offer much hope for more than a marginal expansion in nutrient availability in rural areas.

There is some evidence that when fertilizer responsive varieties exist, farmers who use fertilizer do not use it in optimal amounts. In one study, Norman (43) found the MVP of fertilizer to be 2.8 times its cost. Spencer and Byerlee (62) found it to be 15 times the cost of fertilizer among mechanized rice farmers in Sierra Leone. Though both these areas were suffering from a shortage of fertilizer supplies at the time of the survey, these results are supported by observation elsewhere in West Africa. This point does require closer attention, however, since it has a direct bearing on the use of fertilizer subsidies in stimulating the economic use of fertilizer.

Falusi's study of Nigerian farmers (15) highlights the importance of institutional and educational considerations in the adoption of fertilizer by peasant farmers. Membership in a cooperative or farmer's association, attendance at farmer meetings, frequency of extension contact and availability of credit all proved more closely associated with adoption of fertilizer than economic factors such as the size of farm or crop prices.

His cross sectional analysis did not include fertilizer prices since these were everywhere the same.

Economic factors played a much more important role in determining the amount of fertilizer to use among farmers who had adopted fertilizer. Expenditures on hired labor, number of years a farmer had used fertilizer, use of improved varieties of seed, crop prices and the use of improved practices in general, all were associated with higher levels of fertilizer use. These results are quite consistent with David's findings in Asia (13). The only disturbing conclusion which seems to flow from Falusi's analysis is that most of the factors associated with the adoption and use of fertilizer are highly correlated with wealth. This has implications for defining the role of fertilizer in reaching the rural poor.

Other factors affecting farmer decisions to adopt fertilizer or crop varieties which respond well to fertilizer include consumer tastes and technical characteristics of the new varieties. Walkup (81) notes that higher yields are possible in Nigeria with yellow corn but existing varieties have a hard seed coat and are difficult to grind. Furthermore, Nigerians consider yellow pap to be unclean and yellow corn does not process into white pap. High yield sorghum varieties developed at Samaru are not utilized extensively because they are short stemmed and stover is required for construction and fuel in a fuel deficient area. Yams respond extremely well to fertilizer but yams grown with fertilizer appear to have shortened storage life, making them difficult to market (81). The string of examples is endless and, by now, well appretiated by plant breeders.

Investments in fertilizer and fertilizer responsive crop varieties can not be considered apart from other investments required to make the fertilizer responsive technology acceptable to farmers. Such additional investments make this technology a lot less economic than it often appears at first glance or as might be suggested by fertilizer value/cost ratios. Indeed factors such as these no doubt go a long way in explaining a great deal of farmer reluctance to use fertilizer. They suggest, in turn, a need to field test new varieties and follow them through the food production and marketing chain before promoting their widespread adoption. And lastly, these factors suggest a need for more effective feedback from farmers to the research stations.

D. The Role of Extension

On the surface, Falusi's study (15) suggests that the extension service plays an important role in stimulating the adoption of fertilizer. However, the close apparent association of extension agent contact with wealth and progressive farmer characteristics suggests more than usual caution over inferring causation from correlation. Few persons familiar with the dynamics of farmer-extension agent contact in Africa would doubt that in many cases, the extension agent follows more than he leads. Moreover, as Walkup (81) shows in Nigeria, the incidence of incorrect advice given by agents to farmers is very high, ranging between 30 and 50 percent for specific practices relating to fertilizer responsive technology. This has grave implications both for extension assisted on-farm trials of new technologies and for expansion of fertilizer responsive technologies if indeed the extension input is so important.

Clearly before fertilizer responsive technology can benefit farmers they need to know of its value and how to use it. Before extension agents can be of assistance in either of these areas they themselves must be educated about the new technology and use of fertilizers. It makes little sense to develop technology which will not be applied because farmers never learn how to use it correctly. In this respect it is important to differentiate between constraints on adoption imposed by farmer habits and unwillingness to change, and farmers' lack of knowledge. Research can deal with the former while extension deals primarily with the latter.

Another factor restricting the ability of the extension service to promote fertilizer use is its frequent preoccupation with male farmers. This is especially important for food crops since throughout much of the region women have primary responsibility for food crop production. At best, the women get their information second hand from their husbands, no doubt resulting in substantial distortion. Much the same can be said for poor farmers who must rely on what information trickles down from the progressive farmers who seem to preempt a good proportion of available extension time.

In spite of all their negative aspects, the crop specific regional development organizations such as riz-Mopti in Mali and CFDT in Upper Volta have been quite effective in increasing production through broadly based extension services. Part of their ability to do so stems from the direct control they exercise over extension agents, part from their relatively narrow focus and part from their continued efforts at recycling agents in training programs. Their success suggests that with a proper information base, a better understanding of farming systems, and an effective system of control, the ability of non crop-specific extension agents to stimulate adoption of fertilizer responsive varieties and the use of fertilizer can be greatly increased. If, at the same time, the extension services could adopt a less paternalistic attitude toward farmers and orient agents more toward poor farmers, extension activities could indeed become an important vehicle for reducing income disparities within rural areas. Clearly, creating this kind of extension service should have a high priority in USAID fertilizer policy.

E. Agricultural Credit

Robinson and Falusi (54) cite empirical evidence pointing to the availability of working capital as the most important constraint on the use of fertilizer in Northern Nigeria. Yet in the same study they show that the best farmers spent 10-20 times as much money on hiring labor as on fertilizer. Many farmers invested in expensive mechanical innovations in preference to spending modest amounts on fertilizer. This suggests that availability of working capital is less of a problem than the set of priorities on which to use it.

Obviously, if fertilizer is profitable, making it available on credit would encourage its use. The real question for a capital scarce country, however, is the return from money invested in fertilizer as compared with money invested elsewhere. By providing credit for fertilizer rather than other inputs, governments effectively skew investment toward imported fertilizer and against other inputs such as hired labor which has a very high local cost component.

The real problem with credit in West Africa is getting farmers to use it as intended. Norman (42) cites a study by Vigo which showed that over 80 percent of credit obtained by farmers was used for consumption purposes. Giving credit in kind is not foolproof either. Farmers in Senegal take fertilizer on credit and immediately discount it for sale in order to raise cash for non-agricultural purposes. It is not true that this kind of diversion poses no problem since the fertilizer at least will be used. If farmers selling fertilizer discount it at rates normally prevailing in local credit markets at pre-harvest time--the most likely case--farmers purchasing it have to get twice its cost to them in output just to pay for the original cost of the fertilizer to the country. If it was subsidized in the first place, a country may be getting local production for foreign exchange at the rate of 50 cents on the dollar--hardly an attractive investment from a national point of view.

Repayment poses another problem with agricultural credit whether for fertilizer or other inputs. The history in Africa is by no means encouraging where input credit is not tied to a marketing monopoly. A recent study of untied credit in Upper Volta (85) showed 45 percent of outstanding equipment loans in the Eastern Rural Development Organization in arrears of two years or more. Loans made by The Société d'Assistence Technique pour le Modernisation de l'Agriculture en Cote d'Ivoire (SATMACI) and the Société pour le Developpement de la Riziculture (SODOERIZ) in Ivory Coast in 1967 showed less than 15 percent and 45 percent repayment respectively, the latter being specifically for fertilizer (14). Where credit is tied to marketing, repayment rates rise to very respectable levels. Repayment rates in Chad for credit from the Office National pour le Developpement Rural (ONDR) for cotton are said to average 95 percent (29). In Mali in 1975 delinquent loan repayments were only 3 percent for cotton but were 35 percent for peanuts (32). Clearly, control over marketing makes a substantial difference.

As with discounted sales of fertilizer obtained on credit, repayment rates are of more than just distributional interest. To the extent that farmer expectations about not repaying credit become factored into their decision to use fertilizer, then the use of fertilizer may indeed become very uneconomic. A 2:1 or even 4:1 expected value cost ratio does not amount to much increase in output where the fertilizer is effectively free in the first place.

Credit sales of fertilizer assume that the fertilizer will be paid for out of marketed production. For poorer farmers the chances are high that increased production will be consumed rather than sold. If rainfall falls below normal, output may be little more than without fertilizer and then the accumulated indebtedness becomes an additional constraint on fertilizer use. It was not an accident that fertilizer consumption in Senegal fell by 65 percent between 1968 and 1971 under the impact of poor rainfall and increasing farmer indebtedness for fertilizer, only to begin rising sharply in 1972 after all outstanding debts were cancelled, even though rainfall was low for two more years.

Finally, there is increasing evidence that much of the success attributed to increases in fertilizer consumption associated with agricultural credit programs arises not because of the credit per se, but because of the increased availability of fertilizer that normally accompanies such programs.

There is ample room for some creative thinking in the field of agricultural credit in Africa. The rural poor are precisely those farmers who rely more heavily on food crop production and who produce for immediate sale. Extending credit for fertilizer to them puts them in a precarious position vis-a-vis the weather and their pressing needs for cash for non-agricultural uses. Ensuring that input credit does not become an easy road to greater indebtedness, but rather a vehicle for increasing their production and incomes, will not be easy. Recent experiments with group credit provide some hope that repayment problems can be overcome. But without an increase in production resulting from the use of the fertilizer on their farms, repayment rates only beg the question as far as the rural poor are concerned. Increasing the availability of seasonal agricultural credit does increase fertilizer consumption. On that point the evidence seems reasonably clear. But making credit accessible to and effective for the rural poor is an area where knowledge needs more to be acquired than implemented.

F. Availability of Fertilizer

There is considerable evidence that mere unavailability of fertilizer at the farm level is one of the most important obstacles to its increased use by farmers (15, 77). Black markets in fertilizer exist in Ghana and Nigeria and one is struck by the conspicuous absence of fertilizer in important regional, sub-regional and local markets throughout West Africa. In the World Bank project area at Funtua in Northern Nigeria, fertilizer consumption has grown from 500 tons three years ago to 10,000 tons last year simply by installing retail outlets and providing them with adequate supplies. Project officials expect 25,000 tons to be marketed this year in an area that contains about 100,000 farm families. Gains of this magnitude are not likely unless subsidies are high or substantial groundwork has already been laid by agricultural research and extension as is the case in Nigeria. But this experience does emphasize the importance of developing agricultural input markets for the increased use of fertilizer.

V. SOME MACROECONOMIC AND OTHER POLICY ISSUES RELATING TO FERTILIZER USE IN WEST AFRICA

A. Cheap Food Pricing and Trade Policies

1. Effect on Output

One must be careful in attributing the failure of food crop productivity to keep pace with total population in West Africa simply to a lack of farmer responsiveness or to climatic variables, although the latter no doubt has played a part in recent years. Food crop production in Ivory Coast and Cameroon has consistently outstripped population growth in spite of a very high rate of urbanization in the former. Very sharp apparent increases in production in Mali, Senegal, Ivory Coast, Sierra Leone and elsewhere during 1975 and 1976 in response to sharply higher producer prices suggest that cheap food pricing and trade policies have been operating to restrict food crop production.

Several studies note the scant attention given to rural incomes in setting official producer and consumer prices in West Africa (5, 28, 69, 70). Although official prices for food grains frequently do not mean much in terms of actual farm level prices, subsidies on imported foodstuffs and other trade related policies usually do. An example of the importance of trade issues, even with respect to crops normally considered to be poor substitutes for each other, comes from Senegal where periodic subsidies on imported rice have discouraged domestic production. In 1975, under pressure of high world prices for rice, producer prices for paddy were raised from 22 to 45 FCFA and the consumer price for rice was raised from FCFA 60 to FCFA 100. As a result, imports of rice fell from previous levels around 200,000 tons per year to about 100,000 tons. This was only partly offset by an increase in domestic paddy production of 50,000 tons. Apparent rice consumption fell from about 240,000 tons in 1974 to around 180,000 tons in 1975 while producer income from rice almost quadrupled. At the same time, producer prices for millet remained strong in the face of a record harvest as consumers turned away from rice to more traditional staples such as millet and sorghum. Clearly there was a very substantial substitution of millet for rice and a dramatic impact on millet prices, rice production and rural incomes by this increase in rice prices, and the corresponding reduction in the level of subsidies on rice imports.

Additional evidence attests to farmers' willingness to expand food crop production in response to higher prices. Since 1970-71, fertilizer used on millet has increased proportionately more than fertilizer used on groundnuts in Senegal as millet prices in rural areas rose more rapidly than groundnut prices. In 1974-75, farmers applied an almost equal amount on each crop even though acreage of peanuts was larger (60). Not coincidentally, the 1974-75 millet crop was a record.

Evidence from Ivory Coast, Ghana and Mali suggests the same farmer responsiveness to higher prices for food crops. The former has maintained consistently high prices for rice by taxing imports and subsidizing inputs. Production has expanded, interrupted only by the drought, more than doubling between 1961-65 and 1975. Using the same policies, Ghana more than tripled its rice production over the same period (79). In Mali, rice production soared to record levels in 1975 and 1976 as the producer price rose by 60 percent (63). A similar situation occurred in Sierra Leone.

Although the data from Senegal and Mali must be interpreted in the context of their emergence from the drought, the magnitudes of the responses are difficult to explain by this alone. Even during the drought, while aggregate production fell, farmers throughout the region abandoned export crops and shifted to food crops as prices for the latter skyrocketed while export crop prices stagnated. Certainly this shift was not motivated entirely, nor perhaps principally, by the sharp rise in the price of food crops in such short supply as much as by the need for food for survival. But those farmers who had surpluses to market, and clearly there were many, were not about to resume export crop production until farm level prices for food crops returned to a more "normal" parity with export crop prices.

One cannot overlook the political considerations behind cheap food policies. At the same time, there is a greater need to consider their effect on farmers, especially during periods of serious shortfalls in domestic production. Efforts to hold the line on commodities consumed largely by the urban sector by increasing imports effectively impose a double tax on farmers. They frustrate the compensating tendency of producer prices to rise with a decline in aggregate output. As a result, farmers lose real income in proportion to any reduction in output which they suffer. At the same time, farmers must generate surpluses elsewhere to provide the foreign exchange required to feed the urban population. Thus, instead of losing only the drought year's surplus, farmers lose another one or two years surplus through insulating the urban population from the effects of such natural disasters. Given the small margin above consumption which underdeveloped economies are able to generate even in good years, one must ask whether such policies promote rural development. Perhaps the time has come to deal more forcefully with urban-rural income distribution issues rather than focus so narrowly on agricultural production.

2. Effect on Consumption Patterns

Cheap food pricing and trade policies which restrict effective demand for local foodstuffs by encouraging consumption of imported cereals are only part of the reason the region finds attainment of food self-sufficiency difficult. Consumption patterns which these policies have established also restrict effective demand for local foodstuffs and need attention as well. Consumption of wheat provides the most dramatic case in point. Almost 30 percent of the grain deficit projected for 1985 consists of wheat imports. Yet there is little likelihood that wheat production in the region will expand sufficiently to reduce the projected import gap to any significant degree. One alternative to total reliance on wheat for bread is a blend of millet and wheat flour now being used in Senegal on a pilot basis.

The Senegalese also have developed an instant millet couscous which reduces greatly the length of time spent in food preparation--a major impediment to the wider use of millet in urban areas. This should encourage substitution of millet for imported rice and increase effective demand for local foodstuffs. Similar developments may be possible with other local grains and for other products provided the interest in developing and applying the technology is generated. Pro-local-grain pricing policies will be essential for such efforts to succeed. Consumer education and grain promotion programs would also be needed. Finally legislation on food composition, properly phased, can be a most important inducement to shifting consumption patterns more toward domestic resource availabilities.

B. Surplus Generation Capacity of West African Agriculture

Substantial agricultural surpluses have been generated within West Africa, even over rather harsh periods. In Senegal, for example, the "price stabilization fund" generated a surplus of 20 percent of marketed production net of food subsidies over the period 1971-75. Excluding the food subsidies, which went mostly to urban consumers, the surplus amounted to 25 percent of marketed production. A similar though less spectacular situation prevailed in Upper Volta, Ghana, Ivory Coast, and other African countries during this period as world prices climbed to record levels and farm prices were either held stable or allowed to rise to only a fraction of world prices.

Even in normal times, West African agriculture has shown a remarkable ability to generate significant surpluses through production of cash crops for export. The remarkable expansion in their production during the 1950's and the early 1960's attests to this. The problem for governments has been to fix producer prices at levels which balance their own desires to maximize extractable surpluses with the economic benefits of increased national and farm incomes resulting from higher farm prices and expanded production. The extensive use of fertilizer subsidies no doubt reflects a compromise on this issue.

Recent World Bank studies of four West African countries provide an an indication of the magnitude of potential gains in both national and farmer income which are available to West African countries by adopting policies more favorable to agricultural production. Using an opportunity cost framework[1] covering the economy as a whole, the studies show that

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[1]The studies cited here are those done by Stryker (66, 67, 68, 69). These studies calculate the domestic resource cost (DRC) of producing a unit of foreign exchange, a methodology developed by Balassa (4). The DRC gives a measure of the gain in net value added to be had by expanding output of a given commodity. A DRC between 0 and 1 indicates that expansion of production generates less value added than alternative uses for the same inputs. A negative DRC indicates an actual reduction in value added over no production at all.

production of peanuts and cotton in Mali, and cocoa in eastern Ghana have substantial potential for increasing national income. Smaller but none-the less substantial gains could arise from increased production of palm kernels and maize in Ghana, rice and millet in Mali, cocoa, coffee, copra, rice, maize and cotton in parts of Ivory Coast, and peanuts, millet and cotton in various areas of Senegal.

In general, the study shows cash export crops to be more efficient at converting domestic resources into foreign exchange than food crops, like millet, sorghum, rice and maize are in saving foreign exchange. Although relying on the CIF price of U.S. sorghum to value millet biases the results against millet,[2] the general conclusions of the study seem quite reasonable. This does not imply that food crop production should be neglected at the expense of export crops. Rather it suggests that any aggregate income lost by shifting resources from cash export crops to food crops has to be weighed against income distribution and broader dynamic development objectives. In some cases, it will make good sense to make the shift. In others, the gains from export crop production will simply be too large to ignore no matter what use is made of the surpluses generated by the agricultural sector.

C. Fertilizer Subsidies

In the recent past, at least 15 of the 17 countries in West Africa have subsidized fertilizer directly. Additional government subsidies in the form of transportation, storage, credit and extension also are common. The magnitude of fertilizer subsidies varies widely both within and between countries in the region, ranging as high as 100 percent of the village de-

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[2]Evidenced by the substantial price differences which often existed between these commodities in local markets during the drought.

livered cost in parts of Mauritania in 1976.[1]

Two rather distinct objectives seem to underly the use of fertilizer subsidies in much of West Africa: to temper the adverse terms of trade between the urban sector and the agricultural sector; and to increase output by stimulating adoption and use of fertilizer.

1. Distributional Aspects of Fertilizer Subsidies

Practically speaking, fertilizer subsidies are limited as a redistributive device. Subsidies on fertilizer used on food and other domestically consumed crops benefit primarily early adopters--not the poorer farmers usually and, once self-sufficiency has been achieved, urban and rural consumers alike. Subsidies on fertilizer used on export crops do increase rural incomes relative to urban incomes, especially if the money to finance them is not being made available at the expense of other investments in rural areas or through higher export taxes. However, it is generally agreed that the redistributive impact within rural areas favors wealthier farmers. Being the most frequently contacted by the extension service or sufficiently literate to inform themselves, they are the first to adopt fertilizer. And since subsidies on fertilizer increase income only to the extent fertilizer is used, these early users are the ones who benefit from the initially higher value/cost ratios generated by fertilizer subsidies for commodities facing an inelastic demand. Furthermore, though widespread

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[1]Port charges, transportation and handling can add $15-$150 (1975 prices) per ton of fertilizer depending on the transportation mode employed and distance from the coast. When discussing the amount of subsidy at the farm level, these and other costs must be included in the farm delivered cost of fertilizer to get a measure of the true subsidy. Some authors do this; but many measure the subsidy only as the percentage of C.I.F. not paid by the farmer. This grossly understates the amount of the subsidy.

adoption of fertilizer for use on commodities facing a more elastic demand may increase rural incomes across the board, the gap between the wealthy and the poor will not likely be diminished.

From a distributional point of view, fertilizer subsidies, in effect, take that portion of the surplus extracted from the entire agricultural sector and redistribute it partly to farmers using fertilizer--as often as not the wealthier rural farmers--and partly to urban consumers in the form of lower food prices. The rural peasant who produces largely for his own consumption, who is usually among the last to adopt new practices, has the same amount of output which he must then sell at constant or lower prices. If fertilizer policy is to be supportive of efforts to assist resource poor farmers, its orientation must be directed less toward increased output and more directly toward the ways it can increase consumption by the rural poor. Probably a better way to deal with income distribution issues within rural areas would be to increase the access of poorer farmers to a range of supporting services than to focus on fertilizer subsidies.

2. Subsidies to Stimulate Adoption of Fertilizer

The economic rationality of subsidies designed to stimulate the adoption of fertilizer--as opposed to subsidies designed to encourage use of fertilizer--needs to be measured in terms of their long run impact on aggregate output. Much depends on the profitability of the underlying technical packages on which fertilizer is used. Also important are the extent to which subsidies, as opposed to other policy variables, increase the rate of adoption of fertilizer and when the subsidies are reduced or removed. Just when subsidies intended to stimulate adoption of fertilizer should be phased out can be determined through a discounted cash flow analysis of the output stimulation effort.

Subsidizing fertilizer use on unprofitable technical packages or continuing subsidies long after early adopters are using a much larger proportion of fertilizer than late adopters only increases agricultural output at the expense of other output, with a diminishing hope of recovering the investment in subsidies. Eventually, orienting extension services to the laggards or perhaps a fertilizer demonstration/grant program aimed only at non-users would be a more efficient way of stimulating their use of fertilizer. In any case, once the momentum of adoption begins declining, the case for subsidies to encourage adoption of fertilizer begins to lose its justification.

3. Subsidies to Encourage Use of Fertilizer

Subsidies to encourage use of fertilizer need to be differentiated according to their use on export crops--for which demand is essentially perfectly elastic at prevailing prices--and on food or domestically consumed crops which face a more inelastic demand once the import substitution phase is completed. The dominant effect of the former is income generation (reduction) while the dominant effect of the latter is to reduce agricultural prices and shift income away from farmers toward urban consumers.

One aspect of the economic rationality of using fertilizer subsidies relates to the extent to which production systems are in equilibrium prior to the introduction of subsidies. If farmers face a severe capital constraint or if they use fertilizer in sub-optimal amounts given the prices they face, then fertilizer subsidies can have a favorable impact on aggregate agricultural output and national income by stimulating its use to more optimal levels. This is an empirical question but evidence available to date indicates that farmers in West Africa do use fertilizer in sub-optimal amounts (43, 62).

a. Export crops

Where export crops are taxed, neo-classical production theory suggests a need for ongoing input subsidies to achieve an optimal allocation of production resources. Taxes reduce prices paid to farmers below their social value (the value they earn the national economy). As a result, they restrict production and reduce income as resources are diverted from taxed crops toward untaxed crops. Only by reducing the cost of inputs used in the production of such crops by a proportionate amount can output rise to more socially optimal levels.

For political and budgetary reasons, there appears to be little likelihood of reducing export and marketing board taxes in West Africa. Furthermore, in most cases price elasticities of supply do not appear to be sufficiently high nor marketing margins sufficiently large to suggest that higher producer prices would increase the amount of tax revenue available to the public sector.[1]

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[1]Only where taxes on a crop exceed its farm price and, at the same time, the price elasticity of supply for that crop is greater than unity, could farmer prices be raised without reducing marketing board margins. Except for rather brief periods of high world prices, marketing board margins in recent years have not been this high in West Africa. It is also unlikely that price elasticities of supply would often be greater than unity. Where they are, the impact of an expansion of the production of one crop on production of other crops may cause partially offsetting losses in the net surplus extracted from the agricultural sector.

A review of supply response studies undertaken throughout the world by Askari and Cummings (3) indicates that for food crops, short-run elasticities seldom rise above .5 and long-run elasticities seldom above .75. For cash crops, supply elasticities appear somewhat higher with .7 being a common maximum for short-run elasticities and 1.0 for long-run elasticities. Normal ranges are considerably below these maximums but variation

Subsidies on fertilizer for export crops provide one possible way of increasing farmer incomes while minimizing any reduction in the size of the tax surplus extracted. In many cases, if used judiciously, fertilizer subsidies can even increase the size of the tax surplus, net of subsidies, at the same time as they increase farmer incomes. As a general rule, the larger the marketing board surplus, the lower the price elasticity of supply and the greater the crop response to fertilizer, the greater will be the increase in output arising from fertilizer subsidies, as opposed to an equal amount in the form of higher prices. Obviously, the lower the subsidy the greater will be the increase in marketing board revenue relative to the cost of the subsidies since a given volume of subsidies generates greater amounts of farmer investment.[2]

b. Food and other domestically consumed crops

The appropriate use of fertilizer subsidies on domestically consumed crops, especially food crops, is much more complex than for crops which face perfectly elastic export markets. Price determination is more a matter of domestic supply and demand which tends to shift income between producers and consumers rather than to increase or decrease aggregate national income. This does not deny the net income effect. Rather the effect of price changes on aggregate income is usually small in relation to the amount of income redistributed. Fertilizer subsidies, on the other hand, offer to lower consumer prices with no decline in producer incomes over

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between areas is very great. Supply elasticities for groundnuts, palm oil, rubber, cotton, tobacco and cocoa in Nigeria and cocoa in Ivory Coast reflect these patterns. For cocoa, in parts of Ghana, and in the Cameroons, long-run elasticities exceeded unity over the 1949-1963 period.

[2]This assumes, of course, that farmers will use the subsidized fertilizer and that the level of subsidy is not so high as to encourage uneconomic use of fertilizer.

the long run.

Where imports of food crops are subsidized, subsidies on inputs used to produce domestic substitutes are necessary in order to reestablish equilibrium input-output relationships in much the same way as for export crops which are taxed. In both cases, however, national income measured in opportunity cost prices is reduced over what it would be in the absence of both taxes and subsidies.

4. Some Time Dimensions of Fertilizer Subsidies

Many West African farmers grow few, if any, cash crops and are only marginally linked to the market economy. They do not, in general, use fertilizer. Inducing them to use subsidized fertilizer on their food crops in order to stimulate output substantially would require a massive extension effort aimed at stimulating adoption of fertilizer; perhaps also requiring a reorientation of the extension service. Needless to say, this process would take several years and limits the possible impact of fertilizer subsidies in the short-run.

Higher producer prices induce a more immediate increase in output from such farmers. To the extent that higher prices draw into production previously under-utilized resources, the output resulting therefrom may cost the economy very little. Evidence of the potential for this kind of gain comes from Sierra Leone where doubling of the price of rice in 1974-75 appears to have increased acreage in rice considerably without much apparent reduction in acreage devoted to other crops. Given the high proportion of active labor time already devoted to agricultural activities in Sierra Leone (95 percent according to Spencer and Byerlee (61)), even greater gains in output might be possible with similar policies in other countries.[1]

[1]Norman (42) reports that 47 percent of male adult labor in three villages studied in northern Nigeria was devoted to off-farm occupations.

Even for cash export crops, the very low levels of fertilizer use in most West African countries suggests that even large increases in fertilizer use will have a relatively small impact on total output in the short run, relative to higher producer prices. And more of the increase in output due to higher prices would, no doubt, come at the expense of other agricultural production than would be the case with food crops. In any case, for stimulating output of both food and cash crops, fertilizer subsidies and pricing policies become effective substitutes for each other only at rather high levels of fertilizer use.

5. Other Aspects of Fertilizer Subsidies

a. General subsidies

Moderate general fertilizer subsidies are appropriate where most cash crops are taxed and food imports are subsidized or where cash crops are taxed and a government desires to skew output toward production of food crops--common situations in West Africa. In both cases, the fertilizer subsidies would be permanent until the taxes and food subsidies are removed or until food crops no longer were to be favored. However, general subsidies do not make sense where fertilizer is in short supply. Indeed, fertilizer supply constraints call into question the very purpose of fertilizer subsidies.

b. Area and crop specific subsidies

Where distributional or crop specific issues become more important, administration of subsidy programs becomes considerably more complex. Distortions are more likely to arise as black markets, commercial exploitation and corruption become more difficult to control. Only where the crop at which the subsidies are aimed is one of the most profitable in the farming system are crop specific subsidies likely to be effective (11). Thus, until price relationships are favorable to food crops, fertilizer subsidies aimed at expanding food crop production may be ineffective.

Uniform national pricing is a generally effective form of area subsidy. This involves either direct government distribution, or payments to private transporters in order to ensure that more distant areas receive fertilizer supplies. However, if fertilizer supplies are insufficient to meet the demand of more centrally located users, or if payments to distributors are not sufficient, then uniform fertilizer prices aggravate rather than reduce regional disparities. This seems to be occurring in Ghana at the present time.

c. <u>International differences in the level of fertilizer subsidies</u>

The large differences in fertilizer subsidy levels between West African countries encourage smuggling and draw fertilizer supplies away from high subsidy countries. In 1975, when compound fertilizer was selling for 60,000 FCFA ($240) per ton in Ivory Coast and 56 cedies ($50) in Ghana it was possible to purchase a ton of fertilizer in Ghana for $50, sell it in Ivory Coast and return to Ghana and exchange the proceeds for $600 worth of cedies. Were fertilizer supplies in Ghana going to small farmers this might, in fact, constitute a rather ingenious redistribution strategy. Evidence indicates, however, that available fertilizer supplies in Ghana tended to go to large rather than small farmers (66, 77). Establishing more realistic and more uniform rates of subsidy between countries in the region should help to ensure more adequate fertilizer supplies for those countries now losing large amounts of fertilizer through smuggling.

d. <u>Fertilizer subsidies as an alternative to agricultural credit</u>

Credit programs are costly to operate. Administrative and other costs associated with an efficient agricultural credit program aimed at small farmers amount to about 20 percent of credit extended (26). In credit programs in West Africa arrears in excess of 50 percent are not at all uncommon. Only where credit repayment is tied to marketing a cash crop do repayment rates approach sustainable 90-95 percent repayment levels. As arrears and defaults rise, so also do the costs of administering credit programs. In this context, fertilizer subsidies may be an effective alternative to agricultural credit for facilitating the use of fertilizer. Subsidies as high as 40 percent for fertilizer used on food crops could be justified on the basic of cost savings alone in many countries. At the same time, subsidized fertilizer is less likely to benefit only wealthy farmers as much as agricultural credit programs generally do.

6. Setting Fertilizer Subsidies

From a purely national income point of view, an appropriate level of subsidy is determined by the rates of tax and subsidy on the principal crops and import substitutes on which fertilizer is used, their respective fertilizer response functions; the supply elasticities of other factors of production; and the extent to which farming systems are using fertilizer in near-optimal amounts given those response functions. Where subsidies are being considered as an alternative to raising producer prices, then the price elasticity of supply of the crop in question also is important.

In practice, all these factors vary for different crops at different locations within the country. This forces policy makers to use very rough rules of thumb that apply in general but which admit of considerable exception. Both budgetary and economic factors, therefore, become important.

As a general rule, where the purpose of subsidies is to induce farmers to adopt fertilizer so as to increase national income, it does not seem wise to subsidize more that 50 percent of the farm delivered cost of fertilizer. With this rate, newly adopting farmers responding to a perceived 3:1 value-cost ratio would earn the country only slightly less than a break even return on the fertilizer used, leaving 50 percent of the cost of the fertilizer to cover other costs of production. With a 50 percent subsidy, existing users responding to a perceived 2:1 value-cost ratio would produce enough output to cover only the cost of the fertilizer but would not cover other costs of production. For this reason, a lower rate of subsidy, about 25 percent, appears to be close to the maximum desirable for subsidies intended to promote fertilizer use toward the same objective. With these levels of subsidy, marginal users would be able to cover the cost of the fertilizer and associated inputs with a margin of error sufficient to ensure the economic use of fertilizer for the economy as a whole.

Where taxes on output are high or subsidies are provided as an alternative to credit, the maximum levels of subsidy could be somewhat higher without reducing national income and aggregate output. At the same time, as farmer perceptions of risk associated with the use of fertilizer become more realistic, the maximum economic level of subsidy will decline, eventually disappearing for all but distributional objectives. In both cases, the lower the level of fertilizer subsidy, the higher will be the increase in output per unit of expenditure on fertilizer subsidies. Similarly, the higher the rate of subsidy, the less likely use of fertilizer is to generate additional crop production sufficient to cover the cost to the economy of the fertilizer consumed.

The question of an optimal level of subsidy is an empirical one, no doubt quite different from country to country as the factors which underly their use vary. But until better information is available on the marginal value product of fertilizer on a wide range of crops and technologies within a given country, the maximum levels of subsidy indicated here should prevent fertilizer subsidy programs from becoming a drag on aggregate output.

7. Conclusion and Policy Implications

As long as increasing aggregate output is the objective, defining the role of fertilizer subsidies is relatively simple. Conventional economic analysis yields solutions which offer to increase national income without significantly endangering the existing distribution of power and income. Even using fertilizer subsidies to redistribute income between urban and rural areas in the aggregate presents few problems. But once increased consumption by the rural poor becomes the objective, then fertilizer subsidies need to be combined with a reoriented extension service aimed at the target group. Defining this target group in practice then becomes an important part of fertilizer policy, and reaching them, the heart of fertilizer subsidy program design. The central problem is to draw the poorer farmers into the market and to induce them to adopt output-increasing innovations such as fertilizer before, rather than after, other more informed farmers. Otherwise they will continue to lag behind the informed farmers and benefit from agricultural development primarily by increasing their real consumption from what they produce rather than from what they sell.

D. Agricultural Marketing and Effective Demand Constraints on the Use of Fertilizer

The previous discussion on prices and subsidies focused primarily on their economic use in stimulating aggregate output. Additional substantial gains in production, especially of food crops, appear possible through improvements in agricultural marketing institutions throughout the region.

1. Marketing Cash Export Crops

In discussing agricultural marketing it is once again useful to distinguish between cash export crops and domestically consumed food crops. Reasonably effective institutions for assembling, moving and storing large quantities of export crops over wide areas seem well established in virtually every country in the region. Their generally higher value, coupled with the very large portion of total production which is marketed, provide a relatively stable base around which marketing activities can be planned and implemented. As a result, major marketing problems center around the transportation network and pricing policies as they affect output, producer incomes, and agricultural surpluses rather than the ability to find markets and move commodities.

2. Marketing Food Crops

The generally lower value of food crops and their primarily domestic use make transportation and effective demand much more important issues in the marketing equation. So does the very large proportion of output consumed on the farm which causes large fluctuations in marketed surpluses for even relatively small changes in total production. At the same time, distributional issues involve more direct conflict between the interests of rural producers and urban consumers. Moreover, the political importance of food prices seems to invite public intervention which has had a tendency to impede efficient marketing of food crops.

a. Inelastic demand

With relatively high cost transportation facilities and inadequate markets, food crops sold in rural areas face very inelastic demands. This limits both the effectiveness of national pricing policies at the farm level and restricts the use of fertilizer and new production technologies. Beyond producing for their own needs, farmers have little incentive to increase output. Presumably aiming to cover their basic needs in a bad year, they dispose of surpluses obtained during good years at whatever prices they can get.

To the extent that rural markets are effectively linked to urban markets via market infrastructure and prices, the elasticity of demand for excess foodstuffs produced in rural areas increases. As these linkages develop and are reinforced by price changes, farmers become more willing to produce food crops for exchange on a continuing basis since money incomes from food crop production become more stable between good and bad crop years. Creating these linkages will require governments to abandon cheap food policies and to force urban consumers to bear part of the social cost of crop failures. Without them, producing food crops for sale becomes a very risky business indeed, especially where cash inputs such as fertilizer are an important part of production technologies.

There are, of course, several obstacles to creating effective linkages between urban and rural areas apart from price restrictions and cheap food policies. Urban areas need assured supplies of food staples on a continuing basis. The ability of the commercial sector to mass and deliver foodstuffs in this way is crucial. With large fluctuations in marketed output in rural areas this will be possible only if adequate reserves are available locally. Otherwise, urban consumption must be diverted toward imported grain and the dynamic link between the urban and rural sector will be compromised.

b. Food grain marketing monopolies

There is general agreement that government intervention in grain markets, especially in the Sahel, has hindered rather than promoted production of food crops (5). Created with the intent of reducing both seasonal fluctuations in grain prices and overall marketing margins, these agencies have tended to lack the managerial and financial ability to deliver on their promises. Constrained between their unusually high operating margins and the narrow commercial pricing margins allowed by price fixing authorities, such agencies have often pushed private traders out of the market while offering no effective intervention in return. In some cases, most notably in easern Upper Volta in 1975 and in Mali in 1976, they have actually destabilized prices by promising to purchase food crops at fixed prices and then failing to enter the market with sufficient financial resources to prevent prices from falling sharply.

c. Private commercial traders

It is becoming increasingly trite to say so but more attention needs to be given to utilizing the resources and the distribution network of private commercial traders for marketing food grains. Although one cannot discount out of hand the frequent charges of commercial exploitation leveled against traders, available evidence indicates that they are at least as efficient as government marketing monopolies. The extremes between pre-harvest and harvest season food crop prices which are often cited as evidence of trader exploitation conceal the fact that very small quantities of grain probably are actually traded at these prices. In any case, the relevant measure of exploitation is not harvest season prices and prices prevailing during the following "soudure" but those between the "soudure" and the following harvest season. The former includes an element of scarcity due to weather variables and their impending impact on harvests as these unfold over the growing season. The latter reflect more accurately the liquidity problems facing farmers which make them vulnerable to commercial exploitation.

Even if private traders do extract abnormally high profits from grain trade, one cannot ignore the fact that they are effective in actually getting the crops moved and distributed. To the extent that they do this better than other institutions, grain markets are expanded and stabilized. With larger more stable markets, farmers should be more willing to expand food crop production and adopt new fertilizer responsive technologies. However, the question of exploitation and instability in grain markets does need to be addressed, not so much to document its nature as to identify policy measures which can deal with it. It may well be that the best solution to the entire problem would be to take a more positive approach to private grain traders and to encourage rather than restrict competition.

3. Need for Farm Level Storage and Resource Flexibility

Opening grain trade to the private sector will not solve the major problem facing producers of food crops--weather variability. Hard experience has taught farmers the need to plant sufficient food crops to ensure adequate food supplies during bad crop years. This level of production causes gluts in grain markets during good years. Even if prices for food grains in urban areas are allowed to fluctuate, it would take a tremendous amount of intervention and storage by public marketing agencies to effectively support prices at such times. In general, they have not been able to do so and the sharp declines in producer prices which occur at these times make the use of fertilizer an economically risky proposition.

One effective way of stabilizing producer prices in the face of large fluctuations in output due to weather factors is to increase farm level storage while actively stimulating greater resource flexibility in agricultural production. If farmers could store two to three years of their food grain needs and be reasonably sure that storage losses would be negligible they would face considerably less risk in shifting resources to cash crop production following exceptionally good food grain harvests.[1] If the next crop fails, farmers would still have adequate grain reserves to carry them another year while they shift resources back to food production and rebuild their reserves. Once reserves are rebuilt, they can resume a heavy orientation toward cash crop production. With greater storage capacity and resource flexibility, farmers could produce for a continued high level of effective demand--shifting between food and cash crops as required while maximizing their incomes and reducing their risk exposure. The marketed surplus of food crops would also be stabilized as farm level reserves fluctuate in response to price changes--less drastic price changes for a given volume drawn from storage because of the greater quantity in storage.

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[1]In a study of three villages in Northern Nigeria by Hays (24) only about 15 percent of the previous year's crop remained in farm storage eleven months after the harvest. About 20 percent of the crop had been sold and another 20 percent went as gifts required to meet social obligations. Thus, farmers consumed about 50 percent of one year's total harvest before the next crop was harvested. Considering needs for cash and social obligations during an unfolding subsequent bad crop year and the fact that almost half of gifts and sales occur at harvest time when little is known about the following year's harvest, farm families in this area do seem to be in a rather precarious position vis-a-vis available food supplies. However, much more research is needed to identify the amount of grain in store as well as farmer decisions to store grain under a variety of ecological conditions.

The key to developing greater resource flexibility between food and cash crops is a farm level storage technology that will permit storage of grain for 2-3 years with little or no storage loss. In order for individual farmers to feel secure enough to release resources to cash crop production, they must be convinced that the stored grain is theirs when and if they need it--without having to pay exorbitant prices for it. While it may be possible to create such a feeling of security through community stocks, it is much more likely to arise from storage in a farmer's own grain silo. The storage technology should, therefore, be suitable for individual farms.[2] Clearly this is an area of research that bears directly on a farmer's ability to effectively use fertilizer on both food and cash crops.

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[2] One possibility which offers promise is a heavy black polyethelyne bag for lining a traditional 300-500 kg mud silo. See M.C. Gough and D.J.B. Calverley (23).

VI. CONSUMPTION, PRODUCTION AND DISTRIBUTION OF FERTILIZER IN WEST AFRICA

A. Nutrient Consumption

1. Present Consumption

In 1975 the 17 West African countries included in the study consumed about 156,400 metric tons of fertilizer nutrients. Of this, nitrogen accounted for 58,500 tons, P_2O_5 contributed 46,700 tons and K_2O, 51,200 tons. These proportions have not changed substantially from those which prevailed in 1968. Senegal and Ivory Coast, the only two countries in the region with their own fertilizer plants in 1975, account for 68,300 metric tons or 44 percent of total regional consumption of plant nutrients supplied by fertilizer. Nigeria and Cameroon, which began production of fertilizers in 1976, used another 45,500 tons or 29 percent of the total. The remaining 13 countries used 42,600 tons of nutrients or only 27 percent of the total for West Africa. Appendix C, Tables C.2 to C.5, give a detailed country breakdown of nutrient consumption since 1965.

2. Estimate of Future Consumption

Estimating future consumption of fertilizer in West Africa with any degree of accuracy is virtually impossible on a country by country basis. A wide range of policy and technology variables affect fertilizer consumption and any estimates are only as good as assumptions about these variables. Crop and fertilizer prices, fertilizer subsidies, fertilizer distribution facilities, availability of credit, the priority given to agricultural development and the use of fertilizer, availability and adoption of fertilizer responsive varieties are only a few of the variables having a substantial impact on future consumption. The longer the horizon, the more unreliable are assumptions relating to these variables.

In light of these problems a simple projection of past consumption trends for the region was felt to yield the most reliable results. These trends were estimated by fitting both linear and exponential functional forms to 1965-75 regional consumption data with the exponential forms giving the best fit. The exponential rates for the region, with a slight adjustment in the coefficient for nitrogen, were then uniformly applied to the 1975 base consumption of each nutrient for each country. Table VI.1 details the results of these projections.

Total nutrient consumption is projected to continue growing at the 12 percent rate prevailing over the past 11 years. For N, P_2O_5 and K_2O, the rates are 14 percent, 12 percent, and 10 percent, respectively. These rates correspond with what we know about the higher responsiveness of cereals to N and P_2O_5, the general deficiency of soils in the region in P_2O_5, and the general lack of response to K_2O where soils are not intensively cultivated.

Consumption of nitrogen is projected to grow from 58,500 tons in 1975 to 212,000 tons in 1985. P_2O_5 consumption is estimated to increase threefold to 141,000 tons. Consumption of K_2O should grow from 51,000 tons in 1975 to 130,000 tons by 1985. Overall nutrient consumption is projected to increase more than 300 percent from 156,000 tons in 1975 to 484,000 tons in 1985.[1] These projections seem quite reasonable given the very rapid expansion of doner financed rural development projects being planned and

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[1]Results for the six Sahelian countries in Table VI.1 are generally consistent with the more careful estimates made in the West Africa Fertilizer Study (30)--163,000 tons of total nutrients versus the 178,000 tons estimated by the latter for 1985. On an individual nutrient basis, only our estimate for K_2O falls substantially short of the estimate made in that study.

TABLE VI.I
PROJECTED CONSUMPTION OF FERTILIZER NUTRIENTS
FOR WEST AFRICA, 1975-1985, BY COUNTRY

Country	1975 Base Consumption				1980 Projected Consumption				1985 Projected Consumption			
	N	P_2O_5	K_2O	Total	N	P_2O_5	K_2O	Total	N	P_2O_5	K_2)	Total
Senegal	11.0	12.5	11.5	35.0	21.2	22.0	18.5	61.7	40.8	38.8	29.8	109.4
Ivory Coast	8.0	4.5	18.5	31.0	15.4	7.9	29.8	53.1	29.7	14.0	48.0	91.7
Nigeria	10.0	10.0	5.0	25.0	19.3	17.6	8.1	45.0	37.1	31.1	13.0	81.2
Cameroon	10.0	2.5	5.0	17.5	19.3	4.4	8.1	31.8	37.1	7.8	13.0	57.9
Ghana	3.5	3.0	2.5	9.0	6.7	5.3	4.0	16.0	13.0	9.3	6.5	28.8
Mali	2.3	4.3	0.4	7.0	4.4	7.6	0.6	12.6	8.5	13.4	1.0	22.9
Chad	2.8	1.8	1.4	6.0	5.4	3.2	2.3	10.9	10.4	5.6	3.6	19.6
Benin	2.6	1.8	1.6	6.0	5.0	3.2	2.6	10.8	9.6	5.6	4.2	19.4
Liberia	2.0	0.8	1.0	3.8	3.9	1.4	1.6	6.9	7.4	2.5	2.6	12.5
Sierra Leone	1.2	1.1	1.2	3.5	2.3	1.9	1.9	6.1	4.4	3.4	3.1	10.9
Guinea	1.2	0.5	1.0	2.7	2.3	0.9	1.6	4.8	4.4	1.6	2.6	8.6
Upper Volta	1.0	1.1	0.4	2.5	1.9	1.9	0.6	4.4	3.7	3.4	1.0	8.1
Gambia	0.5	0.7	0.3	1.5	1.0	1.2	0.5	2.7	1.9	2.4	0.8	5.1
Togo	0.4	0.2	0.2	0.8	0.8	0.4	0.3	1.5	1.5	0.6	0.5	2.6
Guinea Bissau	0.3	0.1	0.1	0.5	0.6	0.2	0.2	1.0	1.1	0.3	0.3	1.7
Niger	0.2	0.2	0.1	0.5	0.4	0.4	0.2	1.0	0.7	0.6	0.3	1.6
Mauritania	0.2	0.2	0.1	0.5	0.4	0.4	0.2	1.0	0.7	0.6	0.3	1.6
Total	57.2	45.3	50.3	152.8	110.3	79.9	81.1	271.3	212.0	141.0	130.6	483.6
1975 Actual consumption	58.5	46.7	51.2	156.5								

implemented for the region. In fact it wouldn't take very many projects like the World Bank financed project at Funtua in northern Nigeria to push consumption substantially above these levels.

B. Fertilizer Production

1. Raw Materials Identified in the Region

a. Phosphate rock

Practically every country in the region has identified reserves of phosphate rock. Only deposits in Senegal and Togo have been exploited on a large scale. 1974 phosphate rock production amounted to 1.7 million tons in Senegal and 2.6 million tons in Togo. Very small extracting and grinding operations also exist in Mali and Upper Volta but these operations only serve very local markets. Deposits in the Tilemsi valley of Mali appear to be of a quality suitable for direct application and single superphosphate production. However, reserves of high quality ore appear to be small with the amount amenable to surface mining amounting only to about 1,000,000 tons. Phosphate ores occurring in the remainder of West Africa require further study and classification to determine their usefulness for fertilizer production. Phosphate from Tahoua, Niger appears to be suitable for direct application but the feasibility of mining and grinding has not been determined.

b. Potash

No known deposit of potash exists in the region. Neighboring People's Republic of the Congo has been producing potash at a rate of 280,000 mt per year. This quantity is sufficient to provide the needs of West Africa well beyond 1985. However, mining was discontinued in 1977 because of technical problems and future supplies are in doubt.

c. Sulfur

Mauritania contains the only known sulfur reserve existing in the West African region. Some deposits of pyrites of unknown quality have been identified in Mali, Niger, Upper Volta, and Senegal. Byproduct sulfuric acid may be available from copper smelting operations in Mauritania but the quantity of acid available from the copper operation is not known. Furthermore, it is located at a considerable distance from known phosphate deposits in the region and from fertilizer use areas.

d. Petroleum

Nigeria has the only natural gas or oil production in the region. Enough gas is flared yearly in Nigeria to provide adequate feedstock for ammonia production in three 1,000 mt/day plants. One such plant will meet the needs of West Africa well beyond 1985. Petroleum exploration is being carried out by Gulf, the Bureau des Resources Geologique et Mineral, and Sun Oil in various Sahelian countries. Oil has been found in at least two wells in Chand and sources in Cameroon are being evaluated.

e. Other

The only other minerals which would be of interest in production of fertilizer would be Natron or Trona found in the dry lake regions of Chad and Senegal. Natron and Trona can be used in production of Rhenania phosphates. More detail on these and other deposits already noted can be found in the West Africa Fertilizer Study (30).

2. Economics of Fertilizer Production and Blending

Fertilizer production costs are dependent upon investment costs, size of plant, portion of capacity utilized, and cost of raw materials, utilities, labor, etc. The effect of the first three of these factors upon the capital costs of production for several processes is shown in Appendix D, Figure D.1. These and other data in Appendix D illustrate the substantial economies of scale in large plants, the desirability of designing plants to maximize utilization of capacity (particularly for high investment plants), and the need to locate plants to utilize the lowest cost raw materials.

Capital investment in a 1000 mt per day ammonia-urea complex in a developed country in 1977 is about $120 million. In developing countries some recent instances have shown costs of $250 to $350 million. In Nigeria the IBRD estimates such a complex would cost $350 million. Much of the additional cost in a developing country is attributed to costs for infrastructure, often not required in a developed country. Each $100 million capital investment adds about $28 per mt to the cost of producing urea in such a complex with the complex operating at 100 percent capacity. These higher investment costs reduce the fertilizer export value of the natural gas raw material very sharply, by about $2.00 per thousand cubic feet in a $350 million facility as compared to a $120 million operation. Obviously, with urea prices running at about $150 a ton delivered to West African ports, a $350 million Nigerian plant operating at one half capacity would not be able to compete on the export market without substantial subsidies even if the gas were free.

The cost of capital investment for a $5.5 million simple superphosphate granulation complex adds about $28 per mt of product when the plant is operating at 50 percent of design capacity as compared to operating at 100 percent of capacity (See Appendix Figure D.2). With a capital investment of $2 million, operating at 50 percent of capacity only increases capital costs by $11 per mt of product. Clearly operating at close to full capacity is much more important in developing countries where the capital costs from a given production facility are usually much higher than in developed countries. However, with more labor intensive technologies, such as the bulk-blend facility recommended in the West Africa Fertilizer Study for Mali, capital investment contributes little to total costs of production at rates of capacity utilization above 50 percent. This can be seen graphically from Appendix Figure D.1.

Appendix Figures D.3, D.4 and D.5 show economies available from producing sulphuric acid, phosphoric acid, diammonium phosphate and triple super phosphate in optimally sized plants versus plants 1/3 to 2/3 as large. In general total production costs are 12 to 33 percent higher in the smaller units with the relative differences in total costs declining as the cost of raw materials to both large and small plants rises.

Turning to the relationship between costs of production and raw materials' cost, Figure D.6 shows that a change of $1.00 per thousand cubic feet of natural gas changes the production cost of urea by $33 per mt. In production of SSP (20 percent P_2O_5), increasing phosphate rock cost by $10 per mt increases production cost by $7 per metric ton of product and increasing cost of sulfuric acid by $10 per mt increases production cost by $4. For TSP (45 percent P_2O_5), increasing the cost of PR by $10 per mt increases production cost by $15 and increasing phosphoric acid cost by $10 per mt increases production cost by $6.50.

3. Present and Planned Fertilizer Production

Togo and Senegal together produce about 4.3 million mt of phosphate rock or 1.4 million mt of P_2O_5. Basic processed P_2O_5 production capacity in the region is about 67,000 mt (Table VI.2).

No ammonia or potash production facilities are located in West Africa

TABLE VI.2
PRESENT AND PLANNED FERTILIZER NUTRIENT
SUPPLY CAPACITY IN WEST AFRICA

Country	Basic Production Capacity, 1,000 mt/yr.[a]		
	Product	N	P_2O_5
Present Capacity			
Cameroon	SSP	--	4
Ivory Coast	SSP	--	5
Nigeria	SSP	--	18
Senegal	H_3PO_4	--	40
Subtotal		--	67
Planned Additional Capacity[b]			
Nigeria	NH_3	246	
Senegal	NH_3, H_3PO_4	74	120
Togo	H_3PO_4	--	300
Subtotal		320	420
GRAND TOTAL		320	487

[a]Excludes P_2O_5 capacity from acidulation of phosphate rock in NPK granulation plants (unavailable) in Cameroon, Ivory Coast, and Senegal.

[b]Assumed 300 operating days per year.

at the present time. But additional basic production capacity amounting to 320,000 mt of N and 420,000 mt of P_2O_5 is planned for Nigeria, Senegal and Togo. Thus total basic production capacity in the region will be 320,000 mt of N and 487,000 mt of P_2O_5 by 1981 if all presently planned facilities are built. This compares with an expected demand of 212,000 mt of N, 141,000 mt of P_2O_5 and 133,000 mt of K_2O by 1985.

In addition to the basic production of primary materials, Cameroon and Ivory Coast have a capacity to produce 8,000 and 4,000 mt of N, respectively, as ammonium sulfate (AS) from imported ammonia and sulfur. Also, Cameroon, Ivory Coast, and Senegal have existing granular NPK production capacities equivalent to about 4,000, 9,000, and 20,000 mt of nutrients, respectively. These NPK fertilizers are produced from AS, ammonia, PR, SSP, TSP, sulfuric acid, phosphoric acid, and/or potassium chloride basic materials and, therefore, add little to the total nutrient supply capacity.

Senegal plans to triple the capacity of its NPK granulation facilities in addition to increasing sharply its production of N and P_2O_5 basic materials. Coupled with Nigerian and Togo plans, it appears that the region will have substantial export capacity for N and chemical phosphate fertilizers from about 1981 onward. Phosphate fertilizers produced in Senegal and Togo should be able to compete on world markets against low-cost supplies from north Africa. However, production costs for ammonia produced in Senegal are likely to be relatively high because of the small plant envisioned and use of refined hydrocarbons produced from imported oil as raw material. By 1985 Senegal could only use about half of its planned N production domestically, and would either have to subsidize exports or raise nitrogen costs to Senegalese farmers in order to remain commercially viable. The Senegalese would do well to learn from the Tanzania experience where over-optimistic demand projections and conservative cost estimates stimulated establishment of a monopolistic, excess capacity, imported raw materials based compound fertilizer processing plant that has produced fertilizers costing Tanzanian farmers 50-300 percent more than identical imports (8). Obviously this proposed project should receive a thorough evaluation before proceeding. Even the level of NPK production currently planned for Senegal may have to be revised downward. Hopefully this already is happening since fertilizer orders placed by ONCAD were reportedly down by 50 percent in response to a sharp reduction in fertilizer subsidy levels in 1976.

The situation is less ominous for Nigeria where the size of plant will exploit available economies of scale, and presently flared gas is available. Favorable government policies could easily stimulate sufficient consumption of N by 1985 to utilize 25 to 30 percent of the planned capacity in Nigeria alone. The rest of the West African market could absorb enough of the remaining production to get capacity utilization to economic levels by that time if no other production is realized in the region. However, if Senegal goes ahead with its plans for ammonia production, West Africa as a region would have about 100,000 mt of N for export to more distant markets outside the region.

4. Further Potential for Fertilizer Production in the Region

Of the landlocked countries, only Mali has a defined suitable raw material (PR) and a level of consumption sufficient to consider a chemical processing plant. Considering the level of consumption and the quality of PR, SSP is the only chemical fertilizer plant that can be considered. Estimated investment and production costs for a granular SSP complex are shown in Appendix E. The complex requires capital investment of \$5.49 million and an annual working capital of \$3.46 million. Estimated production cost of granular SSP near Bamako is \$117 per mt of product or \$650 per mt of P_2O_5 when the 33,000 mt per year plant is operated at 100 percent capacity without considering interest on working capital. An Italian firm (IFAGRARIA) recently estimated production cost at \$129 per mt and a UNIDO consultant estimated \$92 for nongranular material. IFDC estimates granulation cost is \$8 per mt of product. Actual delivered cost to Bamako in 1976 was about \$140 per mt of product or \$778 per mt of P_2O_5.

By comparison to the cost of imported SSP, local production would be feasible if the plant could be operated at 100 percent capacity or 33,000 mt per year. Current consumption of P_2O_5 in Mali is equivalent to 24,000 mt of SSP so by the time the plant were constructed it could theoretically be operated at full capacity. However, TSP can be delivered to Bamako for \$250 per mt or \$556 per mt of P_2O_5. Even at 100 percent of capacity, therefore production of SSP in Mali would cost 17 percent more per unit of P_2O_5 than importing TSP. In addition, local distribution costs for SSP are 2.5 times as great as for TSP per unit of P_2O_5. Furthermore there is no agronomic need for the quantity of sulfur contained in SSP and locally ground PR is a still lower cost source of P_2O_5 than imported TSP. <u>Therefore, it does not seem feasible to establish a SSP plant in Mali at this time.</u>

The West Africa Fertilizer Study estimated that 50 percent or more of the P_2O_5 requirement in Mali could be met by using Tilemsi Valley PR. The estimated cost of PR delivered to Sikasso, the point farthest from the PR source and closest to imported supplies of TSP, was \$99 per mt or \$316 per mt of P_2O_5. This compared with \$556 per mt of P_2O as TSP and \$650 per mt of P_2O_5 from locally produced SSP. Agonomic results with Tilemsi Valley PR have also been quite favorable. Clearly this method of supplying P_2O_5 to Malian farmers should receive highest priority. A similar system should be investigated for Tahoua phosphates in Niger when consumption of phosphate fertilizers in Niger reaches economic levels.

In Upper Volta the West Germans have just completed construction of a mining and grinding plant of this type which should meet the demand for PR there for several years to come. PR deposits in other countries in the region should be similarly exploited once classification and field trials indicate their economic suitability for direct application. Benin and Liberia appear to have particular potential in this regard though again, the feasibility of an operation of any size is limited by the small local consumption of phosphate fertilizers.

In addition to PR mining, bulk blending of imported intermediate products appears to offer substantial savings for many countries in the region provided the low cost, labor intensive technology suggested in the West Africa Fertilizer Study proves viable. Nigeria, Chad, Ghana, Mali, Benin, and by 1980, Liberia, Sierra Leone and possibly Guinea and Upper Volta could benefit from it. The technology consists of importing high analysis intermediates in one metric ton bags for blending and bagging locally. As yet, this technology has been untested in Africa but its apparent advantages suggest that a well documented trial operation in at least one West African country should be established at this time. The IFDC study estimates that savings to the land locked countries would be as much as $80 to $100 per mt over imported NPK grades (30). Savings to the coastal countries would be only slightly less but could be more where bulk handling facilities are available at the port.

The major factor contributing to the higher cost of imported NPK fertilizer appears to be ordering non standard grades in small quantities. Recently savings of more than $30 per mt were demonstrated in Ghana through bulk shipment and bagging at dockside (72). These savings emerged even under adverse conditions (first attempt) and small quantity orders of a NPK grade. Products such as urea, diammonium phosphate and muriate of potash are typically less expensive than mixed grade products. Therefore additional savings could be realized by blending those products within the country provided a suitable low cost labor intensive technology is available.

5. A Fertilizer Production Model for West Africa

The low levels of fertilizer consumption in most West African countries suggest a flexible strategy for establishing local production facilities. Such a strategy should consist of a progression of phases with increasing capital and technological inputs as consumption increases. At consumption levels less than 15,000 to 20,000 mt/year of total fertilizer materials, desired products generally should be imported in 50 kg bags. With consumption from 20,000 to 100,000 mt/year of materials and bulk-handling facilities available at a port, products may be imported in bulk and bagged at dockside. Without bulk-handling facilities at the port of entry or for landlocked countries, minibulk (1 mt containers) may offer a feasible delivery system to a bagging facility near the center of the most concentrated area of use. Finally when demand for NP and NPK fertilizers reaches 80,000 to 100,000 mt/year the feasibility of establishing a granulation complex using domestic and imported raw materials needs to be assessed.

C. Fertilizer Distribution

1. The Transportation Network and Associated Costs

The existing transportation infrastructure in West Africa provides adequate access to the populated areas of the region. However, improvements and maintenance are needed in the sparsely populated areas. Most of the 17 countries have rail lines, and several have seasonally navigable waterways, although road movement is the primary mode of transportation. All-weather roads, and/or rail lines, link the primary market centers in most countries with a port. The road network of the landlocked countries appears adequate to serve the major trade centers, though movement is hampered during the rainy season.

Ghana, Ivory Coast, and Nigeria each have 12,000 to 15,000 km of all-weather roads and Cameroon and Senegal have about 8,000 km each. Rail lines are most extensive in Nigeria with 3,500 km. Cameroon, Ghana, and Senegal each have 1,000 to 1,300 km of rail lines. Additional information on the road and rail network in West Africa is shown in Appendix F.

Rates for rail transport are $0.04 to $0.05/mt/km, except in Nigeria, where the rate is about 1/3 as great. Rates for truck transport are: paved roads--$0.03 to $0.04: all-weather gravel roads--$0.05 to $0.06; and poor roads--$0.10 to $0.16/mt/km. On-off handling charges are $3 to $4/mt.

In international trade, the region is largely dependent on overseas markets, as most of the countries produce and consume the same commodities. Hence, there is little incentive to maintain efficient inter-country transportation routes, except to the landlocked Sahelian countries where north-south routes and the Bamako-Dakar route provide access to ports.

Thirteen of the 17 countries in the region have ports of varied quality and operating efficiency. The landlocked countries rely on lengthy, time-consuming and costly routes to access ports. Lowest cost routes to these ports from the capital cities are: Chad--$73 per mt; Mali--$77; Niger--$74; and Upper Volta--$39. These figures do not mean very much, however, since importers are frequently forced to rely on more expensive road transport in order to avoid very high excess storage charges at the ports due to port congestion and inefficient evacuation by the railroads. This can add as much as $25 per ton to transportation costs to the land-locked countries, effectively doubling their cost of fertilizer relative to coastal areas. Indeed, it is the inability of the Dakar-Bamako railroad to move goods that suggests Sikasso as the more appropriate choice for a fertilizer blending plant in Mali.

2. Distribution Channels

Domestic production plants supply portions of the fertilizer in Cameroon, Ivory Coast, Nigeria and Senegal. Imports are handled by sales companies in Cameroon, Ghana, Ivory Coast, and Senegal, and by government tenders in the remaining countries. In most of the countries, sales, transport and storage are handled by national development corporations or Ministries of Agriculture. Prices to farmers are fixed in all of the countries at 45 percent to 70 percent of c.i.f. port or ex-factory cost. By the time transport and handling costs are added to fertilizer costs the effective subsidies become very high and cause for concern. Credit is generally available through cotton development corporations, cooperatives, or to a limited number of farmers through crop production projects. As a general rule, credit is available more in theory than in fact, or not at all, outside of these kinds of structures. A brief summary of import procedures, marketing channels, storage, pricing, subsidies and credit aspects of fertilizer distribution in the various countries is given in Appendix G.

The tendency for West African governments to rely heavily on the regular agricultural extension staff to deliver fertilizer supplies to farmers--though perhaps necessary and economical at the very early stages of fertilizer adoption--eventually constrains the growth in consumption of fertilizer. This appears to be happening at the moment in Nigeria and Ghana. This kind of distribution system lacks both the organizational flexibility to adapt to changing market conditions and the economic incentives for market expansion. Conflicts tend to develop between the agent's availability for fertilizer distribution and his farm level extension work. At the same time, budgetary problems within the ministry of agriculture frequently result in delays in ordering and distributing fertilizer to the agents.

Clearly there is a need for more creative approaches to the distribution of fertilizer. The low levels of consumption which exist in many West African countries make it uneconomical for private commercial traders to stock and distribute seasonal inputs--especially where storage of unused stocks is a problem. Even at higher consumption levels, distributing fertilizer to a large enough number of retail outlets so that farmers have relatively easy _effective_ access to fertilizer will probably require some kind of public intervention.

One alternative for distributing fertilizer that bears watching is the distribution system currently being developed in Ghana (56). There, a national fertilizer company will distribute fertilizer to wholesale warehouses located throughout rural areas and withdraw unused stocks at the end of the season. By relying on petroleum companies, state development boards, farmer cooperative societies and other companies having an extensive presence in rural areas, the national fertilizer company should ensure a rather complete coverage of the major farming areas. Margins allowed by the government are to reflect transportation and storage costs plus a reasonable profit and clearly will have to be set high enough to make the system work. This kind of system has the dual advantage of providing fertilizer supplies on a commercial, more reliable basis, while still allowing for uniform national pricing through subsidies to one semi-public corporation.

Another alternative for distributing fertilizer is provided by the emerging regional development organizations increasingly common in the francophone countries. They tend to be considerably more commercially minded than government service organizations. Normally, they provide integrated input supply, extension and output marketing services to farmers with a direct budgetary stake in the results. In general, these institutions appear surprisingly effective at distributing adequate fertilizer supplies in a reasonably timely manner. The common practice of deducting the cost of distributed inputs from cash crop sales at harvest time eliminates many of the administrative and money management problems associated with marketing of fertilizer.

Being responsible for both input and output marketing, regional development organizations can realize substantial transportation economies by coordinating purchase, sale and storage activities. They also can be very effective vehicles for administering area or crop specific fertilizer subsidies. The key, as always, is one of management. Indeed, it has been the persistent inability of public institutions to match the standards of the private sector in this regard that convinces many persons of the need to rely heavily on the private sector for distributing agricultural inputs and marketing output.

VII. NEED FOR COORDINATION OF DONOR EFFORTS IN FINANCING FERTILIZER PROJECTS

There has been a sharp increase in bilateral and multilateral foreign aid provided to West Africa in recent years. At the same time, interest in fertilizer and fertilizer-related production technologies has been expanding. This is resulting in the growing possibility of duplication and overbuilding which, in the area of fertilizer production, threatens to destabilize supply and demand relationships within the region. This can only result in heavy losses for the countries producing fertilizer. The large and growing number of agricultural production programs, on the other hand, could stimulate a much higher rate of consumption than that currently envisioned. While this might offset to some extent the large excess capacity projected for nitrogen production in the region, it would be wise to assess the potential demand before proceeding with production plans.

At this time the major area of lack of coordination is in fertilizer production. In Nigeria nitrogen production plans have been continually delayed, complicating planning decisions in other countries, especially Senegal. Senegal appears to be trying to push ahead with its own rather high-cost facility, apparently planning to rely on the same export markets as Nigeria. For the moment, financing is not complete for either project so it may be possible to avoid duplication of facilities that would, no doubt, cost farmers in Senegal dearly.

Feasibility studies are another area of increasingly common duplication of effort. The Germans have already conducted studies in countries where USAID studies are now recommended, especially for phosphate rock mining in Mali and Upper Volta.

There are also a number of soil fertility studies and plant breeding programs planned for the region which will be much more useful if they are integrated both with each other and with national research programs. USAID, ICRISAT, IITA, WARDA, IDRC, and soon the Institute of the Sahel will be financing research to supplement on-going work by IRAT, ORSTOM, OMVS, STRC, and the national centers. Although there is ample work for all, some coordination of effort will be necessary in order to avoid a wasteful duplication or dispersion of effort. The SAFGRAD project is an important step in this direction.

Other areas where coordination would be beneficial include evaluation of price and subsidy policies and linkages between transportation projects and agricultural production projects. In all these areas, it would be useful if the various donors in the region could keep each other informed of their plans and activities so that potential project linkages can be fully exploited and unnecessary duplication of efforts avoided.

APPENDICES

APPENDIX A
CROP RESPONSE TO PHOSPHATE ROCK

	Total Applied P_2O_5		Groundnut Yield Increase			Cereal Yield Increase			Total Crop Response, kg/kg P_2O_5
	Source	Rate, kg/ha	No. of crops	kg/ha	kg/kg P_2O_5	No. of crops	kg/ha	kg/kg P_2O_5	
Meridjonou, Benin,	Dical	160*	2	0	0	2	1390	8.7	8.7
1450 mm rainfall/yr.	PR-Togo	160	2	0	0	2	1110	6.9	6.9
Boukombe, Benin,**	Dical	160*	2	820	5.1	2	550	3.4	8.5
1200 mm rainfall/yr.	Dical	320*	2	980	3.1	2	430	1.3	4.4
	PR-Togo	160	2	730	4.6	2	180	1.1	5.7
	PR-Togo	320	2	760	2.4	2	520	1.6	4.0
Sotuba, Mali,	TSP	225*	2	175	0.8	3	5775	25.7	26.5
1000 mm rainfall/yr.	PR-Tilemsi	80	2	216	2.7	3	2670	33.4	36.1
	PR-Tilemsi	160	2	353	2.2	3	4384	27.4	29.6
	PR-Tilemsi	240	2	263	1.1	3	5320	22.2	23.3
	PR-Taiba	160	2	299	1.9	3	4978	31.1	33.0
Sotuba, Mali,	PR-Tilemsi	80	2	720	9.0	3	2944	36.8	45.8
1000 mm rainfall/yr.	PR-Tilemsi	160	2	864	5.4	3	4640	29.0	34.4
	PR-Taiba	160	2	1056	6.6	3	5296	33.1	39.7
Kita, Mali,	PR-Tilemsi	80	2	816	10.2	3	3344	41.8	52.0
850 mm rainfall/yr.	PR-Tilemsi	160	2	1136	7.1	3	5056	31.6	38.7
	PR-Taiba	160	2	1216	7.6	3	4976	31.1	38.7
Seno, Mali,	PR-Tilemsi	80	1	516	6.4	2	974	12.2	18.6
450 mm rainfall/yr.	PR-Tilemsi	160	1	623	3.9	2	1379	8.6	12.5
	PR-Taiba	160	1	539	3.4	2	1164	7.3	10.7
Magaria, Niger,	PR-Bayliphos	40	2	522	13.0	5	1465	36.6	49.6
550 mm rainfall/yr	PR-Bayliphos	80	2	320	4.0	5	1505	18.8	22.8
(without green manure)									
(with green manure)	PR-Bayliphos	40	2	40	1.0	5	630	15.8	16.8
	PR-Bayliphos	80	2	86	1.1	5	1275	15.9	17.0

*Sum of annual applications.
**Very low yields of sorghum were experienced in these trials.

APPENDIX A - CONTINUED
CROP RESPONSE TO PHOSPHATE ROCK

	Total Applied P_2O_5		Groundnut Yield Increase			Cereal Yield Increase			Total Crop Response, kg/kg P_2O_5
	Source	Rate, kg/ha	No. of crops	kg/ha	kg/kg P_2O_5	No. of crops	kg/ha	kg/kg P_2O_5	
Tarna, Niger, 550 mm rainfall/yr.	PR-Tahoua	45	4	608	13.5	4	828	18.4	31.9
	PR-Tahoua	90	4	436	4.8	4	1144	12.7	17.5
	PR-Tahoua	135	4	656	4.9	4	1596	11.8	16.7
	PR-Tahoua	60	1	18	0.3	4	688	11.5	11.8
	PR-Tahoua	120	1	0	0	4	1140	9.5	9.5
Magaria, Niger, 550 mm rainfall/yr.	TSP	80*	1	109	1.4	3	993	12.4	13.8
	PR-Tahoua	80	1	0	0	3	0	0	0
	PR-Tahoua	160	1	101	0.6	3	810	5.1	5.7
Kala-Pate, Niger, 450 mm rainfall/yr.	TSP	200*	2	464	2.3	4	888	4.4	6.7
	PR-Tahoua	150	2	370	2.5	4	340	2.3	4.8
	PR-Tahoua	300	2	78	0.3	4	212	0.2	0.5
Darou, Senegal,** 850 mm rainfall/yr.	Phospal	136	9	3325	24.4	8	325	2.4	26.8
	Phospal	272	9	4695	17.3	8	2110	7.8	25.1
	Phospal	544	9	6330	11.6	8	2390	4.4	16.0
	Dical	240*	5	4475	18.6	5	1165	4.9	23.5
	Phospal	240*	5	3455	14.4	5	865	3.6	18.0
	Phospal	240	5	4550	19.0	5	1000	4.2	23.2

*Sum of annual applications.
**Very low yields of sorghum were experienced in these trials.

SOURCES: Benin

Comparison Between Effects of Togo Phosphate and Bicalcic Phosphate, IRAT, Note Dy No. 1 10-10-70 (Translation: STRC/OAV - J.P. 26).

Mali

Rapport de Campagne 1974-75, Mission IRAT, République du Mali, 1975.

Rapport Synthétique de la Campagne 1975-76. Mission IRAT - Comité National de la Recherche Agronomique, République du Mali, 1976.

Experimentation Agronomique sur les Phosphates Naturels de Tilemsi en Conditions de Culture Seche -- Point des Recherches. IRAT - Mali.

Niger

J. Nabos, J. Charoy, and J. Pichot: Fertilisation Phosphatic des Sols du Niger, Utilisation des Phosphates Naturels de Tahoua. Agron. Trop. 29(11): 1140-1150. 1974.

Senegal

PHOSPAL Field Trials. 19 pages. Société Sénégalaise des Phosphates de Thies and Société d'Etudes et d'Applications des Minerais de Thies. Paris, France, undated.

APPENDIX B
NITROGEN FIXED BY LEGUME CROPS

Plant	Range of Nitrogen Fixed, kg/ha
Lucerne	56 - 463
Clover	45 - 673
Stylosanthes	34 - 220
Centrosema	126 - 395
Leucaena	74 - 584
Soybean	1 - 168
Lysine	145 - 208
Pigeon Pea	168 - 280
Cowpea	73 - 354
Lentil	88 - 114
Groundnut	72 - 124
Guar	41 - 220
Calapo	370 - 450

SOURCE: Nutman, T.S.: "IBP Field Experiments on Nitrogen Fixation by Nodulated Legumes," in Symbiotic Nitrogen Fixation in Plants, ed. Nutman, T.S.; Cambridge University Press, Cambridge, 1976; pp. 211-237.

APPENDIX C
PRESENT AND FUTURE FERTILIZER CONSUMPTION IN WEST AFRICA

The data in Appendix Tables C.2 to C.5 were fitted to both linear and exponential functional forms of the type $y = a + bx$ and $y = ae^{bx}$. For the regional aggregates, the exponential form gave a better fit than the linear form for total nutrients (R^2 = .95 versus .88), P_2O_5 (R^2 = .87 versus .78), and K_2O (R^2 = .80 versus .77). For N the linear R^2 was only slightly higher than the exponential one (R^2 = .93 versus .90). The consumption figures for 1970-74 were at least partially reduced because of the drought, causing a downward bias in the linear projections. At the same time the exponential form was found to be highly unstable for individual countries, especially those with relatively low levels of nutrient consumption.

In light of these factors we decided to project 1980 and 1985 consumption by applying the regional exponential coefficient to estimated base period consumption for each country. In this way the country totals become much more realistic and when added, correspond to the regional totals. Base period consumption was generally placed very close to 1975 consumption. In some cases, expecially for Senegal and Nigeria, downward adjustments were coupled with recent or inevitable changes in subsidy policies less favorable to fertilizer consumption. The exponential rate for nitrogen was reduced from .15 to .14 because the higher R^2 for the linear form suggests that an exponential estimate overestimates consumption. With the lower rate the sum of the N, P_2O_5 and K_2O components comes much closer to projections for total nutrients using the regional coefficient. The regional coefficient no doubt is the most stable of the three and the exponential form fitted to the regional nutrient totals gives the best fit of all the equations. Its 1985 estimate of 476,000 metric tons of total nutrient consumption for the region (Table C.6) compares very favorably with the 483,600 metric tons obtained by means of the procedure described above and detailed in Table VI.1.

TABLE C.1
FERTILIZER CONSUMPTION PER HECTARE OF
ARABLE LAND AND PER CAPITA, 1973-74
(KILOGRAMS)

Country	Consumption per Hectare of Arable Land				Consumption of N + P_2O_5 + K_2O Per Capita
	N	P_2O_5	K_2O	Total	
Benin	0.8	1.0	1.0	2.8	1.5
Cameroon	1.3	0.3	0.6	2.2	2.6
Chad	0.3	0.2	0.2	0.7	1.2
Gambia	1.5	3.1	0.0	4.6	2.4
Ghana	0.4	1.0	0.8	2.1	0.5
Guinea	0.5	0.1	0.1	0.7	0.2
Ivory Coast	0.7	0.8	1.7	3.2	6.1
Liberia	6.0	2.0	1.0	9.0	2.6
Mali	0.4	0.3	0.0	0.8	1.6
Nigeria	0.2	0.2	0.1	0.5	0.2
Senegal	1.3	1.4	1.4	4.1	5.5
Sierra Leone	0.3	0.3	0.1	0.8	1.0
Togo	0.1	0.1	0.1	0.3	0.3
Upper Volta	0.1	0.0	0.0	0.1	0.1

SOURCE: Annual Fertilizer Review, FAO, Rome, 1974

TABLE C.2
TOTAL NUTRIENT CONSUMPTION IN WEST AFRICAN COUNTRIES
(1,000 METRIC TONS)

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Senegal	9.97	13.71	16.11	21.94	12.15	7.64	7.92	13.57	15.69	25.34	37.40
Ivory Coast	11.14	11.79	12.50	13.87	11.70	13.85	21.19	23.67	30.70	29.84	30.87
Nigeria	2.80	3.35	7.33	7.26	10.10	10.41	6.90	9.25	19.56	15.20	28.90
Cameroon	6.90	8.50	12.00	13.22	17.21	14.35	20.26	14.90	11.86	16.18	16.65
Ghana	1.47	1.03	1.20	1.32	1.35	1.19	3.35	2.89	4.51	6.65	9.73
Mali	0.20	0.31	0.49	0.81	1.22	2.55	5.47	7.31	4.95	4.59	6.94
Chad	0.08	0.46	0.48	1.12	1.40	1.76	1.91	2.23	2.47	4.77	6.00
Benin	0.82	0.80	0.95	2.50	2.99	4.54	5.70	5.30	5.95	4.38	5.77
Sierra Leone	0.20	0.50	0.51	0.85	1.10	2.29	2.52	1.60	1.22	2.80	3.34
Liberia	0.20	0.30	1.40	1.60	1.20	1.80	2.30	1.90	3.73	3.29	3.30
Upper Volta	0.01	0.10	0.10	0.10	0.20	0.45	0.57	0.91	1.25	0.61	3.10
Mauritania	--	--	0.05	0.10	0.20	0.23	0.35	0.09	0.22	0.13	0.25
Guinea	3.10	3.00	3.50	3.50	2.50	2.50	3.00	2.90	2.80	1.00	1.83
Gambia	0.04	0.37	0.55	0.46	0.30	0.22	0.29	0.40	0.85	0.92	1.18
Togo	--	--	0.05	0.10	0.20	0.26	0.43	0.50	0.56	0.64	0.51
Guinea Bissau	--	--	--	--	--	--	--	--	--	0.10	0.39
Niger	0.02	0.24	0.26	0.24	0.33	0.17	0.24	0.31	0.38	0.15	0.30
Total	36.95	44.46	57.48	68.99	64.15	64.21	82.40	87.73	106.70	116.51	156.46

SOURCE: TVA/FAO datafile and IFDC West Africa Fertilizer Study

TABLE C.3
N CONSUMPTION IN WEST AFRICAN COUNTRIES
(1,000 METRIC TONS)

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Senegal	2.27	3.21	5.36	5.27	3.43	3.00	3.78	5.04	5.18	8.08	11.00
Ivory Coast	3.46	3.77	4.00	4.48	3.56	4.49	6.13	6.47	8.77	7.94	7.80
Nigeria	1.10	1.70	4.60	4.00	4.00	3.43	2.57	3.59	9.15	4.70	13.20
Cameroon	2.50	3.00	6.30	8.53	10.73	8.84	11.57	9.00	7.30	9.33	9.76
Ghana	0.15	0.20	0.30	0.51	0.43	0.37	1.38	1.11	2.59	2.95	3.78
Mali	0.06	0.09	0.14	0.22	0.32	0.69	2.33	3.17	3.60	1.38	2.24
Chad	0.03	0.40	0.40	0.64	0.80	0.88	1.13	1.25	1.14	2.21	2.80
Benin	0.13	0.10	0.10	0.69	1.23	1.60	2.00	2.20	2.06	1.30	2.63
Sierra Leone	--	--	0.02	0.12	0.20	1.13	1.15	0.90	0.53	1.14	1.04
Liberia	0.20	0.30	1.40	1.60	1.20	1.50	1.80	1.40	2.47	2.19	1.20
Upper Volta	--	--	--	--	--	0.29	0.37	0.44	0.58	0.36	1.00
Mauritania	--	--	--	--	--	0.03	0.05	0.05	0.17	0.04	0.17
Guinea	0.80	0.50	1.00	1.00	1.00	1.00	1.50	1.60	1.70	0.80	0.65
Gambia	0.01	0.02	0.05	0.05	0.03	0.09	0.15	0.30	0.37	0.30	0.50
Togo	--	--	--	--	--	0.08	0.21	0.20	0.26	0.26	0.30
Guinea Bissau	--	--	--	--	--	--	--	--	--	0.10	0.32
Niger	0.02	0.12	0.15	0.15	0.20	0.07	0.13	0.15	0.22	0.08	0.10
Total	10.73	13.41	23.82	27.26	27.13	27.49	36.25	36.87	46.09	43.16	58.49

SOURCE: TVA/FAO datafile and IFDC West Africa Fertilizer Study

TABLE C.4
P_2O_5 CONSUMPTION IN WEST AFRICAN COUNTRIES
(1,000 METRIC TONS)

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Senegal	4.95	6.43	4.97	10.73	5.29	2.96	2.71	3.71	5.91	10.26	13.40
Ivory Coast	1.50	1.98	2.00	3.08	2.12	2.02	3.22	3.22	4.03	4.18	4.47
Nigeria	1.20	1.40	1.80	2.20	5.40	6.35	3.26	4.37	6.63	5.50	10.70
Cameroon	0.40	0.50	0.70	1.59	2.18	1.17	3.83	1.00	0.80	2.30	2.13
Ghana	0.70	0.43	0.50	0.51	0.71	0.70	1.32	0.94	0.87	2.10	3.22
Mali	0.14	0.22	0.35	0.57	0.85	1.80	3.08	4.06	1.32	2.76	4.30
Chad	0.05	0.06	0.08	0.48	0.60	0.88	0.78	0.76	0.75	1.44	1.80
Benin	0.17	0.10	0.15	0.52	0.32	0.54	0.70	1.20	1.15	1.50	1.78
Sierra Leone	0.20	0.50	0.48	0.68	0.80	1.00	1.21	0.50	0.51	1.13	1.00
Liberia	--	--	--	--	--	0.30	0.50	0.50	0.97	0.75	0.80
Upper Volta	0.10	0.10	0.10	0.10	0.20	0.16	0.20	0.44	0.49	0.10	1.70
Mauritania	--	--	0.05	0.10	0.20	0.20	0.30	0.04	0.03	0.04	0.04
Guinea	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.10	0.10	0.10	0.45
Gambia	0.03	0.35	0.50	0.41	0.27	0.13	0.14	0.10	0.48	0.62	0.68
Togo	--	--	0.05	0.10	0.20	0.12	0.17	0.23	0.16	0.20	--
Guinea Bissau	--	--	--	--	--	--	--	--	--	--	0.07
Niger	--	0.08	0.08	0.07	0.08	0.07	0.08	0.10	0.10	0.06	0.20
Total	9.94	12.65	12.31	21.64	19.72	18.90	22.00	21.27	24.66	33.04	46.74

SOURCE: RVA/FAO datafile and IFDC West Africa Fertilizer Study

TABLE C.5
K_2O CONSUMPTION IN WEST AFRICAN COUNTRIES
(1,000 METRIC TONS)

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Senegal	2.75	4.07	5.78	5.94	3.43	1.68	1.43	4.82	4.60	7.00	13.00
Ivory Coast	6.18	6.04	6.50	6.31	6.02	7.34	11.84	13.98	17.90	17.72	18.60
Nigeria	0.50	0.25	0.93	1.06	0.70	0.63	1.07	1.29	3.78	5.00	5.00
Cameroon	4.00	5.00	5.00	3.10	4.30	4.34	4.86	4.90	3.76	4.55	4.76
Ghana	0.62	0.40	0.40	0.30	0.21	0.12	0.65	0.84	1.05	1.60	2.73
Mali	--	--	--	0.02	0.05	0.06	0.06	0.08	0.03	0.45	0.40
Chad	--	--	--	--	--	--	--	0.22	0.58	1.12	1.40
Benin	0.52	0.60	0.70	1.29	1.44	2.40	3.00	1.90	2.38	1.58	1.36
Sierra Leone	--	--	0.01	0.05	0.10	0.16	0.16	0.20	0.18	0.53	1.30
Liberia	--	--	--	--	--	--	--	--	0.29	0.35	1.30
Upper Volta	--	--	--	--	--	--	--	0.03	0.18	0.15	0.40
Mauritania	--	--	--	--	--	--	--	--	0.02	0.05	0.04
Guinea	1.80	2.00	2.00	2.00	1.00	1.00	1.00	1.20	1.00	0.10	0.73
Gambia	--	--	--	--	--	--	--	--	--	--	--
Togo	--	--	--	--	--	0.06	0.05	0.07	0.14	0.18	0.21
Guinea Bissau	--	--	--	--	--	--	--	--	--	--	--
Niger	--	0.04	0.03	0.02	0.05	0.03	0.03	0.06	0.06	0.01	--
Total	16.37	18.40	21.35	20.09	17.30	17.82	24.15	29.59	35.95	40.39	51.23

SOURCE: TVA/FAO datafile and IFDC West Africa Fertilizer Study

TABLE C.6
TOTAL NUTRIENT USE IN 1975 AND PROJECTED USE IN 1980 AND 1985 FOR WEST AFRICAN COUNTRIES USING LINEAR AND EXPONENTIAL FUNCTIONAL FORMS

Country	Actual 1975 Use, 1,000 mt	Projected Use, 1,000 mt			
		$Y = a + bx$		$y = ae^{bx}$	
		1980	1985	1980	1985
Senegal	37.40	31.18	38.52	29.38	41.41
Ivory Coast	30.87	42.33	53.90	58.74	107.03
Nigeria	28.90	30.59	40.38	59.15	152.17
Cameroon	16.65	21.59	25.48	25.93	36.25
Ghana	9.73	10.32	13.91	19.34	55.83
Mali	6.94	10.56	14.26	7.54	493.91
Chad	6.00	7.03	9.53	38.61	212.39
Benin	5.77	9.28	12.11	25.60	76.90
Sierra Leone	3.34	4.34	5.72	11.85	37.99
Liberia	3.30	5.20	6.85	17.41	60.76
Upper Volta	3.10	2.75	3.79	24.71	228.61
Mauritania	0.25	0.37	0.48	--	--
Guinea	1.83	1.13	0.35	12.49	17.90
Gambia	1.18	1.30	1.69	2.71	7.23
Togo	0.51	1.00	1.36	--	--
Guinea Bissau	0.39	--	--	--	--
Niger	0.30	0.37	0.43	0.65	1.18
Region[a]	156.46	179.59	229.11	256.22	476.26

[a]Projections for the region are results of a pooled analysis and are not additions of countries.

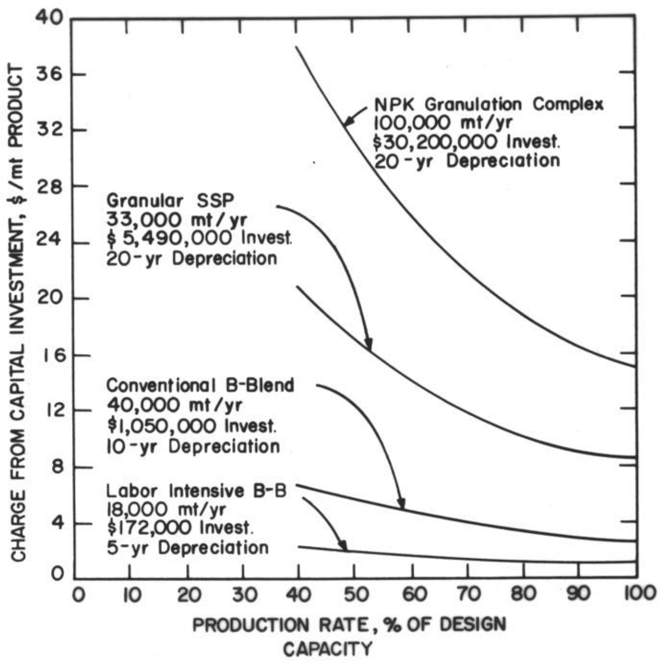

Figure D-1. Effect of Capital Investment and Operating Rate on Capital Charges for Fertilizer (IFDC).

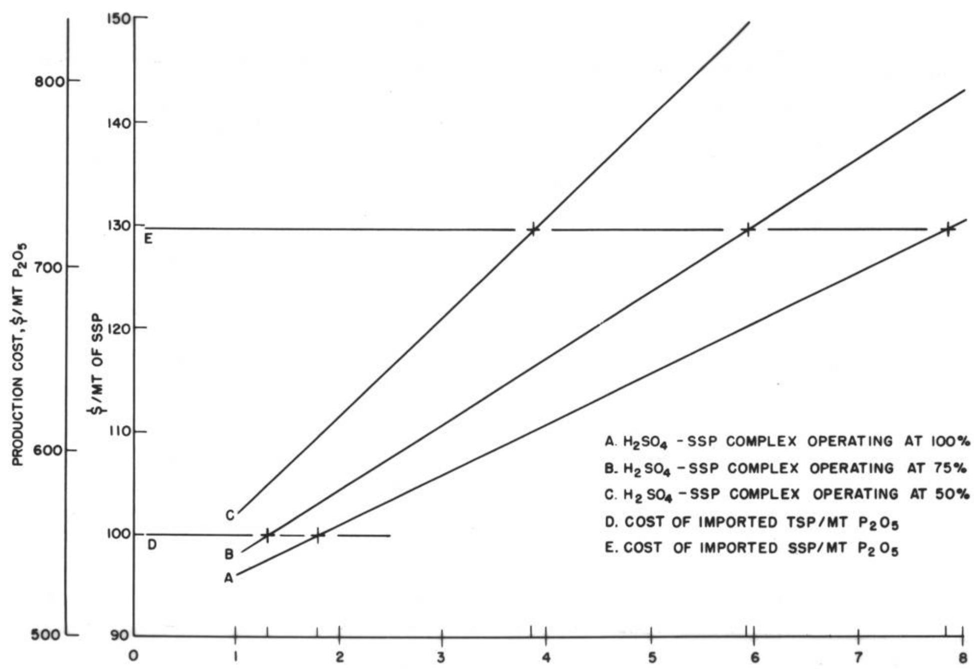

Figure D-2. Influence of Investment Cost and Level of Operation on Estimated Cost of Single Superphosphate Production in a 33,000 mt/yr Plant in Mali. (Production Cost Includes all Cost Except a Return on Equity Over and Above Interest Charge (IFDC).

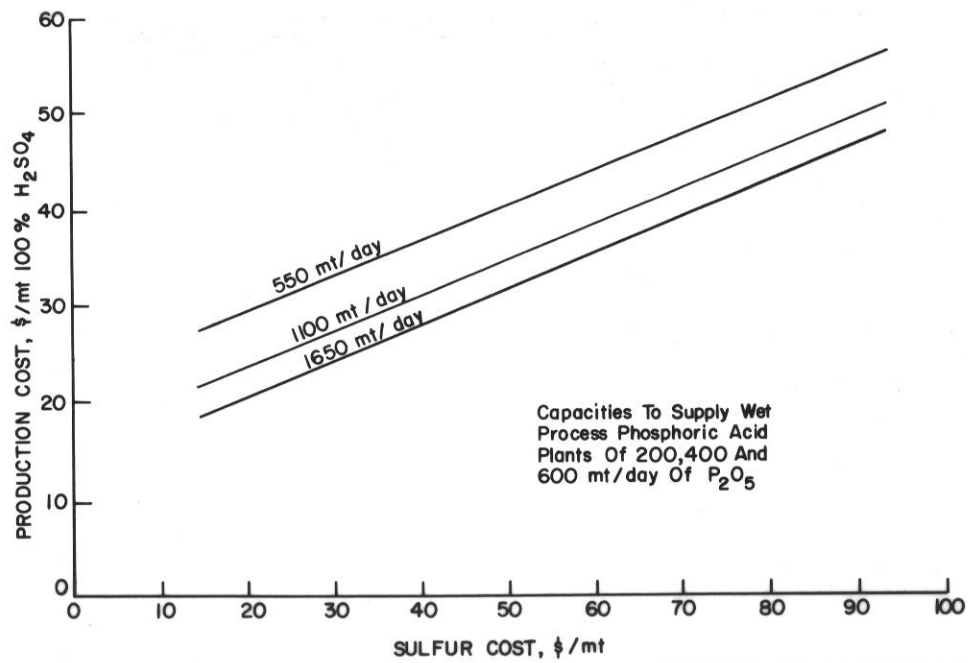

Figure D-3. Estimated Production Cost of 100% Sulfuric Acid versus Cost of Sulfur in Plants with Varying Capacity (TVA Bulletin Y-95, 1975).

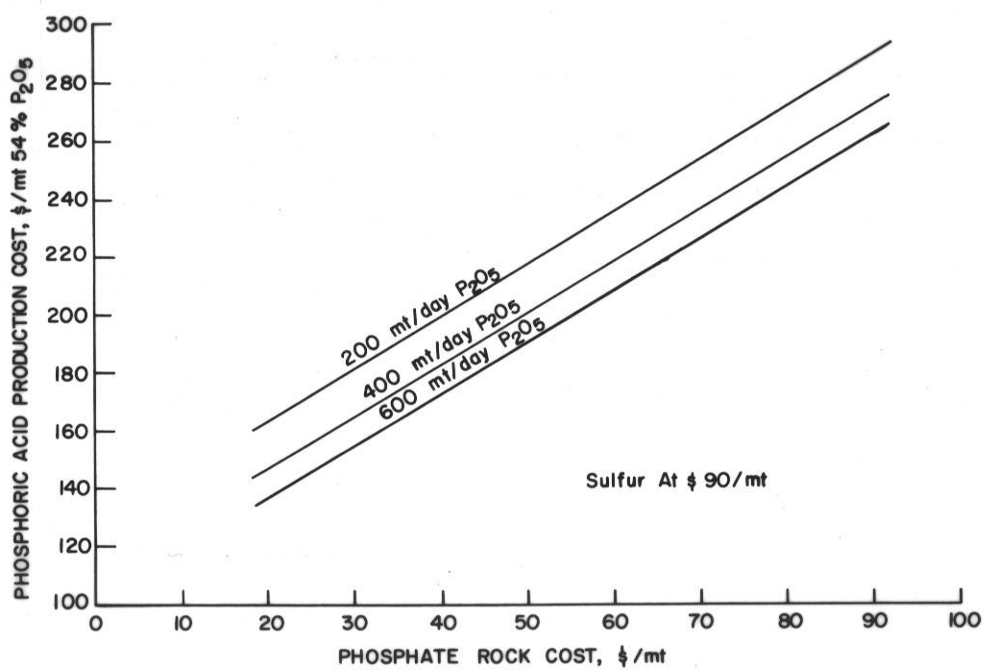

Figure D-4. Estimated Production Cost of Phosphoric Acid (54% P_2O_5) versus Cost of Phosphate Rock in Plants with Varying Capacity (TVA Bulletin Y-95, 1975).

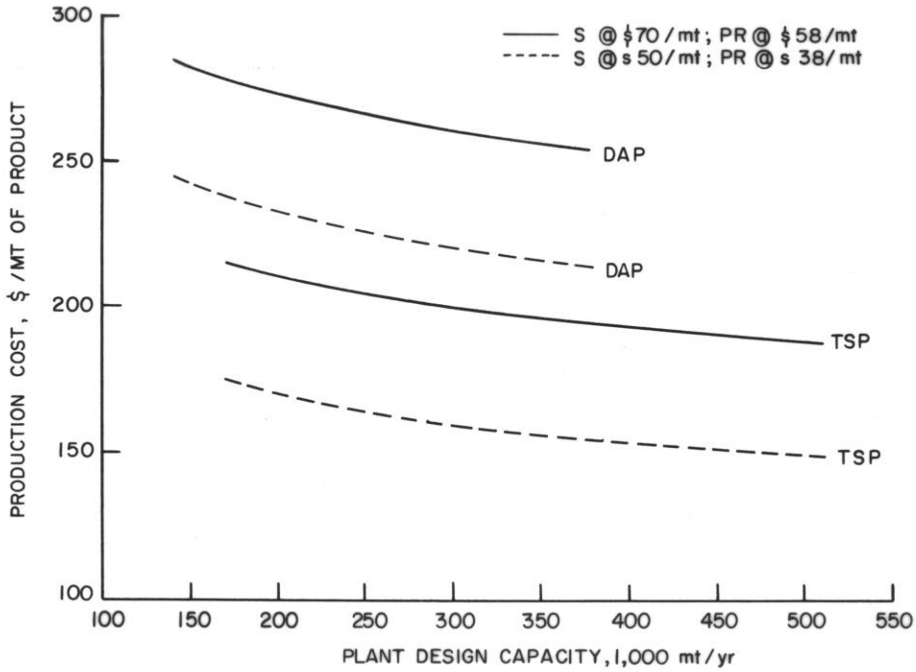

Figure D-5. Influence of Design Capacity and Raw Material Costs on Estimated Production Costs of TSP and DAP (TVA Bulletin Y-95, 1975).

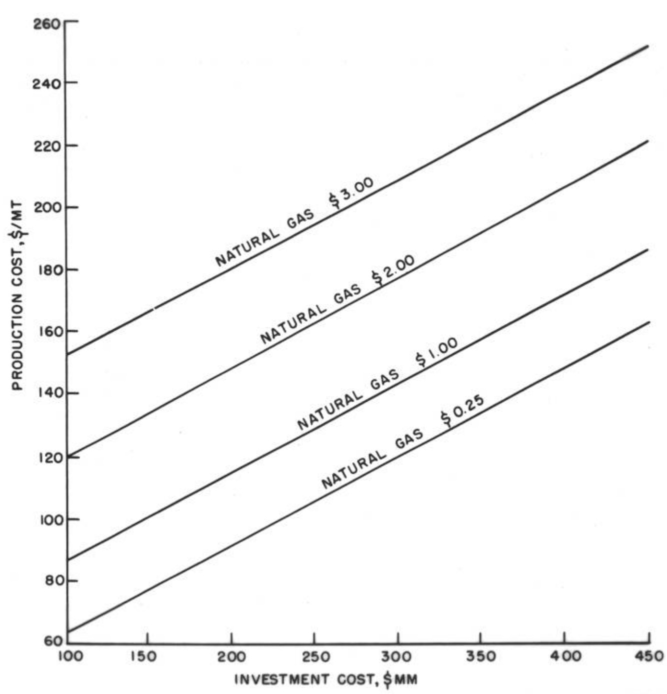

Figure D-6. Effect of Investment Cost and Natural Gas Cost on Estimated Production Cost of Urea in an Ammonia-Urea Complex Producing and Utilizing 1,000 mt Ammonia per Day (IFDC).

APPENDIX E
ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR A GRANULAR SSP COMPLEX IN MALI, 1977

TABLE E.1
COST ESTIMATE - SULFURIC ACID PLANT
50 MT PER DAY CAPACITY

Total equipment cost (TEC) f.o.b. factory[a]	$1,800,000
Internal U.S. transport, packing, ocean freight and insurance for shipment to Dakar (25% TEC)	450,000
Inland transport to Bamko (15% TEC)[b]	270,000
Subtotal: Total delivered equipment cost (TDC)	$2,520,000
Site preparation	$ 200,000
Erection cost (35% TDC)[c]	882,000
Engineering and startup	60,000
Total installed cost	$3,662,000[d]
Contingency (10%)	366,000
TOTAL PLANT INVESTMENT	$4,028,000

[a]Includes H_2O treatment, sulfur melter, sulfur storage for 2 weeks, 2 weeks' storage of 98% product acid, cooling tower, and all required buildings.

[b]ESTIMATE: No data available on cost of moving heavy equipment by rail.

[c]Considers higher delivered equipment cost than for U.S. installation. Assumes all utilities available.

[d]Does not include acquisition of land or escalation over construction period. Assumes adequate infrastructure.

TABLE E.2
COST ESTIMATE - NONGRANULAR SINGLE SUPERPHOSPHATE PLANT
145 MT PER DAY[a]

Total equipment cost (f.o.b. factory)	$148,000
Internal U.S. transport, ocean freight, and insurance (25% TEC)	37,000
Inland transport to Bamako (15% TEC)[b]	22,000
Subtotal: Total delivered cost	$207,000
Erection (35% TDC)	$ 72,000
Building (6,000 T storage)	200,000
Engineering and startup	25,000
Total installed cost	$504,000
Contingency (10%)	50,000
TOTAL PLANT INVESTMENT	$554,000

[a]100 t/d desired; 145 t/d is the smallest commercially available unit.

[b]Estimate; no data available on cost of moving heavy equipment by rail

TABLE E.3
COST ESTIMATE - GRANULATION FACILITY (FOR INSTALLATION AT OR NEAR BAMAKO, MALI) - 100 MT PER DAY CAPACITY

Total equipment, controls, pollution controls[a] (f.o.b. factory, U.S. supplier)	$370,000
Internal U.S. transport, ocean freight, and insurance to Dakar (25% TEC)	92,500
Inland transport to Bamako (15% TEC)[b]	55,500
Subtotal: Total delivered equipment cost (TDC)	$518,000
Erection cost (35% TDC)[c]	$181,500
Building (plant and 3,000 T storage)[d]	100,000
Engineering and startup	25,000
Total installed cost	$824,500[e]
Contingency (10%)	82,500
TOTAL PLANT INVESTMENT	$906,500

[a]The amount of pollution abatement equipment supplied may be in excess of that which is needed in west Africa.

[b]Estimate; no data available on cost of moving heavy equipment by rail.

[c]Considers higher delivered equipment cost than for U.S. location. Assumes all utilities, electricity, water, gas, etc., provided.

[d]Includes minimal coverage for plant equipment and fully enclosed storage. Assumes steel frame construction. Locally erected pole construction would possibly be lower cost.

[e]Not including aquisition of land, site preparation, or escalation over construction period. Cost for instantaneous erection mid-1977. Assumes adequate infrastructure, rail spur, and/or road access.

TABLE E.4
ESTIMATED PRODUCTION COSTS FOR SULPHURIC ACID
(U.S. DOLLARS)

Product: H_2SO_4		Plant investment	$4,028,000
Annual production:	16,500 mt	Working capital	
		Raw material inventory	71,542
Basis of estimates:	50 mt/day	Product inventory	109,336
	330 days/year	Accounts receivable	131,714
	100% capacity	Operating funds	73,027
		Accounts payable	73,027
		Total working capital	458,646
		TOTAL INVESTMENT	$4,486,646

	Units Required Per Mt Produced	Cost Per Unit	Cost Per Mt Produced
Raw materials			
Sulfur (mt)	0.3440	153.9100	52.9450
Process H_2O	0.1775	0.2800	0.0497
Subtotal			52.9947
Other variable costs			
Boiler makeup (mt)	8.5190	0.2800	2.3853
Cool makeup (mt)	2.8000	0.0700	0.1960
Electricity (Kwh)	17.6600	0.0030	0.0530
Steam (mt)	1.000	0.	0.
Subtotal			2.6342
Fixed costs			
Labor (man hrs)	.5800	0.2000	0.1160
Maintenance (5.00% of TPI)			12.2060
Taxes and Ins. (2.00% of TPI)			4.8824
Overhead (150% of labor)			0.1740
Depreciation (15 yrs)			16.2747
Ave. Int. (10.00% of TPI)			6.5099
Int. (0.% of 0.% of working capital)			0.
Subtotal			40.1629
TOTAL PRODUCTION COST			95.7920

TABLE E.5
ESTIMATED PRODUCTION COSTS FOR NON-GRANULATED SSP
(U.S. DOLLARS)

Product: SSP (0-18-0)		Plant investment:	$ 554,000
Annual production:	33,000 mt	Working capital:	
		Raw material inventory	311,802
Basis of estimate:	100 mt/day	Product inventory	297,460
	330 days/yr	Accounts receivable	300,538
	100% capacity	Operating funds	269,859
		Accounts payable	269,859
		Total working capital	$1,449,518
		TOTAL INVESTMENT	$2,003,518

	Units Required Per Mt Produced	Cost Per Unit	Cost Per Mt Produced
Raw materials			
Phos rock (mt)	0.6700	94.6800	63.4356
H_2SO_4	0.3600	95.7920	34.4851
Subtotal			97.9207
Other variable costs			
Steam (mt)	0.1400	0.	0.
Electricity (Kwh)	33.0000	0.0030	0.0990
Bags (20/mt)	1.0000	8.0000	8.0000
Subtotal			8.0989
Fixed costs			
Labor (man hrs)	1.0500	0.2000	0.2100
Maintenance (5.00% of TPI)			0.8394
Taxes and Ins. (2.00% of TPI)			0.3357
Overhead (150% of labor)			0.3150
Depreciation (15 years)			1.1192
Ave.Int.(10.00% of 50% of TPI)			0.4477
Int. (0.% of 0.% of working capital)			0.
Subtotal			3.2669
TOTAL PRODUCTION COST			109.2867

TABLE E.6
ESTIMATED PRODUCTION COSTS FOR GRANULATED SSP
(U.S. DOLLARS)

Product: Granulated SSP		Plant investment:	$ 906,500
Annual production: 33,000 mt		Working capital:	
		Raw material inventory	150,269
Basis of estimates:	100 mt/day	Product inventory	317,125
	330 days/year	Accounts receivable	322,161
	100% capacity	Operating funds	300,620
		Accounts payable	300,620
		Total working capital	$2,297,295

	Units Required Per Mt Produced	Cost Per Unit	Cost Per Mt Produced
Raw materials			
SSP (mt)	1.0000	109.2867	109.2867
Subtotal			109.2867
Other variable costs			
Fuel oil (mt)	0.0250	85.0000	2.1250
Electricity (Kwh)	337.0000	0.0030	1.1310
Steam (mt)	0.0230	1.9700	0.0453
Subtotal			3.3013
Fixed costs			
Labor (man hrs)	0.1500	0.2000	0.0300
Maintenance (5.00% of TPI)			1.3735
Taxes and Ins. (2.00% of TPI)			0.5494
Overhead (150% of labor)			0.0450
Depreciation (15 years)			1.8313
Ave. Int. (10.00% of 50% of TPI)			0.7325
Int. (0.% of 0.% of working capital)			0.
Subtotal			4.5616
TOTAL PRODUCTION COST			117.1496

APPENDIX F
THE ROAD AND RAIL TRANSPORTATION NETWORK IN WEST AFRICA

TABLE F.1
TRANSPORTATION INFRASTRUCTURE

Country	Road Network Distance - km		Motor Vehicles (Trucks and Buses in Use)	Rail Lines Distance-km	Primary Ports Accessibility to Interior	
	Total	All Weather				
Benin	6,800	680	10	579	Cotonou	rail and road
Cameroon	23,000	7,500	38	1,170	Douala	rail and road
Chad	32,000	7,000	6	None	Pointe Noire	rail to Brazzaville (515 km); barge to Bangui (1,300 km); road to N'Djamena (1,460 km)
Gambia	852	306	--	None	Bathurst	road and water
Ghana	32,190	12,070	60	1,290	Tema Sekondi-Takoradi	rail and road rail and road
Guinea	13,263	1,056	--	810	Conarky	rail and road
Guinea Bissau	3,589	426	--	None	Bissau	road
Ivory Coast	38,000	15,000	60	640	Abidjan Sassandra	rail and road road
Liberia	6,760	2,735	11	440	Monrovia Buchanan	rail and road rail and road

TABLE F.1 - CONTINUED
TRANSPORTATION INFRASTURCTURE

	Road Network Distance - km		Motor Vehicles (Trucks and Buses in Use)	Rail Lines Distance-km	Primary Ports Accessibility to Interior	
	Total	All Weather				
Mali	13,000	4,700	--	600	Dakar	rail to Bamako (1,200 km)
					Abidjan	rail to Bobo-Dioulasso (640 km); truck to Bamako (560 km); road to Bamako (1,200 km)
					Cotonou	rail to Kankan (580 km) and truck to Bamako (480 km)
Mauritania	6,000	3,200	5	700	Nouakchott	road
					Nouadhibou	rail to mines
					Dakar	water or road 365 km to Rosso
					St. Louis	water or road 95 km to Rosso
Niger	7,300	1,000	8	None	Cotonou	rail to Parakou (440 km); road to Niamey (610 km)
					Abidjan	rail to Ouagadougou (1,120 km) road to Niamey (520 km)

TABLE F.1 - CONTINUED
TRANSPORTATION INFRASTRUCTURE

Country	Road Network Distance - km		Motor Vehicles (Trucks and Buses in Use)	Rail Lines Distance-km	Primary Ports Accessibility to Interior	
	Total	All Weather				
Niger (cont'd)					Lagos	rail to Kaura Namoda (1,120 km) road to Maradi (200 km)
					Port Harcourt	rail to Kano (1,080 km) road to Zinder (265 km)
Nigeria	88,500	15,300	80	3,500	Lagos	rail and road
					Port Harcourt	rail and road
Senegal	14,000	8,120	25	1,032	Dakar	rail or road
					St. Louis	rail, road or river
Sierra Leone	6,920	966	--	410	Freetown	rail and road
Togo	7,000	2,000	7	490	Lome	rail and road
Upper Volta	17,000	4,450	--	520	Abidjan	rail to Ouagadougou (1,120 km)
					Tema	road to Ouagadougou (1,010 km)
					Lome	road to Ouagadougou (1,000 km)

SOURCE: World Bank transportation studies; Volumes 1-7 of IFDC West Africa Fertilizer Study; and Business International "Indicators of Market Size for 123 Countries."

TABLE F.2
MAJOR DOMESTIC TRANSPORTATION ROUTES
IN THE COUNTRIES OF WEST AFRICA

Country	Route	Mode	Distance-km	Comments
Benin	Cotonou to Parakou	rail	438	
	Cotonou to Bohicon	truck	120	All weather
	Cotonou to Parakou	truck	411	Cotonou-Bohicon (120 km) - all weather; remainder - gravel subject to flooding
	Parakou to Kandi	truck	213	Very good - all weather
Cameroon	Doula to N'Gaoundere	rail	930	
	Douala to N'Kongsamba	rail	170	Service reportedly inefficient
	Douala to Yaounde	truck	275	100 km is paved and the remainder is gravel; may be impassable during periods of heavy rain
	Douala to Bafoussam	truck	260	This paved road carries the greatest volume of traffic in Cameroon
	N'Gaoundere to Garoua	truck	300	Paved (180 km) and remainder is gravel, suitable for year-round use
	Garoua to Maroua	truck	200	Paved (86 km) and remainder is gravel, suitable for year-round use
	Douala to Mamfe	truck	320	All weather road
Chad	N'Djamena to Sarh	truck	560	All weather
	N'Djamena to Bongor	truck	240	Paved, may be impossible in periods of extreme rainfall

TABLE F.2 - CONTINUED
MAJOR DOMESTIC TRANSPORTATION ROUTES
IN THE COUNTRIES OF WEST AFRICA

Country	Route	Mode	Distance km	Comments
Chad (cont'd)	N'Djamena to Moundon	truck	860	Via Sarh - all weather
	Sarh to Moundon	truck	300	All weather
	N'Djamena to Abeche	truck	760	Impassable during flood season
Gambia	Bathurst to Mansa-Konko	road	176	Paved
	Mansa-Konko to Basse-Santa-Su	road	200	All weather gravel The Gambia River is navigable but extent is unknown
Ghana	Takoradi to Kumasi	rail	240	These three routes which basically serve the "Golden Triangle" account for Ghana's rail system
	Tema to Kumai	rail	260	Same as above
	Takoradi to Tema	rail	300	Same as above
	Accra to Kumasi	truck	255	Good all weather
	Kumasi to Tamak	truck	393	Good all weather
	Kumasi to Wa	truck	489	All weather, 175 km is paved and the remainder is gravel
Guinea	Conarky to Kankan	rail	560	
	Kankan to Beyla	truck	260	All weather - gravel
	Conarky to Kissidougou	truck	550	Paved

TABLE F.2 - CONTINUED
MAJOR DOMESTIC TRANSPORTATION ROUTES
IN THE COUNTRIES OF WEST AFRICA

Country	Route	Mode	Distance km	Comments
Guinea (cont'd)	Conarky to Labe	truck	320	Paved to Mamou (225 km); about half of the remainder is paved; other is fair quality
Ivory Coast	Abidjan to Bouake	rail	320	Bouake is on the RAN railway 310 km from the border with Upper Volta
	Abidjan to Ferkessedougou	rail	560	
	Abengourou to Bouna	truck	393	Paved surface (284 km) and all weather gravel (327 km)
	Abidjan to Gagnoa	truck	288	All weather
	Abidjan to Man	truck	555	All weather (360 km paved, 195 km gravel)
	Bouake to Korhogo	truck	260	All weather gravel
	Korhogo to Odienne	truck	240	All weather gravel
Liberia	Buchanan to N.E. border	rail	270	Predominantly used in transporting iron ore from mines
	Monrovia to Buchanan	truck	140	Paved
	Monrovia to Gbarnga	truck	224	All weather
	Gbarnga to Zorzor	truck	95	All weather gravel
	Pt. Harper to Tchien	truck	448	All weather gravel
Mauritania	Rosso to Kaedi	truck	310	Floods during the rainy season

TABLE F.2 - CONTINUED
MAJOR DOMESTIC TRANSPORTATION ROUTES
IN THE COUNTRIES OF WEST AFRICA

Country	Route	Mode	Distance km	Comments
Mauritania (cont'd)	Rosso to Kaedi	river	310	The Senegal River is seasonally navigable
	Kaedi to Kiffa	truck	305	All weather except final 55 km
	Nouakchott to Rosso	truck	203	Paved
Mali	Bamako to Bougouni	truck	165	Paved
	Bamako to Segou	truck	125	Paved
	Bamako to Sikasso	truck	400	Paved
	Bamako to Mopti	truck	635	Paved
	Mopti to Gao	truck	585	Susceptible to seasonal flooding
	Gao to Bamako	barge	1,310	This portion of the Niger River is seasonably navigable; however, a well-coordinated distribution plan may derive the benefits of water transportation.
	Sikasso to Mopti	truck	465	All weather
Nigeria	Lagos to Kaduna	rail	880	
	Port Harcourt to Kaduna	rail	800	
	Port Harcourt to Bauchi	rail	880	
	Port Harcourt to Maiduguri	rail	1,350	
	Kaduna to Gusau	rail	270	

TABLE F.2 - CONTINUED
MAJOR DOMESTIC TRANSPORTATION ROUTES
IN THE COUNTRIES OF WEST AFRICA

Country	Route	Mode	Distance km	Comments
Nigeria (cont'd)	Kaduna to Kano	rail	240	
	Lagos to Kontagora	truck	599	Paved
	Lagos to Onitsha	truck	464	Paved
	Port Harcourt to Onitsha	truck	214	Paved
	Port Harcourt to Jos	truck	901	Paved
	Jos to Maiduguri	truck	596	Paved
	Jos to Yola	truck	519	Paved but subject to flooding
	Jos to Zaria	truck	242	Paved
	Zaria to Sokoto	truck	405	Paved
	Zaria to Kano	truck	172	Paved
	Yenagoa to Jebba	truck	650	Niger River navigable 8 months a year
	Jebba to Yelwa	truck	230	Niger River is navigable 4 months a year
	Yenagoa to Yola	truck	1,120	Benui River is navigable to Yola about 2 months a year
Niger	Niamey to Tillabery	truck	120	All weather
	Niamey to Dosso	truck	140	All weather
	Niamey to Gaya	truck	300	All weather

TABLE F.2 - CONTINUED
MAJOR DOMESTIC TRANSPORTATION ROUTES
IN THE COUNTRIES OF WEST AFRICA

Country	Route	Mode	Distance km	Comments
Niger (cont'd)	Niamey to Maradi	truck	675	All weather
	Maradi to Zinder	truck	240	All weather
	Zinder to Agadez	truck	470	All weather (170 km); dry weather (300 km)
	Maradi to Tahoua	truck	325	All weather
Port Guinea	Bissau to Farim	truck	120	Paved
	Bissau to Bafata	truck	175	Final 80 km may be subject to flooding
Senegal	Dakar to St. Louis	rail	290	
	Dakar to Kidira	rail	640	
	Dakar to Linguere	rail	360	
	Dakar to Koalack	truck	170	Paved
	Dakar to Kolda	truck	680	All weather to Tambacounda (440 km); remaining 240 km is subject to flooding
	Dakar to Kedougou	truck	730	All weather to Tambacounda (440 km); remaining 290 km is subject to flooding
Sierra Leone	Freetown to Bo	rail	200	
	Freetown to Pendembu	rail	320	
	Freetown to Jaiama	truck	280	All weather

TABLE F.2 - CONTINUED
MAJOR DOMESTIC TRANSPORTATION ROUTES
IN THE COUNTRIES OF WEST AFRICA

Country	Route	Mode	Distance km	Comments
Sierra Leone (cont'd)	Freetown to Makeni	truck	200	Paved
	Freetown to Kambia	truck	180	Paved road (120 km); remaining is all weather gravel
Togo	Lome to Blitta	rail	276	
	Lome to Palime	rail	116	
	Lome to Sokode	truck	360	Paved
	Jocode to Dapango	truck	311	Paved (73 km) and all weather gravel (238 km)
Upper Volta	Ouagadougou to Fada N'Gourma	truck	225	Paved (135 km); remainder is gravel (may be susceptible to flooding)
	Ouagadougou to Kaya	truck	100	All weather
	Ouagadougou to Ouahigouya	truck	180	All weather
	Ouagadougou to Koudougou	truck	97	All weather
	Ouagadougou to Bobo Dioulasso	rail truck	360 360	 All weather
	Bobo Dioulasso to Banfora	truck	85	All weather
	Bobo Dioulasso to Gaoua	truck	210	May be impassable

SOURCE: IFDC <u>West Africa Fertilizer Study</u>, IBRD transportation studies; and a map, "Africa, North and West," Michelin Tyre Co. Ltd.

APPENDIX G
SOME CHARACTERISTICS OF FERTILIZER DISTRIBUTION AND MARKETING IN SELECTED COUNTRIES OF WEST AFRICA

Item	Benin (58)	Cameroon (22)	Chad (21, 35)
Import Procedures	Imports handled by private companies (gov't controlled).	Cameroon Fertilizer Company's Production Plant (SOCAME)	Through gov't tender, National Office of Rural Development (ONDR)
Marketing Channels	Development companies (CFDT, SONADER), cooperatives, farmers.	SOCAME to FONADER, cooperatives, agro-industrial societies, or certain growers. FONADER also resells to the others.	COTTONCHAD warehouses to extension service and 3,500 micro-distribution points
Logistics Transport	Development companies' transport.	From Douala warehouse to farmers by SOCAME customers' transport: FONADER, coop, ZAPI de l'est, Agri-Industrial Societies, certain large growers, and administrative services.	COTTONCHAD transport.
Storage	Development companies' facilities.	SOCAME warehouse, FONADER, certain companies, coop warehouse.	22 COTTONCHAD warehouses and at 3,500 micro-distribution points.
Pricing	Fixed according to each region.	2 tariffs: --subsidized --un-subsidized	Fixed.
Subsidies	Only cotton fertilizer (approx. 10% of C.I.F.)	Granted at state level.	By FED and Cotton Price Stabilization Fund.
Credit	Loans in kind, recovery at the harvest, no interest.	Limited credit from banks through FONADER.	Credit is in kind through ONDR for cotton fertilizer.

APPENDIX G - CONTINUED
SOME CHARACTERISTICS OF FERTILIZER DISTRIBUTION AND MARKETING IN SELECTED COUNTRIES OF WEST AFRICA

Item	Ghana (55, 72)	Ivory Coast (57, 64)	Mali (21, 32)
Import Procedures	Ghana Fertilizer Company, Limited (GFC).	Private importers.	Through gov't tender, imports handled by Society of Agricultural Credit and Rural Equipment (SCAER).
Marketing Channels	GFC warehouses to: regional warehouses, distributing company stores, farmers' association/or extension officer, farmers.	Private importers to development companies, village retailers, co-op union, and farmers.	SCAER central warehouse to operations, through extension agents to farmers.
Logistics Transport	GFC contracts with Volta Lake Transport Co. to Yapei and with private truck and railroad.	Private transport by rail and truck.	Pooled by SCAER to operations.
Storage	GFC warehouses and warehouses previously operated by the Ministry of Agriculture.	Private facilities.	SCAER owns central and regional warehouses. Operations own village level warehouses.
Pricing	Fixed by govt. in each zone (Zone 1, 2, 3).	Free but upper limit fixed as agreement between govt. and fertilizer industry.	Fixed.
Subsidies	Granted for certain crops and locations through proposal of National Fertilizer Committee (NFC).	Administered by SIVENG (app. 45% exfactory cost).	Granted at state level.
Credit	Loans are made to farmer organizations rather than to individuals.	Easy to obtain through credit institution and fertilizer trade.	Easy to obtain inside "operations."

APPENDIX G - CONTINUED
SOME CHARACTERISTICS OF FERTILIZER DISTRIBUTION AND MARKETING
IN SELECTED COUNTRIES OF WEST AFRICA

Item	Mauritania (36)	Niger (21, 34)	Nigeria (76, 83)
Import Procedures	Through govt. tender and donation.	Through govt. tender, c.i.f. State warehouses.	Through govt. tender, c.i.f. State warehouse and from fertilizer factory.
Marketing Channels	National warehouse--assisted by two firms: ARIDIS and SOGEA.	Credit and Cooperatives Union of Niger (UNCC) warehouse to Agricultural Service and cooperatives.	Private estates and companies, sales agents, and government agencies and stores.
Logistics Transport	Agricultural Service transport.	UNCC transport.	From State warehouse to village agent by govt. transport. Subsidy granted private transport 5 tons and over.
Storage	Agricultural Service warehouse.	UNCC warehouses to cooperatives' warehouses.	State-owned stores: central warehouses, district depots, side depots.
Pricing	Free except for irrigated rice.	Fixed.	Uniform fixed retail price within State (deviation State to State, 25% max).
Subsidies	Granted at State level.	Granted at State level.	Granted at State level (approx. 50% c.i.f. price, excluding cost of govt. admi.).
Credit	Through crop production projects.	Farmers easily obtain credit through cooperatives at interest rate of 3 - 4%.	Agricultural Development Bank to farmers. Difficult for small farmers to obtain.

APPENDIX - CONTINUED
SOME CHARACTERISTICS OF FERTILIZER DISTRIBUTION AND MARKETING IN SELECTED COUNTRIES OF WEST AFRICA

Item	Senegal (31)	Togo (19)	Upper Volta (21, 33)
Import Procedures	Production, selected and limited imports handled by SSEPC.	Through govt., by National Office of Fertilizer and Production Means (ONEM).	Imports handled by gov't. controlled French Textile Development Company (CFDT).
Marketing Channels	Port-warehouse and SIES factory to cooperatives (through ONCAD, except for cotton through SODEFITEX, and for rice through SAED).	Regional Society of Management and Rural Development to Togo (SORAD), directly to farmers.	CFDT, Regional Development Organizations (ORD).
Logistics Transport	ONCAD transport and private contract.	From SORAD warehouse at Lome--by rail to Parlime, Blitta, Aneho and by trucks to village in 50 kg bags.	CFDT and ORD's.
Storage	Factory/port warehouse, regional storage, inner district storage, cooperative storage.	SORAD storage network is assisted by FAO Fertilizer Project and Center fo Construction and Housing (CCL).	CFDT warehouses and ORD warehouse.
Pricing	Fixed at same level throughout the country.	Uniformly fixed throughout country.	Fixed.
Subsidies	Granted at State level (approx. 45% of c.i.f. of Dakar Port).	Granted at State level (approx. 50% of c.i.f. price).	Granted at State level (approx. 72% of actual cost).
Credit	Easy to obtain through cooperative.	Easy to obtain at 5% of interest.	Credit to farmers is granted through ORD at 5.5% interest.

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