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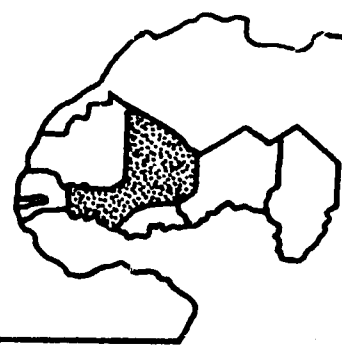

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER IFDC

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by West Africa Study Team
International Fertilizer Development Center

Volume I–Regional Overview
Volume II–Senegal
Volume III–Mali
Volume IV–Upper Volta
Volume V–Niger
Volume VI–Chad
Volume VII–Mauritania

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER
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PREFACE

A series of severe droughts in the late 1960's and early 1970's greatly reduced agricultural production in the Sahelian countries of west Africa. The human suffering during that time led to an international focus on the region in terms of food aid and development assistance.

The U.S. Agency for International Development (USAID) was aware of the contribution of fertilizers to food production and the limited fertilizer use in this region. Thus, USAID requested the International Fertilizer Development Center to determine the current capacity and potential of the Sahelian region to produce, market, and use fertilizers. This series of documents is a result of that assessment. Published and unpublished literature was obtained in each country and from international development agencies. Field level interviews were also conducted.

Principal team members were Ray B. Diamond (team leader), Donald R. Waggoner, and Kham Thanh Pham from IFDC along with Hans Braun on loan from FAO. Many other members of the IFDC staff contributed greatly to the report. Bernard Raistrick (consultant from the United Kingdom) and Travis P. Hignett (consultant from the United States) assisted in preliminary collection and analysis of data before the field visits. Josiah Royce (USAID, REDSO/WA) assisted in data gathering during field visits. Appreciation is expressed to representatives of national agencies, USAID, and other international organizations for assistance.

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ABBREVIATIONS USED IN THIS REPORT

FERTILIZERS

N . . . . . Nitrogen
P . . . . . Phosphorus
P_2O_5 . . . . . Phosphate
K . . . . . Potassium
K_2O . . . . . Potash
S . . . . . Sulfur
B . . . . . Boron
B_2O_3 . . . . . Borate

Fertilizer Formula–% of N-P_2O_5-K_2O by Weight

AS . . . . . Ammonium Sulfate (21-0-0)
DAP . . . . . Diammonium Phosphate (18-46-0)
KCl . . . . . Potassium Chloride (0-0-60)
KS . . . . . Potassium Sulfate (0-0-50)
PR . . . . . Phosphate Rock
SSP . . . . . Single Superphosphate (0-20-0)
TSP . . . . . Triple Superphosphate (0-45-0)
Urea . . . . . Urea (45-0-0 to 46-0-0)

MEASURES

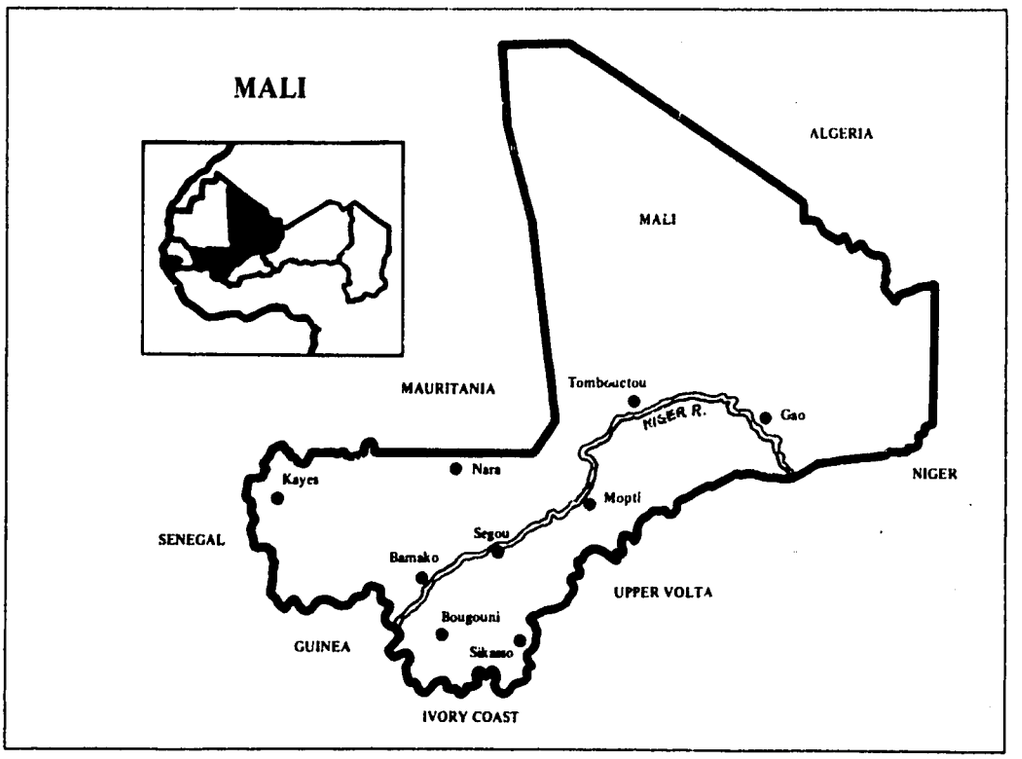
ha . . . . . hectare (2.47 acres)
kg . . . . . kilogram (1 pound = 0.454 kg)
km . . . . . kilometer (1 mile = 1.61 km)
mm . . . . . millimeter (1 inch = 25.4 mm)
mt . . . . . metric ton (2,204 pounds = 1,000 kg)
% . . . . . percent

ECONOMIC AND MONETARY

c.i.f. . . . . cost, insurance, and freight
FM . . . . . Mali Franc (US $1 = 450 FM)
f.o.b. . . . . free on board
GDP . . . . . gross domestic product

GOVERNMENTAL AND INTERNATIONAL AGENCIES

CMLN . . . . . Military Committee for National Liberation
GERDAT . . . . . Study and Research Group for Development of Tropical Agronomy
FAC . . . . . Development Aid Agency of the French Government (Fonds d'Aide et Cooperation)
FAO . . . . . Food and Agriculture Organization
FED . . . . . European Development Fund
GOM . . . . . Government of Mali
IBRD . . . . . International Bank for Reconstruction and Development
IFAC . . . . . French Research Institute for Overseas Fruits
IFAGRARIA . . . . . Italian Industrial and Financial Organization for the Progress of Agriculture
IFDC . . . . . International Fertilizer Development Center
IRAT . . . . . Research Institute for Tropical Agriculture
IRCT . . . . . Research Institute for Cotton and Textile Fibers
IRHO . . . . . Research Institute for Oil and Oil Crops
OPAM . . . . . Office of Agricultural Products of Mali
SCAER . . . . . Society of Agricultural Credit and Rural Equipment
SOMIEX . . . . . Malian Import-Export Society
SONAREM . . . . . State Company in Mineral Resource Exploitation
USAID . . . . . United States Agency for International Development



SUMMARY OF FINDINGS

1. The series of droughts in the late 1960's and early 1970's drastically reduced cereal (the staple food) production in Mali.

2. Cereal imports reached 432,000 mt in 1974 and demand in 1975 was likely 300,000 mt greater than production.

3. Average cereal demand is projected to increase by 30,000 mt/yr between 1975 and 1980 and 37,000 mt/yr between 1980 and 1985. Increased urban demand will account for about 25% of the increases.

4. Cereal deficit could reach 450,000 mt in 1980 and 635,000 mt in 1985 if production is not increased.

5. Mali is conducting a number of integrated rural development and crop production projects. The principal projects are "Operations" Peanut and Food Crops; South (cotton); Mils; Rice-Mopti; and Rice-Segou and Office of Niger.

6. Some constraints on production are low levels of use of fertilizer, mechanization, improved seed, and other improved technology and generally unfavorable fertilizer/crop prices.

7. Agronomic research shows consistent cereal responses to N and P and responses to S under continuous intensive cultivation. No general response to K has been reported.

8. Very little agronomic work has been done on farmers' fields, and much more is needed. It appears that fertilization with N and P is desirable, but S and K only on a selected basis.

9. Tilemsi Valley PR gives satisfactory crop response but needs more evaluation to define the economics of its use.

10. Estimated fertilizer nutrient consumption in 1976 is 8,000 to 10,000 mt (5 kg/ha) and projected to reach about 18,000 and 27,000 mt in 1980 and 1985, respectively. Two-thirds of nutrient use is for cotton and projected to decrease to 50% by 1985.

11. The projected increase in nutrient use for cereals could increase cereal production to meet 75 and 90% of increased urban demand for cereals in 1980 and 1985, respectively.

12. The projected increase in nutrient use for cereal could provide a savings in foreign exchange of $3.1 million/year in 1980 even with importation of all fertilizer nutrients.

13. Transportation network appears adequate for moving increased quantities of fertilizer to the more populated areas in the near future if adequate maintenance is performed. But improved or new roads are likely needed in new production areas.

14. Phosphate ore deposits of 20 million mt exist in Tilemsi Valley. No other potential fertilizer raw materials are known to exist in Mali.

15. Estimated cost of domestic ground PR in bags at Gao is $38 to $44/mt or $103 to $109/mt delivered at Bamako.

16. Establishing a bulk-blending plant at Sikasso, importing fertilizer materials, and blending mixed grades could save more than $800,000/year by 1980 in foreign exchange over importing the mixed grades.

17. Establishing even a minimum size SSP plant in Mali would result in increasing cost by $150-300/mt of P_2O_5 (depending on operating level) over importing TSP or DAP at Bamako.

RECOMMENDATIONS

1. Initiate a study of the effect of public policies for price stabilization and equalization for agricultural inputs and crops on regional and national economies.

2. Conduct an in-depth analysis of social costs and benefits from expanding land area in production as compared with increasing productivity per unit of land.

3. Conduct a study to assess the status and needs of extension, credit, and crop marketing institutions.

4. Conduct a study to identify ways to improve agricultural statistical reporting.

5. Begin a concentrated soil fertility project in liaison with current research and extension groups designed to obtain relevant information for crop response to fertilizer nutrients including PR on small- and medium-sized farms.

6. Establish a PR mining and grinding facility and begin using Tilemsi Valley PR for direct application.

7. Establish a bulk-blending facility either at Bobo-Dioulasso in cooperation with Upper Volta or at Sikasso.

INTRODUCTION

Mali, with a population of 5.7 million and area of 1.2 million km^2, is one of the largest and poorest countries of western Africa. It is a landlocked country located between 11° to 26^oN latitude and 13^oW and 5^oE longitude. Mali is bounded on the north by Algeria; on the west by Mauritania and Senegal; on the south by Guinea, Ivory Coast, and Upper Volta; and on the east by Niger. The principal outlets to the sea are Dakar, Senegal, and Abidjan, Ivory Coast. Each route is about 1200 km from Bamako, the capital city of Mali with a population of 200,000 in 1975.

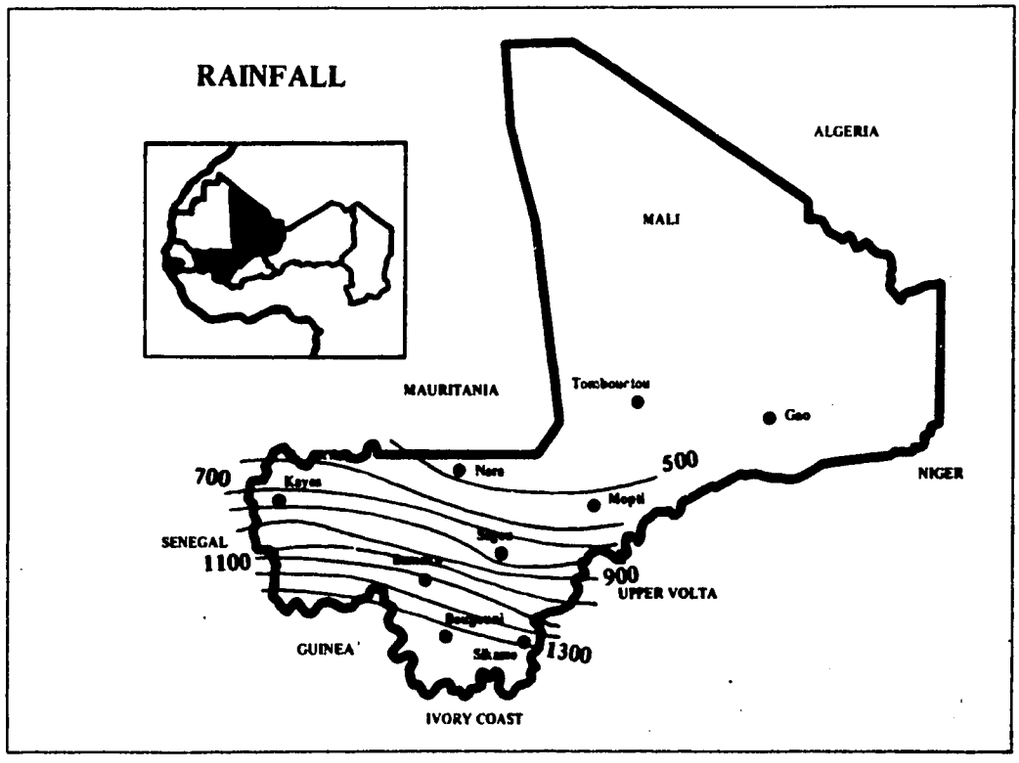
Physical Characteristics

The country lies in Saharan, Sahelian, Sudanian and Guinean ecological zones. The northern 44% of the country is barren desert with virtually no habitation. Another 27% of the country receives between 250 and 500 mm of rainfall/yr. The southern 29% has rainfall ranging from 500 to 1,500 mm/yr. In the extreme south rainfall occurs between May and October with the maximum in July and September.

Soils in the cropped area of Mali are primarily classed as ferruginous tropical and hydromorphic. Soils of the southern part of the country are mostly ferruginous tropical and have been developed on schist or sandstone. These soils are generally sandy, low in organic matter, and often have crust outcroppings and shallow depth. In the southernmost area, soils are generally deeper. The hydromorphic soils are formed on flood plains and in depressions. They are generally higher in clay and organic matter content.

Political Characteristics

Mali achieved independence from France in 1960. Initially, Mali was organized as a Republic with a President as Head of State, designated



by the National Assembly. Executive power was vested in the President who appointed his Vice President and Council of Ministers. Legislative power resided with the National Assembly which was charged with approving the national budget.

The constitution was abrogated by the Military Committee for National Liberation (CMLN) in November 1968 which replaced it with a "Fundamental Law" establishing government by decree. In April 1974, the Head of State and leader of the military government proposed a new constitution and return to civilian rule by 1976. The new constitution called for a republican form of government with an executive, judicial, and legislative assembly. One political party was authorized.

Cultural Characteristics

The ethnicity of Mali is composed of 43% Mande; 20% Fulani; 15% Senufu; 8% Sarahole; 6% Tuareg; 6% Songhai and 2% others (1). The official language is French with Bambara being a major trade language. Ninety percent of the population is Moslem. Most of the population is subsistence farmers and herdsmen.

Economic Characteristics

Mali's 1974 Gross Domestic Product (GDP) was $456 million with per capita income $81 per person (2). Agriculture contributed 43% of GDP in 1972 and provided employment for more than 90% of the population. During the drought, this sector suffered a 30% cattle stock loss, a 30% decline in fresh fish production, and significant declines in food crop output (about 35% for cereals). This reduced agricultural output forced Mali to rely on imported cereals to meet domestic consumption needs. Cereal imports totaled 288,000 tons in 1973 and 432,000 tons in 1974.

The industrial sector fared much better than the agricultural sector during the drought period. Although a decline was experienced in processing in those plants directly related to the agricultural sector (cotton gins, groundnut oil mills, etc.), general industry output increased during the drought period. Development in the industrial sector is encouraged by the government's investment code which offers incentives such as tax free privileges for 5-10 years for those organizations prepared to invest in certain areas of interest to the government.

Mali's financial position is becoming increasingly precarious. Mali's balance of trade deficit, which totaled $60 million in 1973, more than doubled in 1974 (2). Imports increased from $117 million in 1973 to $180 million in 1974, while exports increased from $57 million to $59 million over the same period. Much of the growing deficit is drought related. Food crop yields have been insufficient to meet domestic consumption requirements thus requiring imported food grains. Also, the price of peanuts and cotton, both major export commodities, fell.

The government's financial situation, which recorded mild deficits in the early 1970's, has continued to deteriorate. The deficit for 1974 was $17.3 million. The growing deficit is attributable to the drought, which adversely affected the domestic tax base. Also, growth in current expenditures increased at a rate of approximately 11% per annum since 1970. Current expenditures totaled $75.3 million in 1974.

POPULATION AND FOOD NEEDS

Population

The estimated population in Mali in 1975 was about 5.7 million (table 1). The overall population growth rate is currently estimated at 2.3% and is expected to increase to 3.0% by 1985 (3). Significant regional differences in population growth rates exist. Population in urban areas is increasing at a rate more than twice that of rural areas.

The estimated distribution of population by region is shown in table 2. The Gao region is the least populated with an average density of 0.8 persons/km^2. Density is only 12-13 persons/km^2 even in the most densely populated regions--Segou, Sikasso, and Mopti. Average density for the entire country is 4 persons/km^2.

Total Food Requirements

Foods requirement projections are based on FAO data (3). Food requirements were projected through 1990 using two methods (tables 3 and 4).

One projection (L) assumes that average per capita private consumption levels will remain constant and projects increases based on population changes. The other projection (H)

Table 1. Estimated Population and Growth Rates in Mali (3)

Section of Population	1970	1975	1980	1985	1990
Total, 1,000 persons	5,047	5,668	6,488	7,520	8,753
Rural, % of total	87.9	86.5	85.0	83.4	81.5
Growth rate preceding 5 years					
Total, %/year	-	2.3	2.7	3.0	3.1
Rural, %/year	-	2.0	2.4	2.6	2.7
Urban, %/year	-	4.6	4.9	5.2	5.3
Growth rate of active population preceding 5 years					
Total, %/year	-	1.9	2.3	2.6	2.7
Rural, %/year	-	1.5	1.8	2.1	2.1
Urban, %/year	-	5.5	6.0	6.0	5.8

Table 2. Estimated Distribution of Population of Mali by Region, 1972 (4)

Region	Population 1,000	Density, No./km^2
Bamako	940	10.4
Gao	620	0.8
Kayes	730	6.0
Mopti	1,070	12.0
Segou	770	13.6
Sikasso	930	12.2
	5,060	4.1

Table 3. Estimated Levels of Food Consumption for Mali (3)

Commodity	Estimated Consumption, Kg/Capita/Year[a]				
	1970	1975	1980	1985	1990
Millet/sorghum	143.1	144.1	144.4	144.0	142.9
Rice	14.9	15.5	16.0	16.6	17.2
Wheat	3.6	3.8	4.1	4.4	4.7
Maize	17.4	17.6	17.8	18.0	18.1
Sweet potato	12.1	12.3	12.4	12.6	12.8
Cassava	15.3	15.6	15.9	16.2	16.5
Beans/peas	4.6	4.6	4.7	4.8	4.8
Vegetables	18.8	19.4	20.0	20.5	21.1
Peanut	10.3	10.5	10.6	10.8	10.9
Sugar	5.0	5.3	5.7	6.1	6.5
Fruit	5.7	5.9	6.0	6.2	6.3
Meat	18.8	19.8	20.8	21.6	22.8
Fish	10.3	10.8	11.1	11.8	12.3

[a]Figures for 1970 are estimated actual consumption and others are based upon an elasticity of demand.

includes elasticity of demand changes based upon a 1% annual increase in per capita food expenditures and consequent preference changes in food purchases. Neither projection, however, differs much in magnitude from the other.

Estimated per capita food consumption in 1970 and the projections for the period 1975 to 1990 are shown in table 3. Per capita consumption of millet/sorghum, sweet potato, cassava, and legumes is projected to remain relatively constant. Per capita consumption of rice, vegetables, and meat is projected to increase slightly.

Estimated (H) and (L) projections for total food requirements to 1990 are shown in table 4. Total demand for millet/sorghum is projected to increase by 29% in 1980; 50% in 1985; and 73% in 1990 over 1970 levels. Increased requirements for major cereals over 1975 requirements are shown in table 5. The average annual increase needed to meet food demand is 30,000 mt/year between 1975 to 1980 and 37,000 mt/year between 1980 to 1985.

Urban Food Requirements

A distinction between urban and rural food demand is important in analyzing potential food demand. Subsistence type farming accounts for much of the agricultural production in Mali. With large areas of potentially cultivatable land out of production, subsistence type farming can expand to meet growing rural food demand. In contrast, urban food requirements must be supplied through some form of commercial agriculture (domestic or imports). In Mali, the urban sector population is growing at twice the rate of the rural population.

Urban food requirements were derived for major cereals using FAO (H) per capita consumption projections and urban population growth rates (table 6). Urban food demand for millet, sorghum, maize, and rice is expected to increase at a rate of 7,600 mt/year between 1975 and 1980 and at a rate of 10,000 mt/year between 1980 and 1985. This is the element requiring an intensive effort to supply food requirements.

Table 4. Estimated Food Requirements in Mali, 1975-1990 (3)

Commodity	Estimated Food Requirements 1,000 mt[a]								
	1970	1975		1980		1985		1990	
	L	L	H	L	H	L	H	L	H
Millet/sorghum	722.0	810.8	816.7	928.1	936.9	1075.8	1082.8	1252.2	1250.9
Rice	75.0	84.2	87.6	96.4	104.1	111.7	125.1	130.1	150.8
Wheat	18.0	20.2	21.7	23.1	26.6	26.8	33.1	31.2	41.2
Maize	88.0	98.8	99.8	113.1	115.4	131.1	135.0	152.6	158.7
Sweet potato	61.0	68.5	69.5	78.4	80.8	90.9	95.0	105.8	112.1
Cassava	77.0	86.5	88.2	99.0	102.9	114.7	121.6	133.5	144.2
Beans/peas	23.0	25.8	26.2	29.6	30.5	34.3	35.8	39.9	42.3
Vegetables	95.0	106.7	109.9	122.1	129.4	141.5	154.2	164.8	184.4
Peanut	52.0	58.4	59.3	66.8	68.8	77.5	80.9	90.2	95.6
Sugar	25.0	28.0	30.0	32.2	36.9	37.3	45.9	43.4	57.3
Fruit	29.0	32.6	33.4	37.3	39.1	43.2	46.4	50.3	55.3
Meat	95.0	107.6	111.9	122.2	134.6	141.5	163.8	164.8	200.0
Fish	52.0	58.4	61.1	66.8	73.1	77.5	88.6	90.2	107.9

[a]L is based upon per capita consumption at estimated level of 1970 and H is per capita consumption based upon elasticity of demand.

Table 5. Estimated Increased Requirements for Major Cereals Over 1975, Mali[a]

Food	1980	1985	1990
	- - - - - - -1,000 mt - - - - -		
Millet/sorghum	120.2	266.1	434.2
Maize	15.6	35.2	58.9
Rice	16.5	37.5	63.2

[a]Based upon FAO projections considering elasticity of demand.

Table 6. Estimated Urban Requirements for Major Cereals in Mali, 1975 to 1990[a]

Food	1975	1980	1985	1990
	- - - - - - - 1,000 mt- - - - - - -			
Millet/sorghum	110.3	140.5	179.7	231.4
Maize	13.5	17.3	22.4	29.4
Rice	11.8	15.6	20.8	27.9

[a]Based upon FAO projections considering elasticity of demand and assuming urban consumption pattern similar to national pattern.

Cereal Supply Situation

Mali has the potential to be self-sufficient in the production of millet, sorghum, maize, and rice, although recently it has depended on growing cereal imports to supply domestic food demand. The changing cereal supply situation for selected years between 1961 and 1974 is portrayed in table 7.

The per capita supply of cereals has ranged from 174 to 235 kg/person since 1970 averaging 199 kg/person for the period. Adjustment for milling of rice and the typical losses gives an average annual supply of cereals of 170 kg/person which is reasonably close to the FAO estimated consumption. Statistics for individual years are erratic. However, the trend since 1970 is toward increasing imports. Cereal imports, including grain relief aid, increased to 432,000 mt in 1974.

Reports from Mali indicate that production in 1975 has again reached 1961-65 levels. Total population, however, has increased 30% over this same period. Thus, to achieve self-sufficiency at per capita consumption levels attained in the early 1960's, production would need to be increased by about 300,000 mt over 1975 production levels.

Table 7. Cereal Supply Situation in Mali (5, 6)

Crop	1961-65[a]	1970-71[a]	1972	1973[b]	1974[b]
	Cereal Production, 1,000 mt				
Total	1,037	988	859	709	891
Wheat	4	4	4	4	4
Rice paddy	170	154	195	100	200
Maize	80	80	60	80	87
Millet	782	750	600	525	600
Other	1	-	-	-	-
	Cereal Imports, 1,000 mt				
Total	11	47	73	288	432
Wheat	9	17	17	21	21
Rice paddy	-	15	30	46	65
Maize	-	3	5	25	46
Other	2	13	21	67	100
Grain Relief Aid	-	-	-	129	200
	Cereal Exports, 1,000 mt				
Total	2	-	-	-	-
Rice paddy	2	-	-	-	-
	Total Supply, 1,000 mt				
Total	1,046	1,035	932	997	1,323
Wheat	13	21	21	25	25
Rice paddy	168	169	225	146	265
Maize	80	83	65	105	133
Millet	782	750	600	525	600
Other	3	13	21	67	100
Grain Relief Aid	-	-	-	129	200
	Per capita supply, kg/person				
Total	241	201	174	182	235

[a]Average annual rate.
[b]Includes grain relief aid.

If cereal yields average 650 kg/ha, an additional 462,000 ha under present technology would need to be brought into cereal production. As an alternative, 30,000 mt of fertilizer nutrients, assuming a response of 10 mt of grain/mt of nutrient, could also produce the needed 300,000 mt of additional grain.

The estimated c.i.f. cost of imported sorghum at Bamako was 78,000 FM/mt or 23.4 billion FM for 300,000 mt. The imported cost of nutrients is considered to be 260,000 FM/mt or 7.8 billion FM for 30,000 mt. While fertilizer use, without the appropriate cultural practices, would not produce a 10 to 1 yield response, the difference in foreign exchange requirements between imported food and imported nutrients (23.4 billion FM versus 7.8 billion FM) makes increased fertilizer use an attractive alternative in augmenting cereal supply.

It appears that Mali can benefit most by increasing crop production through both expanding cropland area and increasing productivity per unit of land. An in-depth analysis of these alternatives would be a useful guide to the government. The study would analyze the social costs and benefits from facilitating a more rapid expansion of area used for agricultural production as compared to increasing productivity by expanded use of improved technology including use of fertilizer.

It is anticipated that cultivated area will be expanded somewhat as a result of increased rural population. The cultivated area in Mali can increase through either subsistence or commercial types of farming. Subsistence farming feeds only the immediate population and leaves little surplus for export outside the immediate area. In order to increase agricultural production per worker, greater use of animal traction, fertilizer, and improved cultural practices will be required.

FOOD PRODUCTION

Agriculture contributes nearly half of Mali's GDP and almost all of the country's foreign exchange earnings. Total food and agricultural production grew rather consistently between 1961 and 1971 (table 8). However, per capita production of both has declined since 1967. Since 1971, total production and per capita production have declined.

Agricultural Policy Institutions

Agricultural development is the responsibility of the Ministry of Rural Development. The Ministry plans development projects, coordinates and controls agricultural research and education, and operates government-owned farms. Agricultural research and technical assistance are largely accomplished by members of Study and Research Group for Development of Tropical Agronomy (GERDAT).

The Ministry's Department of Production controls production development projects called "Operations" through its Agricultural Service. Other Services are responsible for irrigation, machinery, animals, and forestry.

In the 1960's, Mali went through a stage of cooperative organization. A lack of success of the cooperative movement brought about the creation of "Operations" in 1969 to conduct crop production projects. "Operations" are administrative entities with a high degree of management and financial autonomy. They cover zones ranging in size from a section of an administrative Region to all or part of several Regions. In 1975 there were 19

"Operations" including Office of Niger which is considered a special "Operation" (7).

"Operations" originally were primarily concerned with a single crop within their zone of control; but their responsibility has expanded to include all major crops of participating farmers.

"Operations" typically provide a variety of support services needed by farmers, including material inputs, credit, extension, and crop collection. "Operations" essentially act as agents for other agencies in supplying material inputs and credit and in crop collection. Funds accrue from commissions for these services, from the national government, and funding agencies such as IBRD, FAC, FED, USAID, and others.

Sale of Farm Inputs

The sale of farm inputs and credit is made by the Society of Agricultural Credit and Rural Equipment (SCAER) which is under the control of Ministry of Finance and Trade. SCAER acts more as a central supply organization for "Operations" which themselves deliver inputs to farmers, collect cash and credit repayments, and hold stocks of inputs on behalf of SCAER. SCAER obtains its capital from levies on cotton and peanuts purchased by "Operations," grants from aid agencies, operational revenues, and rediscounting money provided by the central bank.

Sale of Farm Outputs

Two other agencies controlled by the Ministry of Finance and Trade have monopolies for purchasing farm output. The Malian Import-Export Society (SOMIEX) is the sole purchaser of peanuts outside "Operations" areas and sole exporter of peanuts and cotton. SOMIEX imports a wide range of products and sells at a standard price throughout the country. The Office of Agricultural Products of Mali (OPAM) has monopolies for local marketing of cereals and import and export of cereals and fruits. In recent years its major role has been to distribute foreign relief supplies of cereals.

Table 8. Indices of Population and Agricultural and Food Production, Mali (5)

	Indices[a]				
Year	Population	Food Production	Agricultural Production	Per Capita Food Production	Per Capita Agricultural Production
1961	96	94	93	98	97
1962	98	101	101	103	103
1963	100	100	101	100	101
1964	102	100	101	98	99
1965	104	105	104	100	101
1966	107	105	105	98	98
1967	109	109	110	100	101
1968	112	102	103	91	93
1969	114	113	115	99	100
1970	117	106	109	90	93
1971	120	114	118	95	98
1972	123	91	95	74	77
1973	126	72	75	57	60
1974	129	93	96	72	74

[a]World--1963 = 100.

Table 9. Producer Prices in Mali (FM/kg)

Year	Rice	Millet/Sorghum	Peanut	Cotton
1967	18	16	24	40
1968	18	18	30	40
1969	25	18	30	45
1970	25	18	30	50
1971	25	18	30	50
1972	25	20	30	50
1973	25	26	30	-
1974	40	30	40	-
1975	40	32	40	75

Agricultural Credit

Credit is extended only to farmers participating in an "Operation"--other sales are for cash. Representatives from "Operations" prepare loan documents but are not responsible for loan recovery. There is no classical guarantee of loans, only the technical guarantee through farmer groups supervised by "Operations." SCAER charges no interest but charges a 3% commission on all sales and pays 5% commission to "Operations" as sales agents. Delinquent loan repayments by "Operations" in 1975 were: 3% for cotton and 35% for peanuts. Rice (Mopti and Segou) "Operations" were completely repaid.

FED and FAC reduced financial subsidies to SCAER in 1974. Its financial deficit in 1975 was 3.08 billion FM. Even though sales prices of all agricultural inputs were increased by 35% in the 1975-76 season, the residual deficit was still 200 to 250 million FM at the beginning of 1976.

Agricultural Prices

Mali has traditionally maintained low producer prices for farm produce and generally maintained less subsidy on agricultural inputs than neighboring countries. Official producer prices in recent years are shown in table 9. Between 1971 and 1975, millet/sorghum, rice, peanut, and cotton prices have increased by 78, 60, 33, and 50%, respectively. Most of the price increases occurred in 1974. However, in 1975 prices of most inputs for agricultural production increased by 35%. Since 1970, the prices of seeders, cultivators, and carts have increased by 35, 73, and 102%, respectively. Prices of oxen, donkeys, and horses have increased 46, 253, and 133%, respectively.

Fertilizer Costs and Prices

Cost of fertilizer to the government, prices to farmers, and rates of subsidy for the last three years are shown in table 10. Cost of fertilizer for the 1976-77 season is considerably below the 1974 cost of fertilizer and the anticipated rate of subsidy for 1976 is very low. The effect of analysis of product upon cost of nutrients is shown in the comparison of SSP and TSP. Subsidy is low on each. But because TSP has a higher nutrient analysis than SSP, P_2O_5 costs the farmer 39% more in SSP compared with TSP.

A detailed description of fourth quarter 1975 fertilizer prices, overseas freight rates, and cost of

Table 10. Fertilizer Cost and Rate of Subsidy in Mali, 1974-1976[a]

Material	Year 1974	1975	1976
	- - - Material Cost, FM/kg c.i.f. Bamako - - -		
Urea	217	245	99
SSP	71	99	63
TSP	161	189	111
DAP	184	204	136
19-31-0-12S	177	205	136
	- - - -Farmer Price for Material, FM/kg- - - -		
Urea	63	85	92
SSP	40	55	60
TSP	74	100	110
DAP	40	55	95
19-31-0-12S	55	75	110
	- - - -Farmer Price for Nutrients, FM/kg - - -		
Urea	137	185	200
SSP	222	306	333
TSP	161	217	239
DAP	62	86	148
19-31-0-12S	110	150	220
	- - - -Rate of Subsidy, % of Actual Cost - - -		
Urea	71	65	7
SSP	44	44	5
TSP	54	47	1
DAP	78	73	30
19-31-0-12S	69	63	19

[a]SCAER, Bamako, 1976.

fertilizer delivered to major markets is contained in the Regional Overview (Volume I).

Total costs of the commonly used fertilizers in Mali are shown in table 11. The f.o.b. port cost ranges from 57 to 81% of total cost of fertilizers. Transportation costs from the port of Dakar to Bamako account for 8 to 24% of the delivered cost to Bamako. Transportation costs are greatest for SSP--the lowest analysis fertilizer.

Cost:price ratios based upon anticipated fertilizer cost and farmer prices for 1976 for various crop and fertilizer combinations are shown in table 12. Except for cotton, the ratios are 4.5 to 8.3 for subsidized fertilizer and 5.4 to 8.8 for actual cost of fertilizer. These ratios (except cotton) are too high to encourage use of fertilizer in Mali. As a comparison, the ratios are between 1 and 2 in Senegal.

Crop Production

Mali has 14.2 million ha of potential cropland but only about 12% of this area is cropped (3). The estimated number of land holdings in Mali is 440,000 with an average size of 3.8 ha. About 81% of the potential cropland receives more than 300 mm of rainfall/yr and 52% receives more than 600 mm/yr.

Table 11. Composition of Fertilizer Cost in Mali, 1974[a]

Cost, Item	Urea	SSP	TSP	DAP	19-31-0
	- - - -Fertilizer Cost, FM/kg- - - -				
f.o.b. price, port	200	54	144	167	160
Transport to Bamako	17	17	17	17	17
c.i.f. Bamako	217	71	161	184	177
Transport to interior	12	12	12	12	12
Administration charges	7	4	9	4	6
Financial	8	5	10	5	7
Sellers commission	3	2	4	2	3
Total cost	247	94	196	207	205
	- - - Freight Cost (Port to Bamako), % c.i.f. Bamako - - -				
Transport	8	24	11	9	10
	- f.o.b. Port Cost, % of Total Cost-				
f.o.b. port cost	81	57	73	81	78

[a]SCAER, Bamako, 1976.

Table 12. Cost:Price Ratios for Crops and Forms of Fertilizer, Subsidized and Unsubsidized, Mali, 1976

Crop	Fertilizer to Supply Recommended Rates	Cost:Price Ratio	
		Subsidized Fertilizer	Unsubsidized Fertilizer
Millet/sorghum	Urea + DAP	5.2	6.7
	Cotton mix	6.9	8.5
Rice	Urea + DAP	4.5	5.4
Peanut	SSP	8.3	8.8
	Cotton mix	5.5	6.8
Cotton	Cotton mix	2.9	3.6

The estimated distribution of crops by regions is shown in table 13. Millet and sorghum are grown on 60% of the cropped area. Seventy percent of all rice is grown in Mopti and Segou Regions. Peanuts are grown in the four western Regions; and 60% of cotton is grown in Sikasso Region.

Trends in crop production are shown in table 14. Total annual production in 1974 was larger than in 1961-65 for rice paddy, peanuts, cotton, sugarcane, and maize. Total annual cereals production, however, was lower in 1974 than in 1961-65. Cropped area, yields, and production for two periods--the early 1960's and early 1970's--are shown in table 15. In cereals, lower yields caused total production to decline even though the cropped area increased. The area and total production of peanuts and cotton, major export crops, increased, although the effect of droughts upon peanut yields can be seen.

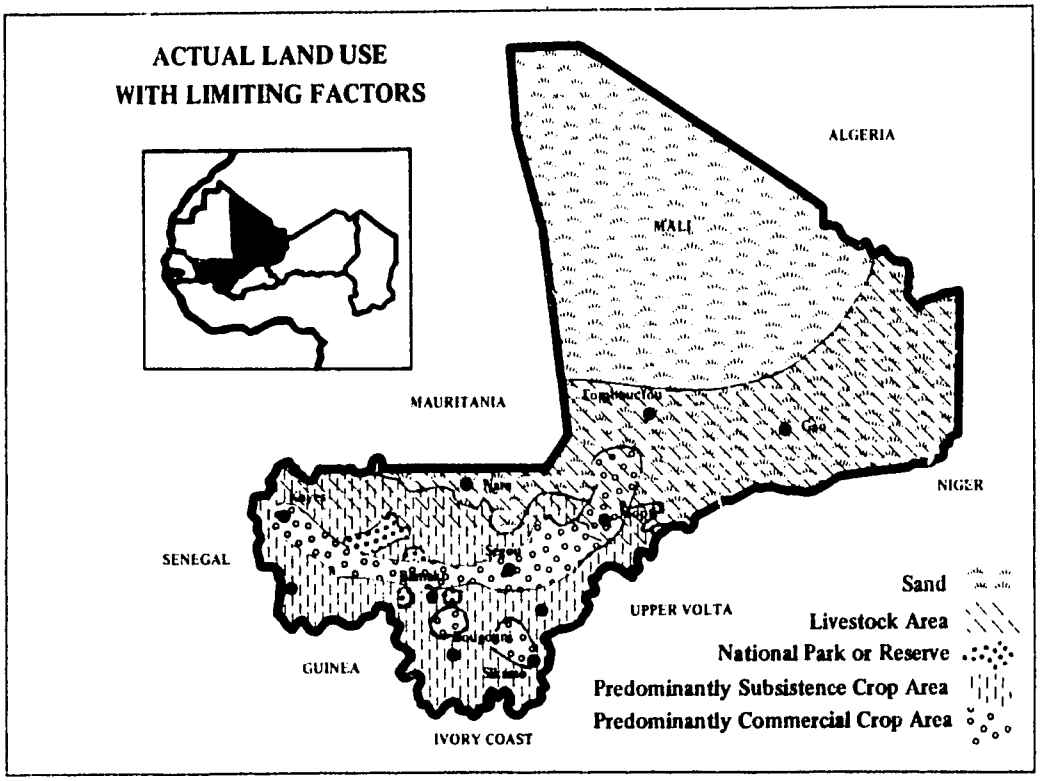


Table 13. Estimated Distribution of Cropped Areas in Mali (7, 8)

Region	Millet/ Sorghum	Rice	Maize	Peanut	Cotton	Total
	-1,000 ha-					
Kayes	140	10	33	79	-	262
Bamako	195	8	10	67	18	298
Sikasso	217	15	32	63	40	367
Segou	176	85	4	57	5	327
Mopti	249	58	2	5	-	314
Gao	23	24	1	-	-	48
Total	1,000	200	82	271	63	1,616
	% Total Cropped Area					
Kayes	8.2	0.6	1.9	4.6	-	15.3
Bamako	11.5	0.5	0.6	3.9	1.0	17.5
Sikasso	13.8	0.9	1.9	3.7	2.4	21.7
Segou	10.4	5.0	0.2	3.4	0.3	19.3
Mopti	14.6	3.4	0.1	0.3	-	18.4
Gao	1.4	1.4	0.1	-	-	2.9
Total	58.9	11.8	4.8	15.9	3.7	95.1
Other Crops						4.9
						100.0

Table 14. Trends of Crop Production, Mali (5)

Crop	Production, 1,000 mt					
	1961-65	1970	1971	1972	1973	1974
Cereals, total	1,037	822	1,154	859	709	891
Wheat	4	4	4	4	4	4
Rice paddy	170	138	170	195	100	200
Maize	80	80	80	60	80	87
Millet	782	600	900	600	525	600
Roots and tubers	227	222	231	180	180	180
Sweet potatoes	67	67	71	60	60	60
Cassava	160	155	160	120	120	120
Pulses	22	24	24	18	18	19
Peanut in shell	136	158	152	150	100	190
Seed cotton	22	59	67	62	44	59
Cottonseed	13.9	37	40	34	25	35
Cotton lint	7.7	22	25	26	18	22
Onion, dry	3	4	4	3	3	3
Sugarcane	25	61	72	80	80	80
Tobacco leaves	0.6	0.15	0.3	0.2	0.2	0.2
Natural rubber	0.5	1.2	1.2	1	1	1.1

Patterns of Land Use

In "Operation Peanut and Food Crops," which covers most of the Sudan zone of Kayes, Bamako, and Segou Regions, it is estimated that there are 105,000 holdings with an average size of 3.45 ha (9). The family size is 7 to 11 people. Land in this area is cleared and cropped for 5 to 7 years, then left to fallow for 15 to 20 years (10). Goats, sheep and poultry are found on most farms in this area.

In 1974-1975, the average size of a peanut holding was 1 ha, producing an average yield of 1,028 kg/ha (yield outside the "Operation" averaged 489 kg/ha). About 34% of peanut area in the "Operation" was fertilized and planted with fungicide-treated seed. The average area of a cereal holding was 2.4 ha and the average yield was 623 kg/ha. Almost no cereal was fertilized but 35% of planted seed was treated.

In "Operation Mils," located in the southern Mopti Region, a survey of 2 *cercles* found the family size of 9 persons (54% active) cultivating an average of 4.55 to 5.05 ha with 91 to 93% of the land in cereals (11). Use of animal traction is very low (1 work animal/400 to 600 ha). Most of the cereal was millet with average yield of 452 to 493 kg/ha. Average yields of millet receiving fertilizer on demonstration farms in 1973 in Bankass and Koro with 1 ha plots were 741 and 1,136 kg/ha, respectively (12).

In "Operation South," located mainly in the Sikasso Region, 57% of the holdings had animal traction, 70% received fertilizer and 91% received at least three pesticide sprayings (13). The average area of a cotton holding was 1.05 ha and average yield was 883 kg of seed cotton/ha. Millet, sorghum or maize followed cotton on about 31,600 ha or 50% of the area in cotton. Less than 2% was fertilized with chemical fertilizer but about 35% received animal manure.

The Office of Niger was established in 1932 to implement an irrigation development scheme in the central Niger Delta (Segou Region). Through 1973, 53,000 ha has been developed. Irrigated rice is grown on 40,000 ha (14). Land is owned by the state. About 3,000 ha is cultivated

Table 15. Cropped Area, Yield, and Production in Mali (5)

Crop	Area Harvested 1,000 ha	Yield kg/ha	Production 1,000 mt
		-1961-1965	
Cereals, total	1,383	749	1,037
Wheat	3	1,485	4
Rice paddy	175	970	170
Maize	74	1,091	80
Millet	1,132	691	782
Sweet potatoes	5	13,400	67
Cassava	11	14,815	160
Pulses	14	1,571	22
Peanut in shell	168	813	136
Seed cotton	38	563	22
Tomatoes	1	3,999	5
Onion, dry	<1	33,280	3
Sugarcane	<1	56,818	25
Tobacco leaves	<1	822	0.6
		-1970-1974	
Cereals, total	1,436	618	887
Wheat	3	1,333	4
Rice paddy	169	953	161
Maize	94	819	77
Millet	1,170	551	645
Sweet potatoes	8	8,154	64
Cassava	10	13,500	135
Peanut in shell	251	602	150
Seed cotton	72	808	58.2
Tomatoes	1.5	3,664	5.4
Onion, dry	<1	14,280	3.4
Sugarcane	1.4	54,833	74.6
Tobacco leaves	<1	1,393	0.21

with tractors by the Office, the remainder by tenant farmers. In 1972-73 there were 35,000 people in 114 villages, 3,390 family holdings, and a cultivated area of 30,450 ha. This gives an average of 10.3 persons per average holding of 9 ha.

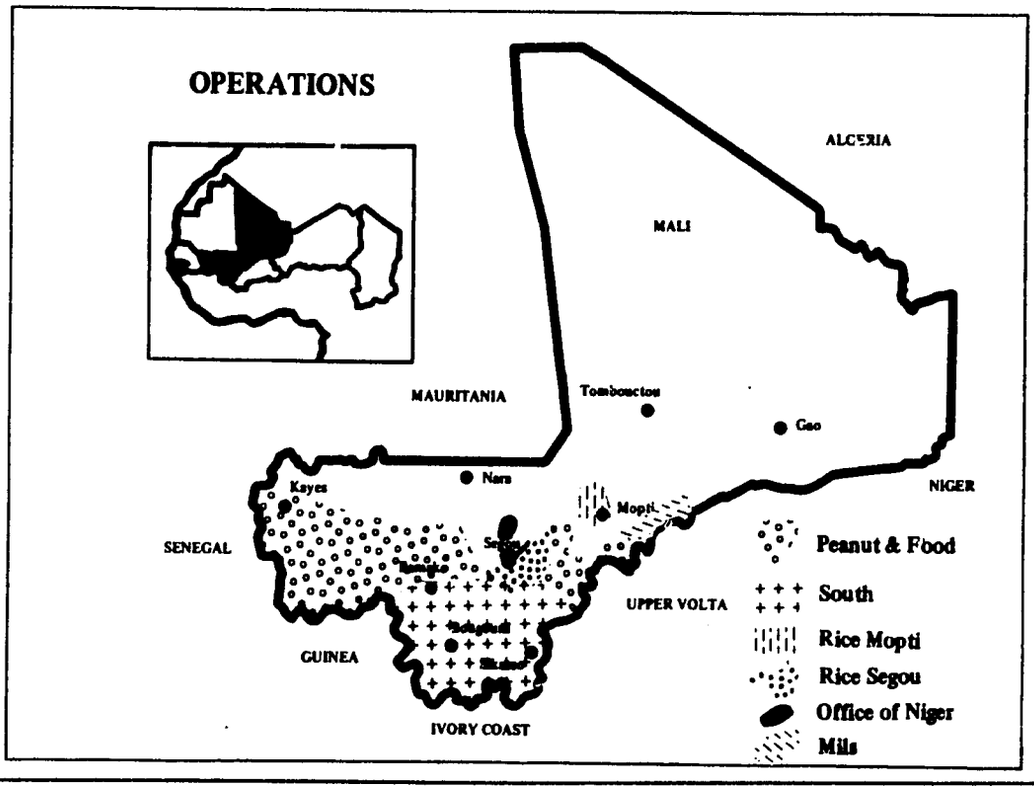
The Office deals with individual farmers, but plans to organize cooperatives. After moving into the area, tenant farmers receive dwellings, livestock, and farm implements which are repaid in 3 annual payments. Tenants also pay "in kind" 400 kg of paddy rice/ha for depreciation and maintenance of installations and supervisory services provided by the Office. Farmers must sell rice in excess of family food and seed needs to the Office.

The average worker cultivated 3.7 ha of rice for a production of 6.52 mt of rice for a net income of 84,100 FM or 512 FM/working day. This compares favorably with the guaranteed wage for farm labor of 296 FM.

Crop Production Projects

As previously mentioned, crop production projects are primarily conducted through administrative units called "Operations." A summary of cropped areas within "Operations" or other projects in 1975 and planned by 1980 are shown in table 16.

The major "Operations" now functioning are:



1. Operation Peanut and Food Crops - The zone of coverage is a strip west to east in the Sudan ecological zone of Kayes, Bamako, and Segou Regions. In the 1974-75 season, advisory and supply services were provided for 107,000 ha of peanuts and 252,000 ha of cereals. In addition, 100,000 ha of peanuts was grown by nonparticipating farmers within the boundaries of the "Operation."
2. Operation South - The zone of coverage is the area south of a line from Bamako to Segou. In the 1974-75 campaign, 63,000 ha of cotton was grown and 32,000 ha of cereal with supervised services. A total of 470,000 ha of cereals was cultivated in the area. The cotton area is planned to expand to 120,000 ha by 1980.
3. Operation Mils - Approximately the southeastern half of Mopti Region is covered by this operation. Cereals are grown on about 90% of the cropped land. By 1980, supervised agricultural services for 250,000 ha of cereals are expected to be provided.
4. Office of Niger - The Office is a specialized type of operation in that it is a developed irrigation project on government owned land. The area contains 53,000 ha of cultivated land with 40,000 ha of rice. By 1980 planned expansion will give 50,000 ha rice, 4,000 ha sugarcane, and 4,000 ha of cotton.
5. Operation Rice (Mopti) - It covers an area of about 15,000 ha of rice and is planned to expand to 46,000 ha by 1980.
6. Operation Rice (Segou) - About 20,000 ha of rice is now grown and expansion to 60,000 ha is planned by 1980.

Several other smaller projects involve the production of cereals, including rice and vegetables, cotton, peanuts, tobacco, tea, and sugarcane.

Mali is also pursuing expansion of irrigated land on the delta for the immediate future. For longer term development, Mali hopes to construct the Selingue Dam on the Upper Niger and the Manantali Dam on the Senegal River as part of the Senegal River development scheme involving Mali, Senegal, and Mauritania.

Table 16. Summary of Cropped Areas Within Crop Production Projects in 1975 and Planned for 1980 (7)

Crop	Cropped Area (1,000 ha) 1975	1980
Major cereals	1,047	1,220
Rice	95	206
Peanut	144	235
Cotton	63	131
Kenaf	1	4
Sugarcane	1	6
Tobacco	1	3
Vegetables	2	3

AGRICULTURAL RESEARCH

Research in agriculture is the responsibility of the Direction of Research in the Institute of Rural Economy. Technical assistance is contracted with GERDAT. Members of this group are: Research Institute of Tropical Agronomy (IRAT), Research Institute of Cotton and Textile Fibers (IRCT), Research Institute of Oil and Oil Crops (IRHO), and French Research Institute for Overseas Fruits (IFAC).

Crop Response to Fertilizer

It is generally admitted that for small farmers to use fertilizers, the value of the last increment of yield increase must be twice the cost of fertilizer needed to produce the increased yield. This calculation is called the marginal "value:cost ratio."

In this report, average value: cost ratios are used to indicate the profitability of fertilizer use. When using average value:cost analysis, ratios somewhat greater than 2 would be necessary to provide an economic incentive to the farmer to adopt or increase the use of fertilizer.

The general fertilizer recommendations of research groups are shown in table 17.

Reports of IRAT (15, 16, 17, 18, 19) and IRCT research results (20, 21, 22, 23) were reviewed for suitable crop response data for regression analysis. Data for experiments in which there was a zero nutrient treatment and at least 2 positive nutrient rates were pooled and fit to a quadratic function. Optimum nutrient rates were determined for several cost:price ratios including those existing in the country for subsidized and unsubsidized fertilizer.

Montgomery (24) performed somewhat similar analysis for cereals and found value:cost ratios slightly greater than one for millet and sorghum at recommended levels of nutrients. However, he found that value:cost ratios for rice were 2.3 to 2.5 at recommended rates.

Millet--The analysis of millet response to N is shown in table 18. At a cost:price ratio of 5.2, the optimum N rate is 40 kg/ha (equivalent to the recommended rate). Yield response is 8.3 kg/kg of N and the value:cost ratio is 1.6; not high enough to encourage N use on millet. The cost:price ratio should be 3.5 or less to encourage N use for millet if the yield response function is reasonably accurate.

Table 17. Research Institute's General Fertilizer Recommendations in Mali, 1975

Crop		Recommended Nutrient Rates, kg/ha N	P_2O_5	K_2O	Remarks
Millet/sorghum		40	48	0	Urea + DAP
Maize		53	48	0	Urea + DAP
Rice (Rainfed)		40	48	0	Urea + DAP
(Irrigated)		54	24	0	Urea + DAP
Cowpea		0	13	0	+ Sulfur
	or	9	18	0	Cotton mix
Peanut		0	13	0	+ Sulfur
	or	9	18	0	Cotton mix
Cotton[a]		50	46	24	+S +B

[a]Revised to include K in 1976.

Experiments were conducted at Sotuba in 1974 and 1975 (15, 16) with maize, sorghum, and millet comparing no fertilizer with light dose (40 to 54 kg N/ha and 46 kg P_2O_5/ha) and heavy dose (64 to 108, 46 and 30 kg/ha of N, P_2O_5, and K_2O). Two varieties were used each year giving 4 observations for each crop. For millet, the light dose gave value:cost ratios greater than 2 in one year and about 1 the other year at existing prices. The added increment from the heavy dose resulted in the recovery of fertilizer cost in one of the 4 trials. At cost:price ratio of 3.5, the value:cost ratio was above 1.4 for the low dose in all trials.

Crop response data for fertilizer use on farms are very scarce. The 1973-74 Report of Operation Mils (18) contained comparisons of fertilizer (23 kg/ha of each N and P_2O_5) for local and improved varieties of millet from 3 demonstrations. Response of local varieties was 7 to 11 kg of grain per kg of nutrient. The yield with no fertilizer averaged 332 kg/ha. Responses of improved varieties were 7 to 18 kg of grain per kg of nutrient. The yield with no fertilizer averaged 483 kg/ha.

Table 18. Yield Response and Economics of N Fertilization of Millet, Mali[a]

Cost:Price Ratio	N Rate, kg/ha	Yield Increase kg/ha	kg/kg N	Value:Cost Ratio
	For Economically Optimum N Levels			
3.5	51	380	7.5	2.1
4.0	48	368	7.7	1.9
5.2	40	332	8.3	1.6
6.9	29	265	9.2	1.3
8.5	19	189	9.9	1.2
	For Recommended N Level			
5.2	41	337	8.2	1.6

[a]Yield response equation: $Y = 11.41\ N - 0.0777\ N^2$.

Sorghum--Sorghum trials at Sotuba (mentioned above) resulted in value: cost ratios of 3.0, 1.5, 1.1, and 0.3 for the low dose at present prices. Cost of additional fertilizer for the high dose was recovered in only one case at existing prices. With a cost:price ratio of 3.5, the value: cost ratio was greater than 1.7 in 3 of 4 trials.

Average yields of 14 regional trials and 8 trials conducted at the N'Tarla-M'Pesoba Station for sorghum and maize were similar with and without applied K_2O.

Results of 8 trials at the experiment station showed average yields of 1,647 and 1,792 kg/ha without and with applied S, respectively. However, only 1 of 13 regional trials gave a significant response to S.

Maize--In the trials at Sotuba, maize response to the light dose of fertilizer gave a value:cost ratio greater than 2 in 3 of 4 trials at current prices and greater than 1.8 in all trials for a cost:price ratio of 3.5. For the heavy dose, value:cost ratios were 0.6, 1.2, 1.7, and 4.6 at existing prices.

Rice--Response of rice to N and return to fertilizer are shown in table 19. The highest rate for the input data was 80 kg of N/ha. At the recommended N rate of 54 kg/ha and the cost:price ratio for subsidized fertilizer, yield response was 20.5 kg of rice/kg of N for a value:cost ratio of 4.6. The value:cost ratio was 4.3 for 80 kg N/ha.

Table 20 shows a response of 14.2 kg of rice/kg of P_2O_5 and a value:cost ratio of 3.2 at the recommended rate of 24 kg/ha using subsidized fertilizer prices. The value:cost ratio is 2.2 at the optimum rate of P_2O_5 (40 kg/ha) using unsubsidized fertilizer prices (cost:price ratio of 5.4). Producer prices for rice appear adequate if yield response data to N and P_2O_5 are accurate.

A study by French Office of Foreign Affairs in Charge of Cooperation (14) summarized results of demonstrations in the Office of Niger as yielding 300 to 400 kg of rice/ha for 23 kg of N/ha. This gives 13 to 17 kg of paddy rice/kg of N.

Peanuts--In 7 experiments conducted by IRCT at N'Tarla-M'Pesoba Station, peanut yields were 1,555 and 1,895 kg/ha without and with applied P, respectively. These experiments gave no response to applied K or S.

Cotton--The data for the response of cotton to P_2O_5 came from 6 experi-

Table 19. Yield Response and Economics of N Fertilization of Rice, Mali[a]

Cost:Price Ratio	N Rate, kg/ha	Yield Increase kg/ha	Yield Increase kg/kg N	Value:Cost Ratio
	For Economically Optimum N Levels			
3.5	227	2,999	13.2	3.8
4.5	216	2,942	13.6	3.0
5.4	205	2,888	14.1	2.6
	For Recommended N Level			
4.5	54	1,106	20.5	4.6
	For Highest Rate in Analysis			
4.5	80	1,551	19.4	4.3

[a]Yield response equation: $Y = 22.78\ N - 0.0424\ N^2$.

Table 20. Yield Response and Economics of P Fertilization of Rice, Mali[a]

Cost:Price Ratio	N Rate, kg/ha	Yield Increase kg/ha	Yield Increase kg/kg N	Value:Cost Ratio
	For Economically Optimum P_2O_5 Levels			
3.5	46	496	10.8	3.1
4.5	43	484	11.3	2.5
5.4	40	469	11.7	2.2
	For Recommended P_2O_5 Level			
4.5	24	342	14.2	3.2

[a]Yield response equation: $Y = 18.8\ P - 0.1584\ P^2$.

ments in which the lowest positive rate of P_2O_5 was 80 kg/ha and there was little additional response to higher rates. This is inadequate to derive a response equation worthy of analysis. However, mean yield increase at 80 kg P_2O_5/ha was 6.0 kg seed cotton/kg of P_2O_5. This gives a value:cost ratio of 2.1 at the present cost:price ratio of 2.9. At a cost: price ratio of 2.0 the value:cost ratio equals 3.0.

In 1974 IRCT conducted 5 trials on farmers' fields to determine response to various fertilizer rates. Results shown in table 21 indicate a yield response of 3.8 to 11.4 kg seed cotton/kg of nutrient (average of 6.1) for the first increment of fertilizer consisting of 27 and 47 kg/ha of N and P_2O_5, respectively. The average value:cost ratio was 2.1, with a range from 1.3 to 3.9. Applying an additional 23 kg of N/ha gave a response of 3.5 to 10.3 kg seed cotton/kg of N (average of 6.1). Value:cost ratios for the additional N were from 1.2 to 3.6, with an average of 2.1.

Response to K in the presence of adequate N and P ranged from none to 5.2 kg of seed cotton/kg of K_2O. The average value:cost ratio was 1.0. The cost of K_2O was recovered in only 2 of 5 trials.

A review of IRCT reports shows that average yields for 9 experiments conducted at N'Tarla-M'Pesoba Station were 2,296 and 2,348 kg/ha for treatments of minus and plus K_2O, respectively. Average yields in 32 regional trials were 1,623 and 1,654 kg/ha, without and with K_2O, respectively.

The above 9 trials gave average yields of 1,798 and 2,348 kg/ha of seed cotton, without and with S, respectively. However, 6 other regional trials gave similar yields with and without S.

Summary--These data indicate that N and P will give yield responses for millet, sorghum, maize, rice, and cotton. Responses to P are found for peanuts. There is no evidence of general crop responses to K. Yield responses to S are obtained only under experiment station conditions under continuous intensive cultivation. Otherwise, S responses appear insignificant. Possible responses to K and S need to be monitored by a consistent series of trials at the farm level.

Crop Response to Phosphate Rock (PR)

Some of the most extensive and useful experiments with PR in west Africa have been conducted in Mali (15, 16, 26, 27). Tilemsi Valley

Table 21. Yield Response and Economics of Fertilizer Use for Cotton, Mali (23)

Location	Incremental Yield Increase, kg/ha			Incremental Yield Increase, kg/kg Nutrient			Value:Cost Ratio for Each Increment[b]		
	27-47-0[a]	50-47-0[a]	50-47-30[a]	27-47-0[a]	50-47-0[a]	50-47-30[a]	24-47-0[a]	50-47-0[a]	50-47-30[a]
N'Tarla	841	80	-	11.4	3.5	-	3.9	1.2	-
Bla Dougolo	461	131	78	6.2	5.7	2.6	2.1	2.0	0.9
Ouelessebougou	332	153	155	4.5	6.7	5.2	1.6	2.3	1.8
Samanko	279	237	41	3.8	10.3	1.4	1.3	3.6	0.5
Bougouni	345	105	146	4.7	4.6	4.9	1.6	1.6	1.7
Average	452	141	84	6.1	6.2	2.8	2.1	2.1	1.0

[a] $N-P_2O_5-K_2O$ in kg/ha.
[b] Cost:price ratio = 2.9.

(Mali) and Taiba (Senegal) PR were compared in cereal-peanut rotation trials at Sotuba, Kita, and Seno, approximately located on the 1,100, 1,000, and 550 mm isohyets, respectively. Four series of 5-year rotations were conducted at Sotuba. Only two complete series were conducted at Kita; experiments were discontinued after 3 years at Seno. Results of the trials are summarized in table 22. Similar results were obtained at Sotuba and Kita.

About 40 kg of grain plus 10 kg of peanuts were produced per kg of P_2O_5 during 5 years from the low rate of Tilemsi PR. The higher rate of each Tilemsi and Taiba PR produced about 30 kg of grain plus 7 kg of peanuts/kg of P_2O_5 during 5 years. At both locations, only about 10% of the total cereal response was derived from the last crop (fifth year after application of PR), indicating that the supply was being depleted. However, the last crop contributed between 25 to 35% of total cereal response for the higher rate of application.

At Seno (with lower rainfall) about 65% as much cereal was produced per kg of P_2O_5 as at the other 2 locations. This may be due to either lower availability of PR in soil receiving less rainfall or to other factors limiting plant growth. Unfortunately, without soluble P included in the experiments, the cause of lower crop response at Seno can only be speculative.

One 5-year rotation experiment alternating cereal and peanut has been completed at Sotuba with comparisons of PR, TSP, and PR plus annual supplements of TSP (table 23).

Yield response was about 2,000 kg/ha for PR and TSP alone. Little additional yield was gained by applying TSP with PR in the first year. Also, response to TSP and the high rate of PR were similar for the second

Table 22. Summary of Crop Response to Phosphate Rock in Mali

P_2O_5 Source[a]	P_2O_5 Rate, kg/ha	Yield Increase, kg/kg P_2O_5				Portion of Cereal Response in Last Crop, %
		First 3 Years		5 Years		
		Cereal (2)[b]	Peanut (1)	Cereal (3)	Peanut (2)	
		4 Series at Sotuba[c]				
Tilemsi	75-80	32.0	4.6	36.8	9.0	13.0
Tilemsi	150-160	22.4	2.1	29.0	5.4	22.8
Taiba	150-160	21.0	0.9	33.1	6.6	36.6
		2 Series at Kita[c]				
Tilemsi	80	38.0	9.2	41.8	10.2	9.1
Tilemsi	160	24.5	5.3	31.6	7.1	22.5
Taiba	160	23.2	5.4	31.1	7.6	25.4
		1 Series at Seno[c]				
Tilemsi	80	20.8	5.9	-	-	-
Tilemsi	160	18.2	5.0	-	-	-
Taiba	160	14.2	3.4	-	-	-

[a]All P_2O_5 was applied in the year prior to the first crop. Tilemsi PR from Tamaguelelt ground to 60% minus 0.2 mm (P_2O_5 = 30%).
[b]Numeral in parenthesis is the number of times the crop was grown in the series.
[c]Annual rainfall: Sotuba - 641 to 1,100 mm with 3 years greater than 1,000 mm.
Kita - 787 to 965 mm with 2 years greater than 900 mm.
Seno - 529, 402, and 382 mm.

Table 23. Crop Response to Phosphate Rock and TSP at Sotuba, Mali (16)

Applied P_2O_5 From PR, kg/ha	Yield Increase From PR, kg/ha		Additional Yield Increase From Annual TSP, kg/ha[a]	
	Cereal	Peanut	Cereal	Peanut
	- - - - - - - - - - - First Crop- - - - - - - - - - -			
0	-	-	2,060	143
80 Tilemsi	1,702	56	645	138
160 Tilemsi	2,391	134	30	-
240 Tilemsi	1,752	-	307	43
160 Taiba	2,026	-	488	270
	- - - - - - - - - - -Second Crop- - - - - - - - - - -			
0	-	-	1,091	32
80 Tilemsi	483	160	830	176
160 Tilemsi	733	219	475	194
240 Tilemsi	1,285	263	159	193
160 Taiba	949	299	400	-
	- - - - - - - - - - - Third Crop- - - - - - - - - - -			
0	-	-	2,624	-
80 Tilemsi	485	-	3,614	-
160 Tilemsi	1,260	-	3,061	-
240 Tilemsi	2,283	-	2,070	-
160 Taiba	2,003	-	2,623	-
	- - - - - - - - - - -5-Year Total - - - - - - - - - -			
0	-	-	5,775	175
80 Tilemsi	2,670	216	5,089	314
160 Tilemsi	4,384	353	3,566	194
240 Tilemsi	5,320	263	2,536	236
160 Taiba	4,978	299	3,511	270

[a]TSP applied at 45 kg of P_2O_5/ha annually.

cereal crop. However, response to TSP alone exceeded all rates of PR in the fifth year and supplemental TSP plus highest rates of PR gave yield increases about twice PR alone in the fifth year.

Yield response of peanuts to P_2O_5 was low (100 to 150 kg/ha/crop) for each rate of PR and for TSP. However, TSP in addition to PR gave another 100 to 150 kg/ha/crop.

Considering only the cereal production, the following results were encountered:

P_2O_5 kg/ha	Grain kg/kg P_2O_5
TSP (225)	25.7
Tilemsi (80)	33.4
Tilemsi (160)	27.4
Tilemsi (240)	22.2
Taiba (160)	31.1

Using the current crop prices and estimated cost of supplying P_2O_5 as PR and TSP, the greatest return above cost of P after 3 years came from 160 kg/ha of P_2O_5 with PR (table 24). After 5 years the treatment of 80 kg/ha of P_2O_5 from PR plus annual supplemental TSP gave the greatest return to fertilizer. Data from this

experiment are insufficient to clearly define the best phosphate fertilization practice but do show that Tilemsi Valley PR can be profitably used.

The data indicate that 160 kg/ha of P_2O_5 from the PR may be adequate for 2-3 years but responses may be obtained to supplemental P_2O_5 as PR or soluble P in succeeding years. Further study is needed to determine the optimum method of using indigenous PR. In particular, basal application of PR and supplemental low rates of soluble P should be investigated.

At Sikasso, maize, cotton and rice gave yield increases of 2,480, 1,401, and 801 kg/ha, respectively, to 160 kg of P_2O_5/ha as Tilemsi PR in the first 3 years of a rotation. Cotton response to Tilemsi PR was only 50% as good as to DAP when each was applied near time of seeding at a rate of 50 kg of P_2O_5/ha. However, without P application for maize or sorghum, following cotton, yield increases were similar where DAP and PR were applied the previous year.

Several tests have shown significant response of cereals, peanuts, and cotton to PR. Cereal and peanut response was good, even with rainfall less than 500 mm/yr. Suitable tests have not been conducted to determine the relative efficiency of Tilemsi PR in comparison with soluble P. No data were found on the effect of placement or incorporation of PR. Generally, the PR used was not identified well enough to determine if similar material was used in all experiments.

Table 24. Estimated Economics of Phosphate Rock and TSP Use at Sotuba, Mali

Applied P_2O_5					
Source	Rate, kg/ha	Cost of P_2O_5,[a] FM/ha	Increased Crop[b] Value, FM/ha	Return Above P_2O_5 Cost, FM/ha	Value:Cost Ratio
3 Year					
PR	80	12,160	78,560	66,400	6.46
PR	160	24,320	114,088	89,768	4.69
PR	240	36,480	107,704	71,224	2.95
TSP	135	29,565	106,552	76,987	3.60
PR + TSP	80 + 135	41,725	124,880	83,155	2.99
5 Year					
PR	80	12,160	94,080	81,920	7.74
PR	160	24,320	154,408	130,088	6.35
PR	240	36,480	180,760	144,280	4.96
TSP	225	49,275	191,800	142,525	3.89
PR + TSP	80 + 225	61,435	269,488	208,053	4.39

[a]Assumed cost of P_2O_5 is 152 and 219 FM/kg from PR and TSP, respectively.
[b]Assumed values of 32 and 40 FM/kg of cereal and peanut, respectively.

FERTILIZER USE AND POTENTIAL

Fertilizer Use

Apparent consumption of fertilizer nutrients based upon import data since 1964 is shown in table 25. Use of fertilizer increased steadily from 1964 through 1972.

Nutrients supplied by various types of fertilizer are shown in table 26. SSP is the only low analysis material contributing more than 10% of nutrient use. Practically no AS has been used since 1971. Table 26 also shows that 5,625 mt of the cotton mix was used in 1972 and none in 1973, which likely means this quantity actually was split over two years. A similar occurrence is shown for urea in 1973 and 1974. Thus, it appears that actual consumption of nutrients was about constant at 6,000 mt from 1972 through 1975.

Table 25. Estimated Nutrient Consumption in Mali (25, 28, 29)

	Nutrient Use, mt			
Year	N	P_2O_5	K_2O	Total
1964	25	63	-	88
1965	56	141	-	197
1966	86	221	-	307
1967	138	353	-	491
1968	218	567	18	803
1969	323	849	49	1,221
1970	693	1,797	57	2,547
1971	2,327	3,083	55	5,465
1972	3,171	4,061	83	7,315
1973	3,601	1,315	34	4,950
1974	1,376	2,761	451	4,588
1975	2,237	4,301	-	6,538
1976	3,618	4,756	1,506	9,880

Table 26. Apparent Consumption of Nutrients by Type of Fertilizer, 1971-1976, Mali (28, 29)

Fertilizer Type	1971	1972	1973	1974	1975	1976
	- - - - - - - - - -total nutrient use, mt - - - - - - - - -					
Urea	782	1,025	3,450	-	360	1,575
AS	567	21	32	32	-	-
SSP	525	399	1,008	347	1,050	840
TSP	-	-	-	21	23	23
DAP	3,510	130	422	422	640	1,280
18.5-31.5-0	-	5,625	-	3,312	4,465	150
10-10-20	-	10	-	-	-	12
14-14-14	-	-	6	4	-	-
6-20-10	36	36	-	-	-	-
13-23-12-7S	-	-	-	1	-	6,000
PS	45	65	23	350	-	-
PC	-	4	9	99	-	-
Total	5,465	7,315	4,950	4,588	6,538	9,880

Table 27. Estimated Nutrient Use by Crops, 1972-1975, Mali

Crop	Area Fertilized	Nutrient Rate			Nutrient Consumption		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
	1,000 ha	- - kg/ha - -			- - - - mt- - - -		
Cotton	44	40	48	-	1,750	2,100	-
Peanut	43	-	15	-	0	650	-
Rice	10	50	10	-	500	50	-
Cereals	8	25	12	-	200	100	-
Vegetables, tobacco, sugarcane	2	75	100	75	150	200	150
Total					2,600	3,100	150

Anticipated consumption in 1976 is about 10,000 mt of N, P_2O_5, plus K_2O. The cotton mix fertilizer accounts for an average of 60% of nutrients consumed in Mali. In addition, some urea is used for cotton. SCAER estimates that 66% of nutrient used in 1972 through 1975 was for cotton (table 27). About 10% was used for rice and peanuts.

Potential Fertilizer Use

Present cost:price ratios of fertilizer and crops are not favorable to promote fertilizer use, except possibly for cotton and rice (where it appears marginally favorable). Three things must be accomplished in Mali to significantly increase fertilizer use. They are:

Table 28. Estimated Potential Use of Fertilizer Nutrients, 1980 and 1985, Mali

Crop	Area Fertilized	Nutrient Rate			Nutrient Consumption		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
	1,000 ha	- - kg/ha- - -			- - - - - mt- - - - -		
	- - - - - - - - - - - - - - -1980 - - - - - - - - - - - - - -						
Cotton	100	40	46	12	4,000	4,600	1,200
Peanut	80	-	15	-	-	1,200	-
Rice	40	50	10	-	2,000	400	-
Maize, sorghum, millet	20	40	20	-	800	400	-
Sugarcane, tobacco, vegetables	10	100	100	100	1,000	1,000	1,000
Total	250				7,800	7,600	2,200
	- - - - - - - - - - - - - - -1985 - - - - - - - - - - - - - -						
Cotton	130	40	46	12	5,200	6,000	1,560
Peanut	100	-	15	-	-	1,500	-
Rice	80	50	10	-	4,000	800	-
Maize, sorghum, millet	40	40	20	10	1,600	800	400
Sugarcane, tobacco, vegetables	15	100	100	100	1,500	1,500	1,500
Total	365				12,300	10,600	3,460

1. Adjust cost:price ratios of fertilizer and crops to a favorable situation and assure readily available markets.

   Based upon the response functions obtained, a kg of nutrient should not cost more than 2.5 to 3.5 times the producer price for the crop. Value:cost ratios of greater than 2 on the last increment of fertilizer are often accepted as necessary for a farmer to use fertilizer.

2. Extension advisory service must be strengthened through training and support to provide greater service to growers.

3. Adequate financing must be provided and utilized by SCAER and "Operations" to procure larger quantities of agricultural inputs.

Fertilizer use will not increase without positive efforts by GOM to stimulate changes. If changes are made to create a favorable economic situation for fertilizer use, fertilizer use can reach levels shown in table 28 by 1980 and 1985. This could result in more than twice the 1975 fertilizer consumption by 1980 and adding nearly 10,000 mt additional between 1980 and 1985. The estimates of consumption of P_2O_5 for 1980 and 1985 are similar to those made by Klockner Industries (30). Even with the proposed changes, cotton and rice are expected to account for 50% and 25% respectively, of the total use by 1985.

FERTILIZER SUPPLY

SCAER is the official government organization which imports all fertilizers. Orders are made after each agricultural "Operation" submits requirements for the approaching season. Fertilizers are imported principally from Senegal (55%), France, Germany, Holland, and People's Republic of China. Imported fertilizers from overseas come through the ports of Abidjan or Dakar. Dakar fertilizers are transported by rail to Bamako, then by trucks to the warehouses of the "Operations." From Abidjan fertilizers are transported via rail and road or road directly to the warehouses of the "Operations," in southern Mali or to Bamako. About 90% of fertilizer used in Mali is distributed to farmers through "Operations."

Raw Materials for Fertilizers

A survey of possible fertilizer raw materials deposits in Mali is included in Appendix I.

Phosphate Rock (PR)--Deposits in Mali have been known to exist since 1927. There are known reserves of 20 million mt containing 27.5% P_2O_5; this represents 53% of the total reserves of PR. This deposit is located in the Tilemsi Valley northeast of Bourem with outcroppings near Tamaguelelt, Chanamaguel, Tin Hina, and Tin Belouki (31). The deposit consists of bone remains, coprolites, sand, and phosphate clay. The deposit at Tamaguelelt was studied by Klockner Industries in 1969 (30). Research showed that the rock could be upgraded to 31.5% P_2O_5 by simple manual methods (screening and hand picking). However, the use of the rock to make superphosphate was not economical at the time. The Liptako-Gourma Authority is resuming studies to better identify PR deposits.

Chemical analysis of material of the size 0.2 mm to 5.0 mm is (32):

P_2O_5---31.4%	MnO---0.35%
CaO----42.5%	TiO_2--0.15%
SiO_2---9.05%	Cl----0.09%
Fe_2O_3--3.6%	F-----3.02%
Al_2O_3--0.57%	

Known reserves near Tamaguelelt equal 11.4 million mt and are found mainly at three depths: 9.5 million mt at 15 m, 40,000 mt at 1-2 m, and 1.8 million mt at the surface.

A state-owned company, SONAREM, has responsibility for prospecting and developing the PR in Tilemsi Valley. Control of SONAREM, as well as negotiations with foreign exploitation companies for any oil or minerals, is the responsibility of the Directorate of Geology and Mines.

Lignite--Bituminous schist was discovered in the Bourem region at a depth of 50 to 70 m but it is of no practical interest (33). Lignite exists at depths of 80 to 200 m in the Bourem and Issaxsagen regions but layers are only 0.1 to 2.9 m thick and contain only 20 to 40% volatile material.

Petroleum--Investigations for petroleum have been undertaken in the three sedimentary basins of Taoudenni, Grahen of Gao, and Iullemeden. SONAREM has drilled two wells on the eastern border but found no oil. Favorable formations were found at 1,600 and 2,000 m in Iullemeden basin and a potential exists to drill again. Texaco has rights to drill in the Akartol-Taoudenni areas and Gulf and Sun Oil have rights in the southeastern Sahel area east of Gao.

Production and Plans

Small amounts of PR for agronomic research work are ground at Markala. Two small grinding mills can produce about 3,000 mt/yr, provided trucks are available to haul rock from mine to barges for transport to grinding mills at Markala. These grinding mills represent the only fertilizer production capacity in Mali at the present time.

Recent estimates by SONAREM indicate that 600,000,000 FM or $1.3 million investment would be required for a mining and grinding operation capable of producing 25,000 mt/yr of ground, bagged PR for direct application. The ex-factory price would be 27,000 FM/mt or $58.50/mt. Plans are to bring rock to Bourem or Gao for grinding. The ground and bagged rock would be barged to Mopti and Markala. Since barge transport is seasonal, another approach could be to stockpile unground rock at Bourem or Gao and transport to Mopti or Markala for grinding when river transport is available. The small grinding units already available could be used to grind the small amounts required for agriculture in the Gao area. A detailed engineering-economic study would be required before deciding which option to use. German aid for financing this project is being considered.

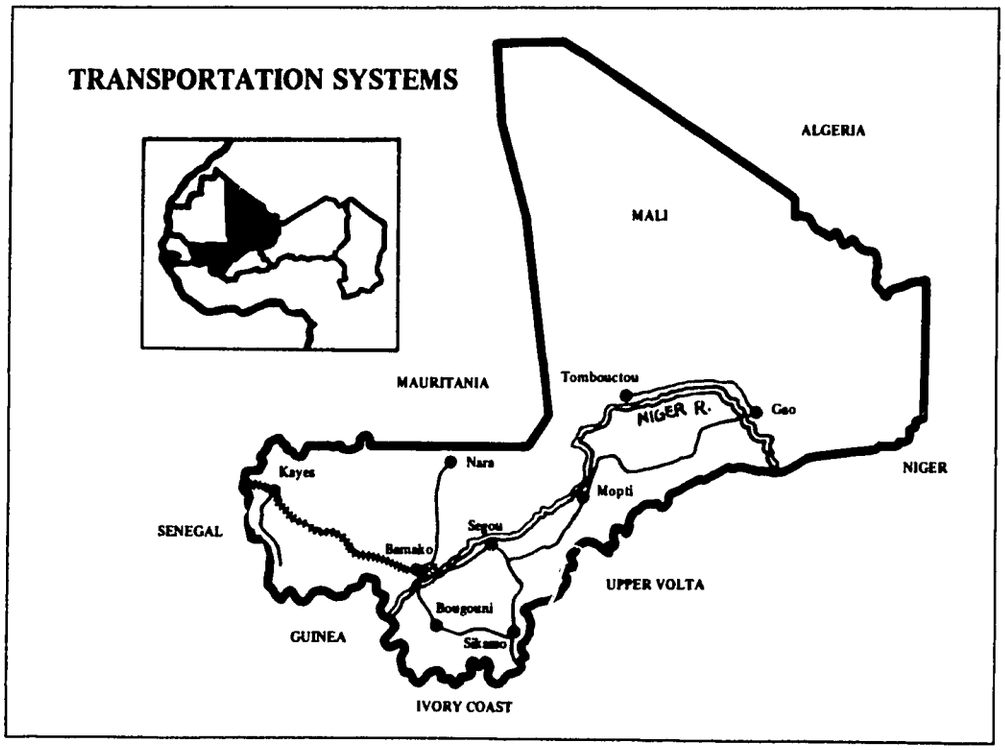
TRANSPORTATION

Because extensive regions in northern Mali are desert, the major economic centers and most of the population are located in the south and along the Niger River. There is little traffic to the sparsely populated north.

International Transportation

The principal international access routes are via Dakar, Senegal, and Abidjan, Ivory Coast. Other routes which have been used to import goods include the ports of Cotonou (Benin), Oran (Algeria), Monrovia (Liberia), Conakry (Guinea), and San Pedro (Ivory Coast).

To date, the import/export gate most frequently used by Mali in accessing world markets has been via the port of Dakar, Senegal. Traffic through Dakar in recent years has averaged about 100,000 mt per annum accounting for 50% of Mali's agri-



cultural exports and 50% of its imports. The distance from Bamako to Dakar is approximately 1,200 km by way of the Senegal-Mali railway.

The operation of the railway is such that Senegal locomotives pull the train within the boundaries of Senegal and Mali locomotives are used within the boundaries of Mali.

The route via Dakar is the fastest and most reliable international route available to Bamako. Still, an insufficient number of freight cars, problems in spare parts and maintenance, and traffic management problems create bottleneck problems during periods of heavy freight movement (34, 35). Transport costs are about $66/mt for bagged fertilizer (30 FM/kg) via the Dakar route.

A detailed description of overseas freight rates to west Africa ports from major fertilizer exporting countries and associated transport costs to market centers is included in the Regional Overview (Volume I). Mali traffic through Abidjan totals about 60,000 mt/year, 50% for imports and 50% for exports. The route from Abidjan may be either by rail and road or by road. The rail and road route involves rail transportation from Abidjan to Bobo-Dioulasso (640 km), transshipment, and truck transport to Bamako. Total distance from Bamako to Abidjan is about 1,200 km. The estimated freight rate using this route is $86/mt for bagged fertilizer and the trip time is 3-4 days. Abidjan may also be reached by road from Bamako. The distance and transportation costs are similar to those of the rail and road route. Both modes (rail and road) out of Abidjan are being used.

Other international routes available but infrequently used in accessing world markets are the ports of Buchannan (100 km from Bamako), Conarky (1,000 km from Bamako), and San Pedro (1,080 km from Bamako).

Gao, some 1,200 km northeast of Bamako and 1,500 km from nearest outlet to the sea, is the primary market center in northeastern Mali. Gao has access to several ports including Cotonou, Lagos, Lome, Tema, Abidjan, Dakar, and Oran (Algeria).

The most direct route which takes 5-6 days is through the port of Cotonou; a rail line extends from Cotonou to Parakou (400 km), and an all weather road from Parakou to Gao via Niamey (1,100 km). Transport cost for fertilizers in 50 kg bags is about $120/mt.

A route of potential value to Mali in accessing world markets will be available following the completion of two dams near Saint Louis, Senegal, and Manantali, Mali, on the Senegal River. The dams, when completed, will render the Senegal River navigable to Kayes, approximately 900 km from Saint Louis, Senegal.

Domestic Transportation

"The internal transportation system of Mali is fairly extensive and serves most of the country adequately" (34). The physical infrastructure consists of about 13,000 km of roads, of which nearly 5,000 km are suitable for year-round travel. The remainder are secondary gravel roads and tracks. Gravel and earth roads are passable in the dry season (November-May), but may be closed during the intense rain season.

Nearly 600 km of the Senegal-Mali railway is in Mali. However, the rail line is primarily used in international trade and is of little value in intracountry transportation.

Mali also has about 1,650 km of inland waterways. Dependence upon water transportation in shipping fertilizers within Mali is not recommended. This mode is poorly developed and the rivers are only seasonally navigable.

Transportation in Mali is heavily oriented toward road movement. The key market centers are linked with Bamako, the central point for imports and exports, by hard surfaced roads that permit year-round use. Most of the key market centers in southwestern Mali may be reached in 2 days from Bamako. Thus, the transportation infrastructure which often suffers from a lack of maintenance, can move fertilizer within the populated regions of Mali, regardless of the season. However, potential new agricultural areas with lower population densities require new investments in transportation infrastructure to more farm inputs and outputs.

The major companies of the transport sector are government owned (Mali Railways, a trucking company which carries about 20% of total road freight, and the largest navigation company). The key elements of transport regulation are the centralization of imports and exports. All domestic road haulage must be handled through government-administered freight offices.

Estimated transportation costs for fertilizer distribution to key market centers are shown in table 29.

Table 29. Estimated Transportation Costs Between Several Locations in Mali

From	To	Distance	Estimated Transportation Cost[a]
		(kilometers)	$/mt of bagged fertilizer
Bamako	Bougouni	163	12.98
Bamako	Segou	125	10.83
Bamako	Sikasso	397	26.25
Bamako	Koutiala	396	26.19
Bamako	Mopti	634	39.69
Bamako	Gao	1,222	73.27
Gao	Mopti	617	38.72
Gao	Mopti (barge)		25.47
Gao	Tombouctou	424	27.78
Kayes	Kenieba	304	20.97
Sikasso	Mopti	465	30.10

[a]Includes handling estimated at $3.74/mt.

ALTERNATE SUPPLY SCHEMES

Agronomic tests using ground Tilemsi PR have been going on since 1962 with generally favorable results. Also, empirical activity tests by IFDC have shown that the material should be acceptable for direct application.

Since Malian agriculture is already using approximately 4,000 mt/yr of P_2O_5 (equivalent to about 13,000 mt of PR), installation of the grinding facility as outlined in the Fertilizer Supply section appears to be justified. The mining and grinding operation could provide impetus for more detailed and systematic prospecting of the deposits than has been the case in the past (31).

The proposed IFDC fertilizer supply scheme for Mali consists of:

1. Surface mine Tilemsi Valley PR, grind, and bag for direct application.
2. Import fertilizer materials in 1 mt bags and blend and/or rebag in 50 to 75 kg bags at Sikasso to supply southern and eastern Mali.
3. Continue to import fertilizer materials and NPK fertilizers via Dakar to supply Bamako Region and western Mali.

Manufacturing Prospects

In 1969 a techno-economic study of exploitation of this deposit was made by Klockner Industries (30). The study included the feasibility of producing materials ranging from ground rock to SSP and TSP and NPK fertilizer. The Klockner Industries Study concluded that mining of the phosphate beds and manufacturing chemical fertilizer could not be recommended at that time for the following reasons:

1. The relatively small demand for fertilizer.
2. The marginal quality of the phosphate ore.
3. The very high transportation rates for phosphate, sulfur, and finally nitrogen and potash.

A fertilizer feasibility study completed in 1976 by IFAGRARIA, Rome, for the Ministry of Rural Development (36) recommends that Mali produce SSP using Tilemsi PR and that a bulk blending plant be established at Bamako. Their estimate for production cost of SSP is 58,173 FM/mt ($129.27/mt). Cost savings calculated by IFAGRARIA, however, used an incorrect cost of 87,313 FM/mt for imported SSP delivered to Bamako. Actual 1976 cost for imported SSP estimated by SCAER is 63,310 FM/mt ($140.69/mt of SSP or $781.61/mt of P_2O_5).

IFAGRARIA's production cost estimate for a cotton mixture with 48% of the nutrient content of the present cotton mixture is equivalent, on a nutrient basis, to the present cost of imported cotton mixture. However, the lower analysis of the proposed locally produced cotton mixture would require 12,000 FM/mt additional transport cost to deliver an equivalent amount of nutrients from Bamako to Sikasso, the major cotton producing area.

For comparison purposes, the IFDC study team calculated the cost of producing SSP at Bamako in a plant with capacity of 33,000 mt per year. Capital investments required for the sulfuric acid and SSP plants were estimated at $11,864,000. An additional $4,103,000 would be required for working capital, making the total capital investment $15,967,000.

A summary of the production costs at operating rates of 100% and 50% of capacity is given in table 30. At 100% of capacity, the production cost was estimated at $129.84/mt of SSP or $721.33/mt of P_2O_5 which is similar to the estimate by IFAGRARIA. At 50% of design capacity the costs were $156.23 and $867.94 respectively.

The present c.i.f. Bamako cost of imported TSP is $250/mt or $556/mt of P_2O_5 (SCAER). Therefore, one metric ton of P_2O_5 produced as SSP in Bamako would cost 1.3 times the delivered cost of imported TSP. This cost difference would increase dramatically at locations other than Bamako because of high freight rates and low P_2O_5 content of the SSP as compared with TSP. The IFDC study team calculated foreign exchange requirement to produce SSP at Bamako to be $59.91/mt of SSP or $332.83/mt of P_2O_5 with the plant operating at 100% of rated capacity. At 50% of capacity, the foreign exchange would be $86.91/mt of SSP or $482.83/mt of P_2O_5.

Since the cost of supplying P_2O_5 through Mali produced SSP is estimated to be $165/mt of P_2O_5 more than the cost of imported TSP and since considerable foreign exchange is needed to produce SSP in Mali, the $16 million investment does not appear to be logical at this time.

The projected need for S in the near future is relatively small. This apparent need could be met by imported AS or SSP until domestic SSP production is economically justified.

PR Mining and Grinding

Mining and grinding of PR for direct application and possible blending of NPK fertilizers from imported materials appear to be logical.

The IFDC study team estimates that 50% or more of the P_2O_5 requirements of Mali can be met with direct application of PR. Based upon estimates of consumption and PR of 31% P_2O_5, the demand for PR could be 6,000, 12,000, and 17,000 mt of PR in 1977, 1980, and 1985, respectively.

Estimates as of July 1976 of the capital and operating costs for a small grinding plant have been made. Details of the estimates are given in table 31.

Table 30. Estimated Production Costs for SSP (0-18-0) Produced at Bamako, Mali

Plant Capacity: 100 mt/day or 33,000 mt/year

Plant Investment: $11,864,000 (for sulfuric acid and SSP plants)

Working Capital: 4,103,000

Total Investment: $15,967,000

Operating Rate			33,000 mt/yr	16,500 mt/yr
	Units	$/Unit	$/mt	$/mt
Phosphate rock	0.67	94.68[a]	$ 63.44	$ 63.44
Sulfuric acid	0.36	89.70[b]	32.29	32.29
Other variable costs (including bags)			8.10	8.10
Fixed costs[c]			26.01	52.40
Total production cost/mt SSP			$129.84	$156.23
Total production cost/mt P_2O_5			$721.33	$867.94

[a]From table 31 plus freight.
[b]Based on sulfur f.o.b. Vancouver at $50/mt bulk. H_2SO_4 plant assumed to operate at 100% capacity.
[c]Includes interest on investment, depreciation, interest on working capital, labor, maintenance, overhead, taxes, and insurance.

Approximate investment required for 12,000 to 25,000 mt/yr (3.5 mt/hr) of mining, grinding, and bagging capacity is $1.1 million. The equipment required would be the same for either a 12,000 or 25,000 mt/yr operation. Actual production would depend on the number of hours the equipment is operated.

The ex-factory cost (Gao) for bagged PR is estimated to be $43.92/mt for a production rate of 12,500 mt/yr (table 32). Delivered cost at Mopti would be $69.39/mt or at Sikasso $99.49/mt ($315.84/mt of P_2O_5). This should be compared with IFDC estimates for TSP of $250/mt or $556/mt of P_2O_5 delivered to Sikasso via Dakar-Bamako (table 33). Actual costs were $286/mt of TSP or $622/mt of P_2O_5 as quoted by SCAER.

It is estimated that the cost of P_2O_5 imported as TSP would be 1.76 times that of Tilemsi PR. Similar comparisons were made at several other points in Mali for operating rates of 25,000 mt/yr and 12,500 mt/yr.

Assuming that 50% of the P_2O_5 requirement can be supplied from PR and that the foreign exchange cost of imported P_2O_5 is $500/mt, foreign

Table 31. Preliminary Estimate of Investment Requirements and Production Costs for Grinding Phosphate Rock at Gao in Mali

Plant Description

Screened material would be fed to a dryer to reduce moisture content to less than 0.5%. Product size would be 90 to 100% minus 200 mesh. A product storage bin of 75-ton capacity is included along with a single-spout, forced-flow bagger with a capacity of 25 mt/h. A diesel generator is provided for power and lighting. The plant would be preassembled on three or four truck trailers and be completely portable.

Investment (Plant Capacity 25,000 mt/y)

Machinery cost, delivered	$661,000
Mining equipment; hand tools, mining cars and track, conveyors, etc.	110,000
Spare parts	19,600
4-wheel drive truck	22,000
Erection and buildings	205,300
Subtotal	$1,017,900
Contingency (10%)	101,800
TOTAL INVESTMENT	$1,119,700

Fixed and Variable Costs

Annual depreciation (10-year)	$112,000
Annual interest (8.5% of 1/2 investment)	48,000
Annual operating costs	228,000
Subtotal	$388,000
Depr., interest, and operating costs, $/mt	15.52
Freight, mine to Gao, $/mt	14.00
Bags, $/mt	8.00
Ex-factory cost, $/mt	37.52
Ex-factory cost, $/mt if operated at 50% capacity	43.92

Table 32. Cost of Bagged, Ground Phosphate Rock (31.5% P_2O_5) at Various Locations in Mali

Basis: Ex-Factory cost at Gao from 25,000 mtpy plant-operating at 25,000 mtpy (100%) and 12,500 mtpy (50%)

Location	Oper. Level	Cost Ex-Factory, $/mt	Transport charges[a] from Gao, $/mt	Total cost, $/mt	Total cost $/mt of P_2O_5
Gao	100%	37.52	-	37.52	119.11
	50%	43.92	-	43.92	139.43
Mopti	100%	37.52	25.47 (Barge)	62.99	199.97
	50%	43.92		69.39	220.29
Bamako	100%	37.52	65.16	102.68	325.97
	50%	43.92		109.08	346.29
Sikasso	100%	37.52	55.57	93.09	295.52
	50%	43.92		99.49	315.84

[a]Includes transfer charges of $US 3.74/mt.

Table 33. Cost of Imported, Bagged TSP at Various Locations in Mali

Location	Delivered Cost, $/mt	Delivered Cost $/mt of P_2O_5	Operating Level, %	Delivered cost as a % of delivered cost of phosphate rock, $/mt of P_2O_5
Bamako	224.14	498.09	100	153
			50	144
Sikasso	250.39	556.42	100	188
			50	176
Mopti	263.83	586.29	100	293
			50	266
Gao	297.41	660.91	100	555
			50	474

exchange savings in 1980 from using Tilemsi PR for direct application could be $1.9 million/year ($500/mt x 3,800 mt). Estimated savings on delivered cost of 3,800 mt of P_2O_5 would be $0.9 million ($240/mt x 3,800 mt) assuming that P_2O_5 in PR can substitute for an equivalent amount of P_2O_5 in TSP.

Bulk Blending of NPK Fertilizer

Since it is assumed that 50% of the P_2O_5 requirement of cotton would be met by direct application of PR, an additional 1,500, 2,300, and 3,000 mt of P_2O_5 from soluble sources would be needed for cotton in 1977, 1980, and 1985, respectively. The cotton mix would then be modified to 15-15-15 or 20-20-10 to supplement PR. B and S could be added.

Requirements for 15-15-15 are estimated to be 10,000, 15,000, and 20,000 mt in 1977, 1980, and 1985, respectively. NPK fertilizers would also be used for sugarcane, vegetables, tobacco, and tea.

IFAGRARIA (36) recommended a 25,000 to 30,000 mt/yr bulk blending facility at a cost of $1.55 million to accompany the SSP plant. Importation in 50-kg bags for blending and rebagging is not likely to be feasible. Also, importation of pure bulk into Mali would not be consistent with available transportation facilities. However, importing fertilizer materials in 1-mt containers could provide considerable savings for handling and transport costs.

It appears that the best location for a bulk blending facility is in Sikasso, since about 65% of cotton is grown in Sikasso Region and since most NPK grades of fertilizer will be used for cotton through 1985.

The DAP, AS, and potassium chloride could be received directly in the 1-mt containers at Abidjan for transfer via Bobo-Dioulasso to Sikasso for blending. Also, straight nitrogen materials, such as urea, could be received in 1-mt containers for rebagging.

The system from the receiving port through the blending, bagging operation is shown schematically in figure 1. Figures 2, 3, and 4 are photographs of 1-mt containers being transferred from ship to warehouse. Figure 5 is a photograph showing a container being filled from a dockside receiving hopper. Details of the investment required and the estimated operating costs are given in table 34.

Calculations were made for the cotton grade 19-31-0-8S which was formulated from DAP and AS. The new cotton grade can be formulated from AS, DAP, and potassium chloride. Borax could be added to the formulas if boron is desired.

The bulk blending facility would contain a 3-ton mixer and have the capability of producing 12 mt/hr. Variations in the annual rate would be obtained by simply varying the number of hours operated.

The raw materials received would be stored in the containers. A forklift would transfer material from the containers to small bins. A small payloader would transfer materials from the bins to the blending system. Material from the blender would transfer to a small mechanical bagger and to truck loading. The entire operation could be carried out under a shed, in an existing building or even outside. This very simple operation has an estimated capital investment cost of about $172,000.

Estimates were made of the raw materials and operating costs for a plant located in Sikasso producing 12,000 mt/yr of 19-31-0-8S grade. The cotton grade could be produced at a rate of 12,000 mt/yr in Sikasso for about $250/mt, allowing a 20% return on investment. For comparison purposes, the same grade delivered via Abidjan-Bobo-Dioulasso at current costs is about $330/mt or a difference of $80/mt.

Based upon the projected need for 4,600 mt of P_2O_5 for cotton in 1980 and the potential for using PR to

supply 50% of the P_2O_5, the 1980 need would be for an equivalent of 7,420 mt of 19-31-0. At $80/mt of material, blending material in Mali could provide a savings of $590,000/year in 1980. Foreign exchange savings could be even greater. It is estimated that material costs for blending can be as much as $111/mt less than the cost of blended 19-31-0. Therefore, foreign exchange savings could be $824,000 a year in 1980 for blended cotton fertilizers.

Additional savings could be realized if the material was produced in a similar plant in Bobo-Dioulasso and shipped to Sikasso. The details of this alternative are given in the regional section of this report.

Table 34. Bulk Blending in Mali and Upper Volta

Production Costs for 19-31-0-8S and 19-35-0-7S in Plant of 12 mt/hr Capacity

Plant Location	Bobo-Dioulasso		Sikasso	Bobo-Dioulasso
Operating Rate, mt/yr	18,000			
	12,000	6,000	12,000	6,000
Investment, $	172,000		172,000	172,000
Working Capital (Cost of 1/2 of annual production), $ MM	1.2	0.6	1.4	0.6
Grade	19-31-0	18-35-0	19-31-0	18-35-0
Raw Materials	$/mt	$/mt	$/mt	$/mt
18-46-0, $216.28/mt at Bobo-Dioulasso	145.77	164.59		164.59
$249.31/mt at Sikasso			168.03	
AS, $121.77/mt at Bobo-Dioulasso[a]	39.45	24.96		24.96
$154.80/mt at Sikasso			50.15	
Subtotal	185.22	189.55	218.18	189.55
Fixed and Variable Costs				
Electricity, gasoline, etc.	0.15	0.15	0.15	0.15
Operating Labor	0.70	0.70	0.70	0.70
Maintenance (5% of equipment cost)	0.35	0.35	0.53	1.05
Depreciation (15 years)	0.64	0.64	0.96	1.91
Taxes and insurance (2% of investment)	0.19	0.19	0.28	0.57
Supplies (20% of mtce.)	0.07	0.07	0.11	0.22
Overhead (100% of Labor)	0.70	0.70	0.70	0.70
Interest (8.5% of 1/2 investment)	0.41	0.41	0.61	1.22
Bags	10.00	10.00	10.00	10.00
Product loss (2% of raw materials)	3.70	3.79	4.36	3.79
Subtotal	16.91	17.00	18.40	20.31
Total Production Cost	202.13	206.55	236.58	209.86
Interest on W.C. (8.5%)	8.50	8.50	10.05	8.50
Ex-Factory Cost	210.63	215.05	246.63	218.36
With 20% ROI[b]	212.54	216.96	249.50	224.09
Freight to Sikasso	17.10			
	229.64			

[a] AS = ammonium sulfate.
[b] ROI = return on investment.

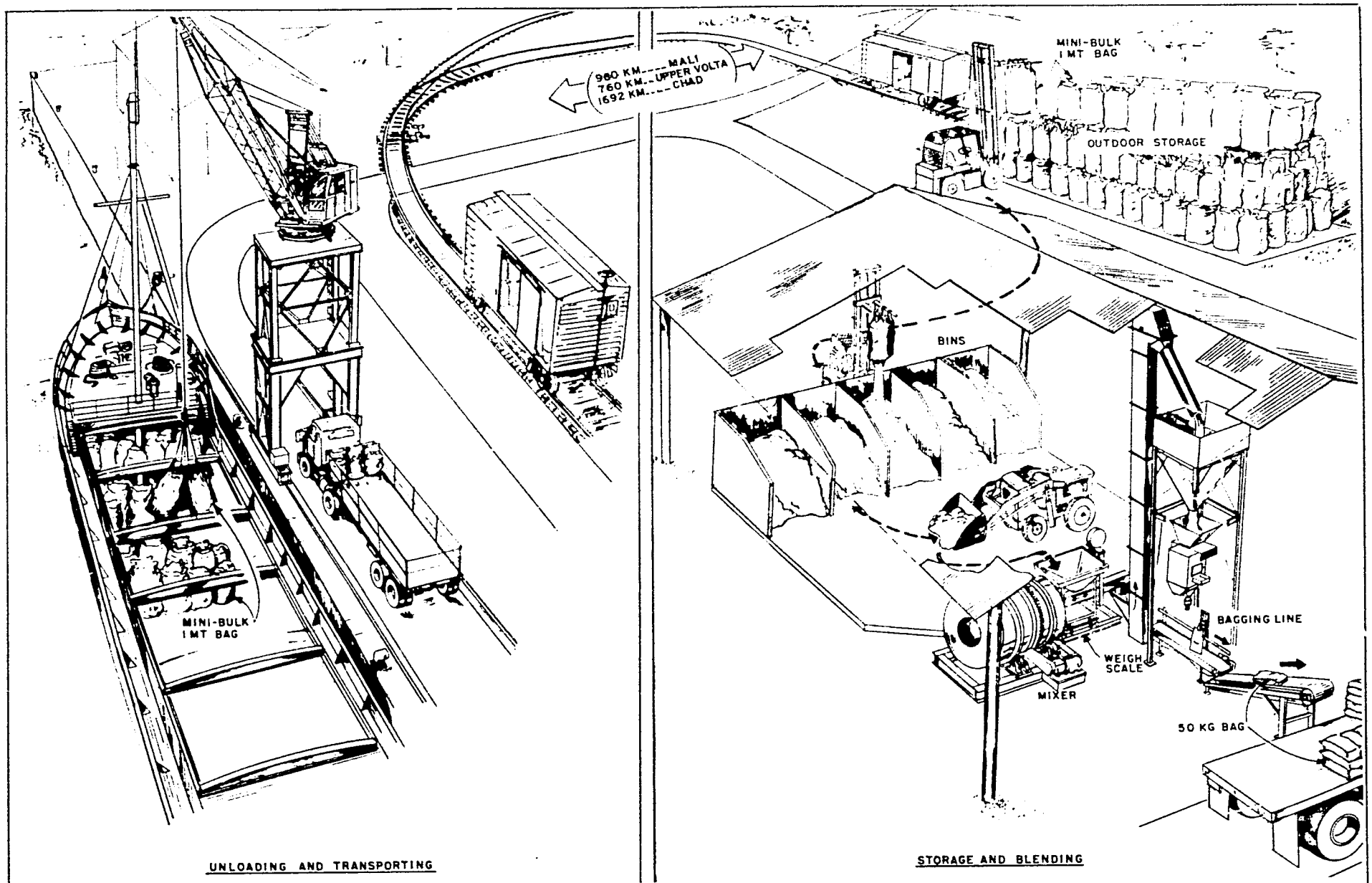


Figure 1

BULK BLENDING SCHEME FOR
(1) UPPER VOLTA – MALI, (2) MALI, (3) UPPER VOLTA AND (4) CHAD

Figure 2. Attaching Hooks to Bags in Ship's Hold

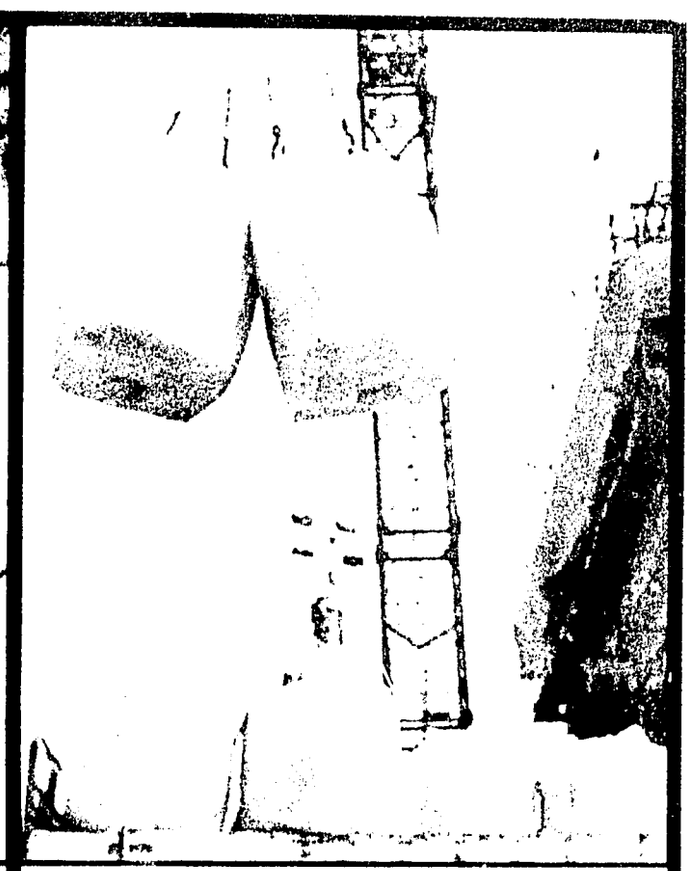


Figure 3. Transferring 1-mt Bags to Truck

Figure 4. Stacking 1-mt Bags in Storage Area

Figure 5. Filling 1-mt Bags from Bulk Shipment

POTENTIAL PROJECTS

Mali has the land resources to achieve self-sufficiency in food production for its people. Only 12% of the potentially arable land is presently under cultivation. While not an easy process, new lands can be brought into production with time. In the short run, food production can be increased through greater yields on existing croplands. The use of improved production practices on currently cultivated land can significantly increase the productivity of Malian agriculture.

Transformation of subsistence farming into commercial agriculture is the key to meeting present and future food requirements. Essential to this process will be market development, more production incentives, new technology, improved transportation, and the increased availability of necessary farm supplies and equipment. A key input in such a development program will be fertilizer, currently only used in limited quantities.

Mali has indigenous resources to produce some of the nutrients needed for expanded fertilizer use. Phosphate rock (PR) deposits exist to supply some of the P_2O_5 nutrient requirements. Other nutrients can be imported in semi-bulk containers and blended to supply Malian agriculture.

Adoption of fertilizer involves more than just the ability to accurately recommend and supply fertilizer. A stable price relationship between the value of yield gain and cost of fertilizer application must provide an economic incentive to the farmer. Even when this relationship appears to be economically favorable, the farmer may still be reluctant to adopt fertilizer. Extension education and fertilizer response demonstrations are important in assisting him to more accurately evaluate the benefits and risks of fertilizer use.

The following project recommendations are suggested to accelerate the use of fertilizer in Mali:

Soil Fertility Project

A fertilizer trial and demonstration program is needed in Mali to obtain data and demonstrate response for major crops at various levels of on-farm management. Method of land preparation and tillage; varieties; plant population; timing of seeding; weeding and harvesting; and soil type and moisture need to be correlated with crop response to fertilizer.

PR deposits exist in Mali and appear to be suitable for direct application. The effectiveness of these rocks in providing plant nutrients needs to be determined for the major crops under varying soil and moisture conditions. Phosphate rock should be tested in comparison with other standard PR and soluble phosphate fertilizers. Research findings can then be incorporated into an extension education and demonstration program which can advise farmers on new production practices.

IFDC recommends that an expatriate team of crop production specialists be assigned to Mali to work closely with existing research and extension organizations to obtain crop response data and demonstrate responses to farmers. Project team members would be responsible for agronomic and economic research on crop response and for training nationals in methods of agricultural research and extension education. The term of the project is 5 years. A detailed description of the proposed project is contained in Appendix II.

Phosphate Rock Mining and Grinding Project

PR reserves of 20 million mt exist in the Tilemsi Valley north of

Tamaguelelt. The ore contains about 27.5% P_2O_5 but can be upgraded to 31.5% by simple manual methods. Grinding of locally available PR for direct application appears to be economically feasible and could be used to supply about 50% of the projected P requirement.

IFDC recommends that Malian phosphate ore be mined, upgraded, and shipped to a grinding facility at Gao. The recommended grinding plant is a portable type capable of producing 25,000 mt/year. Storage capacity and bagging equipment would also be necessary. The ground and bagged rock would be barged to points along the Niger River for further distribution by trucks.

IFDC recommends that an expatriate engineer be assigned for 2 years to this project to work with Malian counterparts. In addition, mechanical engineering assistance for 6 months is proposed. The term of the project is 2 years. See Appendix II for additional project detail.

Bulk Blending of Fertilizers

Mali is currently importing about 12,000 mt/year of finished fertilizer materials. A simple low technology type of bulk-blending facility could be used to supply needed NPK mixtures at a lower cost than imported finished fertilizers.

IFDC recommends the installation of a bulk-blending facility at Sikasso, Mali. Raw materials would be shipped to Abidjan in semi-bulk 1-ton containers and then transported to a storage facility in Sikasso. The recommended bulk-blending and bagging operation has a capacity of producing 12 mt/hour.

IFDC recommends an expatriate team consisting of a mechanical engineer and a chemical engineer to work with Malian counterparts in planning a system to handle 1-ton containers from port to plant site, design plant layout, and write equipment specifications. The consulting engineers would then assist Malian engineers in initial assembly and startup activities. The term of the project is 1 year. See Appendix II for additional project detail.

Some other potential projects or studies not evaluated by the IFDC team but which appear to be worthy of investigation are:

1. Study the status and needs of supporting institutions supplying services in agricultural extension, credit, crop marketing, and input supply.
2. Study methods for improving statistical reporting of information on crop areas in production, yields, and fertilizer nutrient use by crops and areas. The possibility of incorporating aerial sensing into a crop reporting system might be considered.

Public Policy Studies on Price Stabilization and Equalization

Fertilizer use is highly dependent upon the relationship between the cost of fertilizer and crop prices.

IFDC recommends that alternate public policies on price support and cost subsidization be studied to determine their effects on fertilizer adoption, food production, and overall economic development. IFDC recommends that one expatriate economist work with Malian economists from the appropriate planning organization to carry out the study. The term of this project is 6 months. See Appendix II for additional detail.

Estimated Budgets

The estimated foreign exchange requirements for the budgets for the recommended projects are:

Project	Period, Years	Budget
Soil Fertility	5.0	$ 2,350,000
Bulk Blending	1.0	293,000
PR Grinding	2.0	1,352,000
Public Policy	0.5	31,000
		$ 4,026,000

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APPENDIX

APPENDIX I

FERTILIZER RAW MATERIAL DEPOSITS

References	Composition of Samples	Location	Other Information
Reference 1	60-70% BPL	Same as 2	Reserves estimated at 20 mt
Reference 2	%	Tamaguelelt Tilemsi In Tassit	The thickness of the seam is 1.5-2.5 meters (see 1 above) This is probably the deposit studied by Klockner in 1968 and described as being at Bourem, NW of Tamaguelelt.
	P_2O_5 32 CaO 44 Fe_2O_3 8 Al_2O_3 3 SiO_2 4 CO_2 4		
Reference 3	Pebble / Smaller Size P_2O_5 35-37% / 24-27% CaO 48-52 / 34-40 Al_2O_3 1-3 / 1/2-2 Fe_2O_3 1-3 / 16-23 SiO_2 1/2-1 / 2-3	Tin Edam (a) Adrar Tiguirirt (b) Oued Inchaouadj (c) Oued Gachiran (d)	The pebble (coprolites > 3 mm) is clearly a good apatite but the deposit generally contains heavy iron contamination. (a) is 4 m thick (b) is 2-1/2 m thick (c) is 4 m thick
Reference 4 p. 343 and p. 445	Pebble / Smaller Size P_2O_5 37% / 24% Al_2O_3 21-30 / 19 Fe_2O_3 4-8 / 2 SiO_2 2-4 / 35 MgO 1-10 / 0.2 CaO 10-13 / 7	Tamaguelelt Chanamaguel	These deposits are 1/2-2m thick. There is some reason to think that the outcrop rock only is contaminated with iron. But the low calcium values show that most of the aluminum must be in the structure. A ferruginous phosphate sample from Andarakoyen contains 27% P_2O_5, 29% CaO, 0.4% Al_2O_3, and 16% Fe_2O_3.

References	Composition of Samples	Location	Other Information
As No. 2 but pages 128-9	Potash brines	Agorgott-Teghaza, a few km from Taoudenni	Analysis not given.
As No. 1 but page 98	Gypsum	Taoudenni)	These gypsum deposits are unlikely to be useful insofar as fertilizers are concerned unless they can meet soil deficiencies or unless a cement-sulfuric acid plant can be justified in the area.
As No. 2 but page 45	Gypsum	El Guettara) Taoudenni) Bir el Keib)	
As No. 4 but page 408	Gypsum	North Gourma)	
Bull. Serv. Geol. AOF Ann. Rept. 1949, page 38	Pyrites	Doro	Cubic crystals, some up to 3 cm side in metamorphic schists.
Reference 2, page 126	Bicarbonate waters	Igouloulof Touseiet	These solutions occur at 24-26°C and the mineral content includes 60-80% sodium bicarbonate with smaller quantities of potassium, calcium, and magnesium bicarbonates.
Reference 4, pages 367, 397, and 435	Lignites mixed sometimes with oil, pyrites, bitumen and sands	Near Gao	It is difficult to tell from this reference how large the deposits are.

References	Composition of Samples	Location	Other Information
Reference 5, page 70-71	Bituminous and pyritic schists. 10-1/2% oil in the rock 38 litres gas (50% H_2) per kilo of rock	Between Gao and Colomb-Berchar	Thickness of bituminous marl layer 4-1/2m.
Private communication	Brines	Mamoude	
As No. 5 but page 55	Phosphate	Tabankort	
Private communication and Europe-Outremer 1974, May, 153	Oil	Near Menaka and Gao	Studies continuing by an American consortium.

References on Raw Material Deposits

1. Phosphates d'In-Tassit. Chron. Mines colon., 1936, Vol. 5, No. 55, p 344. (In French).

2. Esquisse geologique de l'Afrique Occidentals Francaise. P. Legoux. Bull. No. 4, Serv. Mines A.O.F., 1939. 134 pp, figs., maps. (In French) Phosphates du Tilemsi, pp 102-104.

3. Les phosphates du Sahara soudanais. R. Karpoff and L. Visse. Bull. Soc. geol. Fr., Ser. 5, 1950, Vol. 20, Nos. 4-6, pp 125-131, fig., refs. (In French).

4. Les bassin cretace et tertiaire de Gao. Le detroit soudanais (feuilles Gao et Tabankort) (The Cretaceous and Tertiary basin of Gao. The Sudan through [Gao and Tabankort sheets]). H. Radier. Bull. Serv. Geol. Prosp. min., A.O.F., 1959, No. 26, Vol. 2, Pt. 3, pp 315-566, figs., photos., bibliog., map. (In French).

5. Les resources minieres de l'Afrique occidentals. M. G. Arnaud. Bull. No. 8 Dir. Mines Afr. Occid. Fr., 1945, 100 pp, figs., refs., maps. (In French), pp 70-71.

APPENDIX II

RECOMMENDED PROJECTS

SOIL FERTILITY PROJECT IN MALI

Fiscal year proposed for financing: FY 1977

Priority and Relevance

A goal of AID support in West Africa is to assist in increasing food production, particularly to restore balance between production and demand. Major emphasis is being placed on this goal by AID through support of Semi-Arid Food Grain Research and Development (SAFGRAD) and country and sectional crop production and/or integrated rural development projects. Specifically, AID is funding "Operation Mils" and considering funding "Action Mil-Sorgo" (cereal production projects in eastern Mali). Other agencies are funding crop production projects most of which involve some cereal production.

Requirements for millet and sorghum, primary food crops, are projected to increase 120,000 and 266,000 mt by 1980 and 1985 over 1975 food requirements. To help meet these needs, basic and applied research programs are being implemented to develop and distribute drought tolerant varieties adapted to the soil and climatic conditions and to study cropping systems suitable to the area. These programs are much needed and are essential to bring about improved crop production. In addition, other measures are needed to improve crop yields and expand production.

Research on experiment stations has shown good cereal response to fertilizers, particularly N and P.

PR from Tilemsi Valley has been tested at Malian experiment stations for several years. Generally, PR gives good response for three years after application. An annual application of 45 kg/ha of P_2O_5 from TSP for three years of maize-peanut-sorghum gave the same yield as one application of 160 kg of P_2O_5 as PR. Each gave an increased yield of over 3,100 kg of grain plus 135 kg of peanuts. Even in an area with 500 mm/year of rainfall this rate of PR gave millet yield increases of 10 kg of grain/kg of P_2O_5 in the first year. Unfortunately, experimental design of past experiments has not been adequate to determine the relative value of PR in comparison with soluble P fertilizer. Additional data are needed, particularly under farmer conditions.

Farm level information is scarce for cereal response to fertilizer. Limited data indicate on-farm response to low levels of application may be from 7 to 15 kg of grain/kg of N plus P_2O_5. To maximize the response to fertilizer, improved production practices at the farm level must be implemented. Little is known about farmer attitudes toward acceptance of improved cultural practices. Efforts have been made to introduce changes without much success. The lack of widespread acceptance in many cases may be due to the lack of farmer knowledge, bottlenecks in the delivery system for inputs, limited availability of credit at economical interest rates, inadequate input/output price relationships, and unstable market demand.

Description of Project

This project would implement a soil fertility program in Mali consisting of two "action" components followed by a project evaluation. The term of the project is 5 years. It would be implemented within the framework of existing institutions responsible for agricultural research and extension.

The objectives of the soil fertility project are:

1. Define the nature of response of food crops to fertilizer in various soil and climatic conditions at the farm level;
2. Quantify the value of Tilemsi Valley PR for food crop production in relation to soluble P fertilizer and other widely used PR under varying soil and climatic conditions;
3. Train nationals in improved crop production practices, methods of conducting and analyzing trials and demonstrations, and using results with farmers;
4. Demonstrate to farmers the value of improved crop production practices; and
5. Relate levels of inputs of a crop production program to outputs, changes in attitudes, and changes in practices.

Crop production projects, mostly under the direction of administrative units called "Operations," have responsibility for improving crop production within a specific area or region. "Operations" perform extension advisory service, supply of inputs, service loan applications, and crop marketing. Credit and supply activities are performed as agents for SCAER and crop marketing as agents for national crop marketing organizations.

Crops and soils research is under the direction of National Committee of Agronomic Research with technical assistance from the French Research Institute for Tropical Agronomy for food crop research and funding largely from FAC. Their research includes soil fertility, crop breeding, and variety testing and selection, rotations, residue management, soil preparation, etc. The Institute for Crop Research in the Semi-Arid Tropics (ICRISAT) has the responsibility for improving crop varieties and developing minimum input production packages for small farmers in the semi-arid tropics which includes Mali. ICRISAT has a field trial officer in Mali (funded by AID) working with Operation Mils and is considering other personnel to be stationed in Mali.

This project proposes that one crop production specialist be assigned to work in each of five regions (Kayes, Bamako, Sikasso, Segou, and Mopti) with one production economist stationed at Bamako. If there is an Accelerated Crop Production Officer (ACPO) in the country he should be the coordinator. If no ACPO is in the country, one of the persons assigned to Bamako would be coordinator for this component. Each crop specialist would have 4 and the economic specialist 2 assistants (nationals) that would be trained to carry on the work themselves. One or two additional new assistants would be added each year.

Specialists would be assigned for 2 and 3 years and rotation would be staggered to permit continuity. The first coordinator's term would be for 3 years. The specialists must have training and experience to conduct professional levels of work and must be able to effectively converse in French. Specialists should arrive in Mali in January or February to give time for familiarization and planning before their first crop season. Upon arrival, the specialists would familiarize themselves with existing research data and "Operations" programs, and make detailed plans for the coming season in consultation with researchers and "Operations" management.

Each crop specialist would be responsible for conducting 30 to 40 crop production trials or demonstrations of a design suitable to measure the effect of individual plant nutrients, crop variety, plant population, timing of planting and harvesting, soil preparation, and incorporation of residue or manure application. Long-term experiments would be established to determine the effect of crop rotations and the value of residual fertilizer.

Individual trials with PR would be conducted for 3 to 5 years to determine the immediate as well as residual effect. The trials would include equivalent rates of P_2O_5 applied as TSP and PR and the lowest rates of PR with supplemental TSP. In all trials and demonstrations, soil samples would be obtained and analyzed for attempts at correlation of yield response and levels of soil test P and possibly other characteristics. Arrangements would be made for proper analysis of samples at research station laboratories. Rainfall (quantity and distribution) would be recorded at or near each location.

The economist would coordinate statistical and economic analyses of project results, develop practical farm budgets for various cropping and economic situations, and serve as field advisor for a graduate student conducting adoption studies of changes resulting from crop production program.

The study by the graduate student would include documenting at the village level such things as: kinds and number of farmer contacts; availability of credit and other inputs; input and output prices; price fluctuations; availability of markets; acceptance and implementation of new practices; and effect of these on production, labor requirements, and economic well-being. The study would attempt to define the relative importance of various inputs of a crop production program upon the diffusion, acceptance, and implementation of improved cropping practices.

Training sessions would be conducted with assistants covering how and why various things are done. In addition, training sessions would be held with each cooperating farmer before trials are established, during the growing season, during harvest, and after harvest.

AID and Other Relevant Experiences

AID has funded many applied research, crop production, and extension training projects. The soil fertility project has particular relevance to the SAFGRAD project since it contains an action program to strengthen national institutions and to provide immediate benefits to Malian farmers.

Beneficiary

Principal beneficiaries of the project are Malian farmers. Through better defined crop response data and better informed extension advisors, farmers are more likely to increase crop yields and produce more for the time spent for production.

Feasibility Issues

Indications of cereal response to fertilizer are 7 to 16 kg of grain/kg of nutrient, with 40 to 50 kg of applied nutrient/ha. Present farmer price for 50 kg of each urea and DAP (55 kg of nutrients) in Mali is 9,350 FM. If a response of 10 kg of grain/kg of nutrient is obtained, the yield increase is 550 kg/ha. Using 32 FM/kg as the grain price, the value of the increased yield is 17,600 FM/ha or 8,250 FM/ha above fertilizer cost.

On the national basis, fertilizing 10,000 ha of millet or sorghum would require 550 mt of nutrients and result in 4,950 mt of additional grain. Estimated economic farmgate value of sorghum based upon world prices, margins, and freight is 75,000 FM/mt which gives an economic farmgate value of 371 million FM for the additional grain produced from 550 mt of nutrients. These nutrients supplied as urea and DAP would cost 117 million FM delivered to Bamako (based upon actual cost/mt in 1976). Using the same rate for domestic freight and margins as for grain, these add 13 million FM for a total cost of 130 million FM for the fertilizer delivered to farms. Therefore, each million

FM spent on fertilizer can yield grain to replace 2.85 million FM in grain imports.

Other Donor Coordination

International Bank for Reconstruction and Development (IBRD), Fonds Europeen de Developpement (FED), Fonds d'Aide et de Cooperation (FAC), United Nations Development Program (UNDP), and AID are presently funding crop production projects and/or research and extension activities. The Federal Republic of Germany, Canadian International Development Association (CIDA), and Ford Foundation may be interested in funding for this type of project.

Financial Plan

The annual foreign exchange cost of the project is estimated to be $460,000 or $2.3 million for a 5-year period. In addition, the GOM would be expected to supply the assistants and field hands for the work as well as office space. It is estimated that about 60% of the salaries budgeted in the first year for technical services would be needed in the first year since they will not be in the field a full year in the first fiscal year. However, support costs will be highest the first year.

Estimated Foreign Exchange Support for Five-Year Project

Technical Services	
Crop Production Specialists - 5 at $45,000 x 5	$ 1,125,000
Production Economics Specialist - at $45,000 x 5	225,000
Support	750,000
	$ 2,100,000
Graduate Studert Stipend - 1 at $3,000 x 2	6,000
Support - $17,000 x 2	34,000
Travel - $5,000 x 2	10,000
	$ 50,000
Commodities	50,000
Travel for Specialists, Workshops, Printing and Logistic Support	150,000
Grand Total	$ 2,350,000

Implementation Plan

A contractual agreement will be made with GOM. The project would be administered by a project coordinator probably placed in the administration of the National Committee of Agronomic Research in the Ministry of Rural Economy. Very close collaboration would be needed with the managements of "Operations" and Region Administrations.

Project Development Schedule

Departure, Project Design Team	January 1, 1977
Project Committee Review, Project Paper	April 1, 1977
Review/Approval of Project Paper	June 1, 1977
Project Staff Arrive in Mali	January 1, 1978

MALI PHOSPHATE ROCK MINING AND GRINDING PROJECT

Fiscal year proposed for financing: 1977

Project Development Team: Mining Engineer, Mechanical Engineer

Priority and Relevance

Reserves of approximately 20 million mt of phosphate rock (PR) exist in the Tilemsi Valley north of Tamaquelelt. The ore contains about 27.5% P_2O_5 but can be upgraded to 31.5% by simple manual methods: screening and hand picking. Mali is currently using nearly 4,000 mt/year of P_2O_5 or 13,000 mt/year of PR equivalent.

Grinding of locally available PR for direct application could be used to supply about 50% of this requirement.

Description of the Project

Phosphate ore would be mined, upgraded, and shipped to Gao for grinding. The grinding plant would be pre-assembled on three or four truck trailers and be completely portable. A diesel generator would be provided for power and lighting. Screened material would be fed to a dryer to reduce moisture content to less than 0.5%. PR would be ground to 90 to 100% minus 200 mesh. A product storage bin of 75-ton capacity would be provided along with a single-spout forced-flow bagger with a capacity of 25 mt/hour. The plant would be designed to produce up to 25,000 mt/year. The ground and bagged rock would be barged to points on the Niger River for further distribution by trucks.

AID and Other Relevant Experience

Mining and grinding of PR on a small scale is not widely practiced in the world. However, since transport costs for importing fertilizers into most Sahel countries are so high, use of locally available materials is attractive even on a small scale. German aid is currently being used to set up similar mining and grinding operations in Upper Volta and Niger.

Beneficiary

Timely availability of a cheap source of P_2O_5 fertilizer would benefit the small farmers and lead to increased crop production. Beginning development of an indigenous resource would provide employment for local labor and also be an excellent starting point for future extension of industrial fertilizer activities.

Feasibility Issues

Up-to-date estimates of the capital and operating costs for a small grinding plant have been made (see table 31). The approximate investment required for 12,000 to 25,000 mt/year (3.5 mt/hour) of mining, grinding, and bagging capacity is estimated to be $1.1 million. The actual production rate would depend on how many hours the equipment is operated.

The ex-factory cost (Gao) for bagged PR is estimated to be $43.92/mt for a production rate of 12,500 mt/year (table 31). Delivered costs at Mopti would be $69.39/mt or at Sikasso would be $99.49/mt ($315.84/mt of P_2O_5).

This should be compared with estimates for triple superphosphate of $250/mt or $556/mt of P_2O_5 imported to Sikasso via Dakar-Bamako (table 33). Therefore, the cost of imported P_2O_5 would be 1.76 times the locally produced P_2O_5. Similar comparisons were made at several other points in Mali for operation rates of 25,000 mt/year and 12,500 mt/year (tables 32 and 33).

Other Donor Coordination

Germany has already considered establishment of a similar project in Mali and might be willing to participate in this project. Fonds Europeen de Developpement (FED) has recently financed a study involving use of local phosphates for manufacturing SSP.

Project Cost Estimate

An estimate of the capital investment required for the project is $1.1 million. The estimate is only preliminary. A preinvestment study should be carried out by a firm familiar with mining and grinding equipment. One firm has indicated that the home office portion of the study would cost about $15,000. In addition, one engineer should visit Mali for about 2 weeks to check the mine and grinding sites. Salary, travel, and per diem are estimated at $4200.

A mining engineer should be provided in Mali on a 2-year assignment. In addition, 6 man-months of mechanical engineering assistance would be required. Following is a summary of the estimated project cost:

Estimated Foreign Exchange Financial Support for Two-Year Period

Capital Investment	$ 1,120,000
Preinvestment Study	19,000
Technical Assistance	
Mining Engineer - 1 at $40,000/year x 2	80,000
Mechanical Engineer - 1 at $40,000/year x 0.5	20,000
Support	80,000
Subtotal	$ 180,000
Training	
Specialty training for 90 days - 3 at $100/day	$ 27,000
Travel - 3 at $2,000	6,000
Subtotal	$ 33,000
Grand Total	$ 1,352,000

Implementation Plan

Proceed with preinvestment study and develop contractual agreement with GOM. It seems likely that SONAREM is the organization that will carry out the exploitation of Tilemsi Valley PR deposits.

Project Development Schedule

Begin preinvestment study and project design	January 1, 1977
Project Committee review project paper	March 1, 1977
Review/Approval project paper	May 1, 1977

It should be anticipated that equipment would be delivered to Mali by November 1, 1977, and installed by January 1, 1978. The facilities would then begin operation in April 1978. Ground PR would then be distributed prior to the 1978 crop season.

BULK BLENDING OF FERTILIZERS AT SIKASSO, MALI

Fiscal year proposed for financing: 1977

Priority and Relevance

Mali is currently using about 12,000 mt/year of mixed fertilizers. All of this requirement is imported as finished materials. A simple low-technology type bulk-blending facility could be used to provide the NPK mixtures needed in Mali at lower costs than the imported finished goods.

Description of Project

Raw materials such as diammonium phosphate, ammonium sulfate, and potassium chloride would be imported at Abidjan in semi-bulk, 1-ton containers. The containers would be shipped to Sikasso either directly by truck or by rail-truck via Bobo-Dioulasso. The raw materials would be stored in the containers and fed into a simple bulk-blending, bagging operation capable of producing 12 mt/hour (see figures 1-5).

AID and Other Relevant Experience

The classical approach to bulk blending is to receive raw materials in bulk into a bulk storage and handling facility. For this project, raw materials would be received in 1-ton disposable containers which would eliminate the need for expensive bulk handling and storage facilities.

Beneficiary

Timely arrival of cheaper fertilizers would benefit the small farmers and lead to increased crop production. Establishment of a bulk-blending facility would also provide an excellent starting point for future extension of industrial fertilizer activities.

Feasibility Issues

Calculations of the cost of producing 12,000 mt/year of a 19-31-0-8S grade at Sikasso are summarized in table 34. Allowing for a 20% return on investment, the ex-factory cost is estimated to be approximately $250/mt. For comparison purposes, the current delivered cost via Abidjan-Bobo-Dioulasso of the same grade at Sikasso is about $330/mt or a difference of $80. It is evident that a bulk-blending facility at Sikasso to produce mixed grades for Mali can be justified.

Other Donor Coordination

Fonds Europeen de Developpement (FED) sponsored a study completed in January 1976 which recommended a bulk-blending operation in Mali. The study was carried out by IFAGRARIA, an Italian firm, in conjunction with the Malian Ministry of Rural Development. FED might be willing to participate in this project.

Financial Plan

Capital investment required for the facility has been estimated at $172,000. This estimate includes machinery, freight on machinery, spare

parts, concrete pads, foundations, and installation. Land and building costs have not been included. In addition, technical expertise will be required to help with the following:

1. Work out details of importing and handling the 1-ton containers.
2. Choose site for location of the equipment.
3. Assist in design of the plant layout and writing specifications for the equipment.
4. Assist in evaluating equipment bids and expediting purchase of equipment.
5. Prepare operating instructions for the facility.
6. Startup of the facility.

Following is an estimate of manpower and associated costs for performing these functions:

Estimated Foreign Exchange Financial Support for One-Year Period

Capital Investment	$ 172,000
Preinvestment Study	18,000
Technical Services	
Chemical Engineer - 1 at $40,000/year x 0.7	28,000
Mechanical Engineer - 1 at $40,000/year x 0.3	12,000
Support	30,000
Subtotal	$ 70,000
Training	
Specialty - 3 at $100/day x 90	27,000
Travel - 3 at $2,000 each	6,000
Subtotal	$ 33,000
Grand Total	$ 293,000

Implementation Plan

A two-man team consisting of one chemical engineer and one mechanical engineer, should visit Mali for 4 weeks to assist in working out details for handling the 1-ton containers. A plant site must be chosen followed by design of plant layout, and writing equipment specifications. Two Malians should be provided as counterparts to the team. The two counterparts selected should be the two key persons chosen to operate the facility when built. One should be familiar with operation of mechanical equipment and the other with importation and shipping of goods in Mali.

Subsequent visits of the consulting engineers should coincide with the arrival and assembly of equipment, receiving of raw materials, and startup of the facilities.

It is not clear into what institutional framework the bulk-blending operation will be placed. SCAER presently imports all fertilizer as well as other agricultural inputs. As an agricultural supply organization, SCAER should be considered for the operation of the bulk-blending facility.

Project Development Schedule

Choice of Malian counterparts and arrangement for team visit	January 1, 1977
Initial team study plus final preparation of project details and specifications	March 1, 1977
Bid invitations and bid evaluation	May 1, 1977
Equipment fabrication	July 1, 1977
Equipment delivery	October 1, 1977
Erection and startup	February 1, 1978

STUDY OF PUBLIC POLICIES ON PRICE STABILIZATION AND EQUALIZATION

Fiscal year proposed for financing: 1977

Priority and Relevance

Fertilizer use level is highly dependent upon the cost-price relationship between fertilizer and a crop although other factors influence fertilizer use. Farmers tend to maximize net returns and do not use fertilizer if returns do not cover the cost plus risks involved.

Generally, a kg of nutrient can be expected to give 8 to 10 kg of cereal grain. At current world prices for grain and fertilizer nutrients, imports of grain would cost 2.5 to 3 times the cost of fertilizer to produce the grain in Mali. An in-depth analysis would require consideration of many other factors.

Description of Project

This study would describe alternative public policies on price stabilization and equalization; subsidies for crops, fertilizers, and other related inputs; their implementation; effects upon fertilizer use; and the effects on the economy of the country sectors and regions. It would furnish guidelines for establishing policies related to fertilizer use which could effectively meet government goals. The study would require one expatriate economist working with one or more economists from the national planning agency. The study would be completed in six months.

AID and Other Relevant Experiences

The nature of other studies in this area financed by AID is unknown.

Beneficiary

Agricultural development would benefit rural and urban sectors. Increasing self-sufficiency in food through appropriate agricultural price and incentive policies would substantially strengthen Mali's international positions by helping to correct current balance of payment problems.

Feasibility Issues

Establishing favorable fertilizer product prices could result in increased fertilizer use and increased food crop production provided other inputs are available for favorable response of crops to fertilizer. Given the varying cost:price ratios over the years it would seem worthy of establishing guidelines.

Other Donor Coordination

Unknown.

Financial Plan

The foreign exchange cost of the study is estimated to be $31,000. In addition, the local government would be expected to supply one or two local economists to work on the project.

Estimated Foreign Exchange Support for the Study

Technical Services	
Economist - 1 at $30,000 x 0.5	$ 15,000
Support	10,000
Travel	5,000
Publication	1,000
	$ 31,000

Implementation Plan

A contractual agreement would be made with the local government. The study would be undertaken with the national planning agency. It would require cooperation and assistance from Ministry of Rural Development, Office of Price Regulation, "Operations," and organizations marketing agricultural inputs and outputs.

Project Development Schedule

Visit to the country for project negotiation	January 1, 1977
Visit to field for data gathering (2 months)	April 1, 1977
Completion of study	September 1, 1977