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volume one • REGIONAL OVERVIEW

WEST AFRICA FERTILIZER STUDY

INTERNATIONAL FERTILIZER DEVELOPMENT CENTER IFDC

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 Published and unpublished literature was obtained in each country and from international development agencies.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
Ca . . . . . Calcium
Al . . . . . Aluminum
Fe . . . . . Iron
Si . . . . . Silicon

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)
MAP . . . . . Monoammonium Phosphate (11-54-0)
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

c.i.f. . . . . cost, insurance, and freight
f.o.b. . . . . free on board
FIO . . . . . free in and out
GDP . . . . . gross domestic product

ACRONYMS OF ORGANIZATIONS

BRGM . . . . . French Bureau for Geological and Mining Research
CEAO . . . . . West African Economic Community
CILSS . . . . . Permanent Interstate Committee for Drought Control in the Sahel
CNRA . . . . . National Agronomic Research Institute
FAO . . . . . Food and Agriculture Organization
FERTISEN . . . . . A joint Iran-Senegalese enterprise
IAR . . . . . Institute of Agricultural Research
IBRD . . . . . International Bank for Reconstruction and Development
ICRISAT . . . . . Institute for Crop Research in the Semi-Arid Tropics
IFAC . . . . . French Research Institute for Overseas Fruits
IFAGRARIA . . . . . Italian Industrial and Financial Organization for the Progress of Agriculture
IFDC . . . . . International Fertilizer Development Center
IITA . . . . . International Institute of Tropical Agriculture
IRAT . . . . . Research Institute for Tropical Agriculture
IRCT . . . . . Research Institute for Cotton and Textile Fibers
IRHO . . . . . Research Institute for Oil and Oil Crops
ISRA . . . . . Senegalese Agricultural Research Institute
OMVS . . . . . Organization for the Development of the Senegal River
SAFGRAD . . . . . Semi-Arid Food Grain Research and Development
SCAER . . . . . Society of Agricultural Credit and Rural Equipment
SIES . . . . . Industrial Fertilizer Society of Senegal
SIVENG . . . . . Ivory Coast Fertilizer Society
UNDP . . . . . United Nations Development Programs
UNIDO . . . . . United Nations Industrial Development Organization
USAID . . . . . United States Agency for International Development
USDA . . . . . United States Department of Agriculture
WARDA . . . . . West Africa Rice Development Association

OBJECTIVES OF STUDY

The objectives of the IFDC West Africa Fertilizer Study are to:

1. Determine the present status of the west African region (primarily Sahelian area) to produce, market, and use fertilizers.
2. Inventory the known deposits of fertilizer raw materials within the region and determine their economic potential for use in producing a low-cost fertilizer for the farmers of the region.
3. Provide a preliminary assessment of the present and future fertilizer requirements for the region and suggest possible alternatives to meet those needs.
4. Establish an overall plan of work that will lead to a document which describes the future strategies that are necessary to the development of a sound fertilizer industry in west Africa.

SUMMARY OF FINDINGS

1. Major food deficits loom by 1985. Estimated requirements for millet and sorghum in the six countries are expected to be about 2.2 million mt more than 1974 production. Mali, Upper Volta, and Niger will account for 67% of the potential deficit. About 460,000 mt of rice in excess of 1974 production will be needed in Senegal.
2. Most of the six countries attempt to control prices of agricultural inputs and outputs. Crop prices are either fixed or have minimums set for the producer, or retail prices are set. Crop price supports have been maintained most effectively on export crops. Cereal prices have fluctuated greatly both geographically and seasonally. There appears to be little sound information to substantiate these policy decisions.
3. Most crop marketing development organizations are oriented by commodity. This leads to an apparent duplication of effort in many geographic areas.
4. Statistical reporting generally is inadequate for good agricultural development planning and implementation. Improvement in statistical reporting is needed for land areas in production and for changes in crop yields.
5. Generally, extension advisory services receive limited financial support and require improve-

ments in quality. Immediate attention is needed to upgrade the present scope and effectiveness of the service.

6. The level of fertilizer use is low in all the countries, although Senegal consumes more fertilizers than the other five countries combined. Apparently, less than 5% of the cultivated area is fertilized in Mauritania, Niger, and Upper Volta; 7-12% in Mali and Chad; and about 25% in Senegal.

7. The cost of fertilizers to inland country governments is $80-100/mt higher than world prices (net of freight) because of small quantities purchased and special nature of materials ordered. Substantial savings in fertilizer cost can accrue to the governments of Mali, Upper Volta, and Chad by ordering standard high-analysis fertilizer materials, shipped in 1-mt containers.

8. Very little is known about "on-farm" response to fertilizer. The majority of available data relates only to experiment station conditions. Extremely limited data indicate cereal responses may be roughly 10 kg of grain/kg of nutrients at recommended rates on farms.

9. At 1976 farm prices for fertilizer and millet or sorghum, a response of 10 kg of grain/kg of nutrient gives an average value of increased grain of about 6.5 times the cost of fertilizer in Senegal; 3.0-4.0 in Niger and Upper Volta; and 1.7 in Mali. Price and cost relationships are more favorable for rice, cotton, and peanut than millet and sorghum.

10. Importing and using fertilizer can result in grain production valued at more than three times the cost of fertilizer (each on imported basis) where adequate education is extended on proper fertilizer use.

11. The six countries have a potential to double 1975 fertilizer nutrient consumption by 1980 and triple it by 1985, provided favorable fertilizer/crop prices are established and maintained; agricultural inputs are available; and stable crop marketing channels are established.

12. Significant quantities of phosphate rock exist in Senegal, Niger, Mali, and Upper Volta. Deposits have been reported in Mauritania and are suspected in Chad; however, their extent and quality are unknown.

13. Phosphate deposits in Senegal are developed. Exploration and/or mining and grinding of rock from deposits are under way in Mali, Niger, and Upper Volta. Substantial potential exists for further development of any one or all of these deposits. Development of these deposits to supply PR for direct application where agronomically suitable could materially reduce the cost of phosphates to farmers in the region.

14. Agronomic research has shown direct application of phosphate rocks from Taiba in Senegal, Tilemsi Valley in Mali, and Tahoua in Niger to be effective for some crops in the Sahelian region. Available information is scarce and limited comparisons have been made for different sources of phosphates. Information is inadequate to establish the relative value of phosphate rocks in comparison with soluble phosphates, although some appear to be nearly as effective when considering crop responses over 3-4 years.

15. It appears impractical to chemically process any of the phosphate rocks in the landlocked countries at the present time

because of the low level of use and incomplete characterization of some rocks. Single superphosphate can be manufactured at costs similar to imports of this material. Single superphosphate, however, is more expensive on a nutrient basis than triple superphosphate or diammonium phosphate.

16. The international and regional transportation systems serving the Sahelian countries are generally adequate to handle the anticipated fertilizer movement to the more populated areas. Movement on national systems is hampered during the rainy season and better maintenance is needed. New roads will be needed as new land areas are settled.

17. There appear to be no serious problems in storing fertilizer outside when it is properly bagged in black woven polypropylene outer bags with an inner tubular polyethylene film.

RECOMMENDATIONS

1. Initiate a soil fertility project which combines testing of phosphate rocks, investigation of on-farm crop responses to nutrients, training extension personnel in crop production techniques, and documentation of project outcome in each of the six countries. This project should be conducted in areas where input delivery systems and crop marketing are available.

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

3. Conduct feasibility studies for mining and grinding of phosphate ore for direct application in Niger and Upper Volta. The facilities should be of a size sufficient to supply a major portion of the P_2O_5 requirements of farmers in Niger and Upper Volta.

4. Establish bulk-blending facilities in Chad and Upper Volta. The plant in Chad would serve the domestic market while the Upper Volta plant would serve Upper Volta and Mali. Individual plants to serve each domestic market could be justified, but would show less savings. The system should be a simple low-technology operation utilizing imports in 1-mt bags which can serve for storage as received.

5. Conduct a study to characterize the nature of phosphate rocks in Upper Volta to determine feasible means by which the rocks may be utilized. This should include grinding tests for liberation of phosphate for direct application as well as for chemical extraction and beneficiation.

6. Undertake exploration of phosphate deposits in Mauritania to define the size, quality, and feasibility of mining.

7. Conduct an aerial radiometrics study of the Bahr-er-Ghazal area in Chad to define areas in which prospecting for phosphate rock would be most promising.

8. Conduct a study in each of the six countries to determine the influence of various forms of

subsidy and taxes in the agricultural sector upon regional and national economy and social development and provide guidelines for making these kinds of policy decisions.

9. Conduct a study in Chad, Mali, Mauritania, Niger, and Upper Volta to determine the status and needs of extension, credit, crop marketing institutions, and determine feasibility of consolidating some marketing organizations.

10. Conduct a study in each country to identify problems and recommend solutions for obtaining better statistical reporting information. The possibility of incorporating aerial sensing into the system for crop reporting might be considered.

11. Conduct a study in each country to determine social costs and benefits from increasing productivity per unit of land as compared with expanding land area in production.

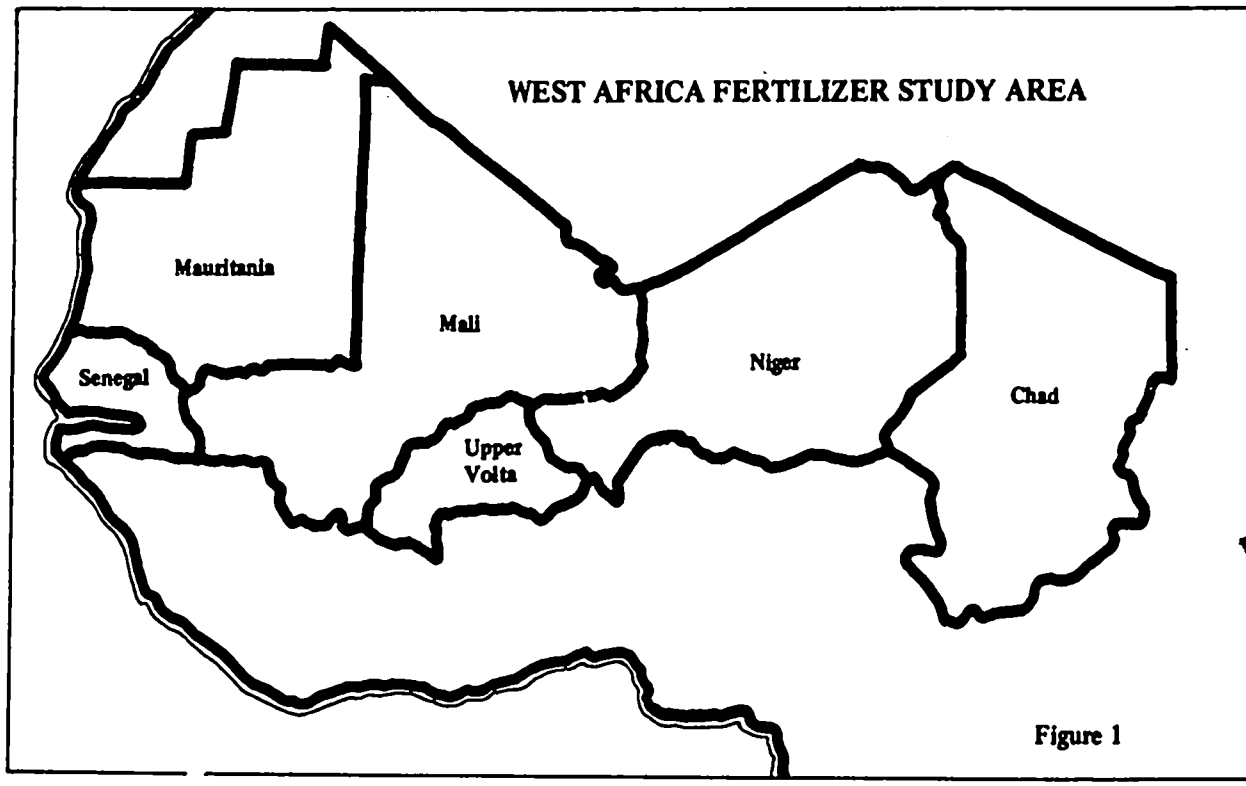


Figure 1

INTRODUCTION

The six Sahelian countries of west Africa (figure 1)--Chad, Mali, Mauritania, Niger, Senegal, and Upper Volta--suffered a series of drought years between 1966 and 1972. The droughts severely decreased crop and livestock production and forced large imports of food, particularly cereals.

National economies in the region are greatly dependent upon agriculture; more than 85% of the population is rural. Agricultural productivity is low throughout the region and less than 20% of potential agricultural land is under cultivation. The potential, however, exists for agricultural development.

Physical Characteristics

The land area of the six Sahelian countries is primarily part of a large uneven plateau area (1). Elevations range from 200 to 500 m. There are three prominent watersheds: the Senegal, Niger, and Chad Basins. The Niger and Senegal Rivers originate in the Guinea highlands and drain into the Atlantic. The Chad Basin drains into Lake Chad.

Five vegetative zones are shown in figure 2. In general, as rainfall and the length of the rainy season decrease, moving from south to north, trees become smaller and more widely separated. Passing northwards from the Savanna-Forest Mosaic in the south

there are successive east-west belts of northern Guinea savanna, Sudan savanna, and Sahel savanna reaching near desert vegetation in the north. Annual rainfall and length of rainy season decrease from about 1,500 mm (over a 4-month period) in southern Guinea to 100 mm (over a 2-month period) in the northern Sahel (2).

Soil classes of the region are shown in figure 3. Ferruginous tropical soils are the dominant agricultural soil class. Brown and reddish brown soils of arid and semiarid regions are second in significance. Hydromorphic and ferrallitic soil classes are third in importance.

Ferruginous tropical soils appear to account for about 90% of the cultivated soils in the region. The soils occur in areas with 500 to 1,200 mm annual rainfall and distinct wet and dry seasons (2). Generally they have been formed on parent material rich in quartz. These soils are characterized by downward movement of clay; formation of mottles, concretions or hardpan; sandy surface; low organic matter content; low base exchange capacity; and a compact subsoil. Most profiles are shallow, less than 150 cm. The clay fraction is predominantly kaolinite. Ferruginous tropical soils are mostly classed as alfisols in the USDA new classification system. Agricultural value of these soils is poor to average. Major problems in these soils are susceptibility to erosion and temporary ponding of water.

Brown and reddish brown soils primarily occur in arid and semiarid regions with less than 500 mm of rainfall per year. They are mostly classed as inceptisols in the USDA new classification system. These soils are principally formed on aeolian sands. Little weathering and leaching have occurred; montmorillonite and illite clays are often present. Exchange capacity can be higher than in ferruginous tropical soil. Organic matter is low, but well distributed in the profile. The soils are most suited to grazing of livestock because of low rainfall but crops can be grown in some areas.

Ferrallitic soils occur in areas of more than 1,200 mm of rainfall per year (3). They are mostly classed as oxisols in the USDA new classification system. They are deeper, better structured, and more porous than ferruginous soils. Ferrallitic soils have slightly differentiated horizons and clay content increases gradually with depth. They contain little or no weatherable minerals and the clay fraction consists of kaolinite and iron and aluminum oxides. Ferrallitic soils have higher cation exchange capacity but lower base saturation than ferruginous tropical soils. The largest areas of ferrallitic soils are found in southwest Senegal and southern Chad.

Agriculturally, soils found along rivers and streams are the most important hydromorphic soils in the region. The largest bodies of hydromorphic soils are along the Niger River in Mali and in south central Chad. These soils vary in characteristics depending upon their origin. Generally, they are higher in organic matter than surrounding upland soils. Agricultural potential is generally good. Typically, rice is grown during the rainy season and maize, sorghum, and vegetables during the dry season.

Political and Economic Characteristics

In the six countries studied, a general pattern of centralized authority and decision making exists in the political system. Local government is rarely local in the sense of decision making; rather, local government is part of a centralized national structure involving appointed positions. Mass participation in local government is not great.

The six Sahelian countries share similar economic problems. All countries have relatively small and sparsely settled populations with only

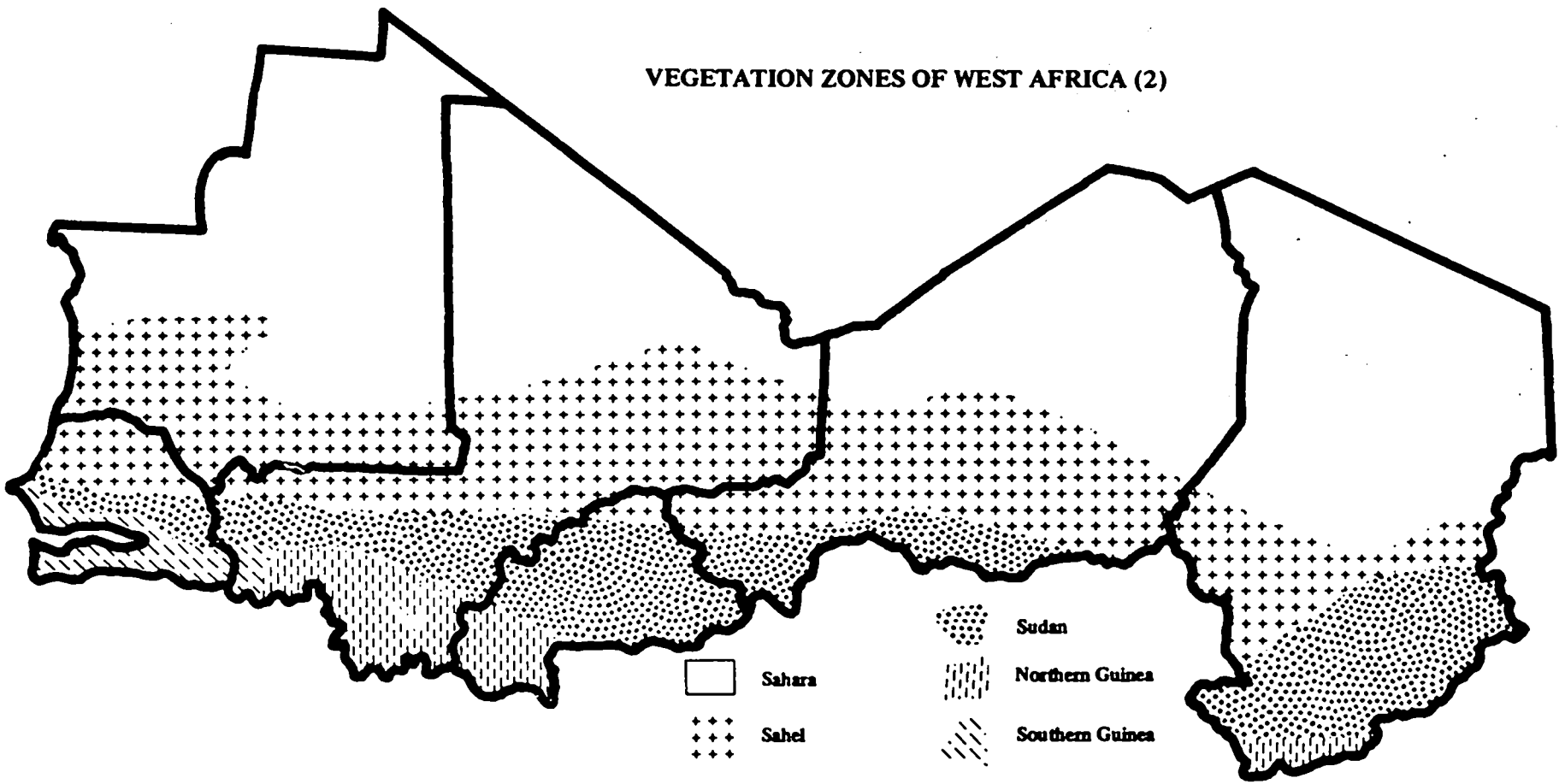

VEGETATION ZONES OF WEST AFRICA (2)
Sahara
Sahel
Sudan
Northern Guinea
Southern Guinea

Figure 2

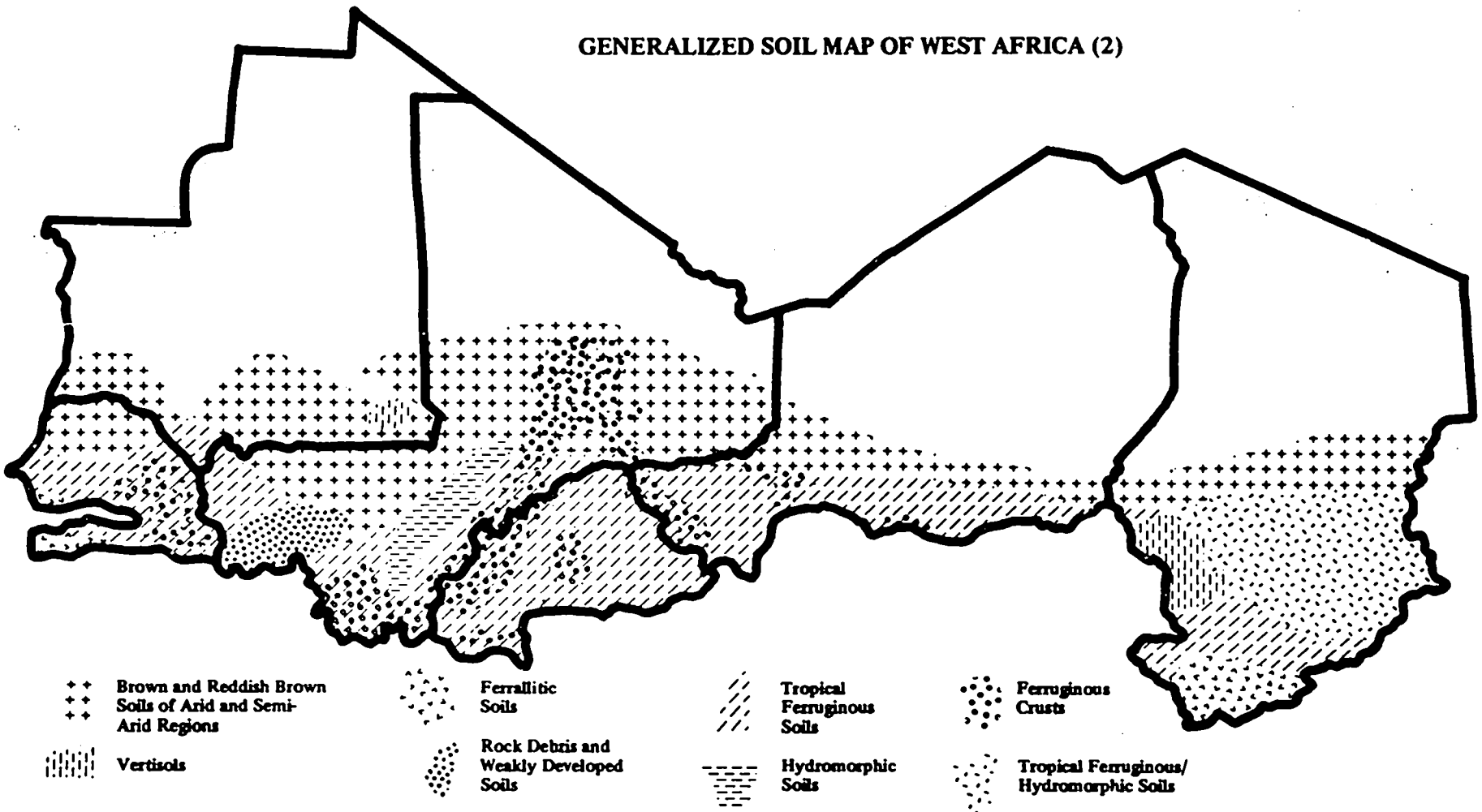

GENERALIZED SOIL MAP OF WEST AFRICA (2)
Brown and Reddish Brown Soils of Arid and Semi-Arid Regions
Vertisols
Ferrallitic Soils
Rock Debris and Weakly Developed Soils
Tropical Ferruginous Soils
Hydromorphic Soils
Ferruginous Crusts
Tropical Ferruginous/ Hydromorphic Soils

Figure 3

spots of high population density. The labor forces are largely unskilled and most countries have 85 to 90% of the active population engaged in agriculture. Per capita income is low, less than $200 per year in all countries.

The region has an unusually high degree of dependence on foreign aid assistance to finance economic development projects; this has been particularly the case since Sahelian drought relief programs began.

Despite the many similarities, differences among the six countries can be detected. Senegal and Mauritania, both coastal countries, have per capita incomes substantially higher than the inland countries of Chad, Mali, Niger, and Upper Volta (table 1). Likewise, Senegal has a much higher level of industrialization (16% of GDP in 1970) and urbanization (29.4% in 1975) compared with the other countries, where industrialization ranges from 2 to 10% and urbanization ranges from 9 to 14%.

Levels of exports and imports vary considerably among countries as do trade balances (table 2). Of the six countries, only Mauritania has a positive trade balance (90% of Mauritania's export earnings come from the production and sale of iron ore).

Food is a major import in all countries, accounting for over 25% of total imports, except in Niger. Between 1969 and 1973, the imports and exports of agricultural products were generally in balance (table 3). However, by 1974, only Chad's and Upper Volta's agricultural exports exceeded imports. The shift in trade balance was more a result of increased agricultural imports than a decline in agricultural exports.

POPULATION AND FOOD NEEDS

Population

Populations of the six countries range between 4.2 and 6.1 million, except for Mauritania with a population of 1.3 million (table 4). Average national population growth rates range from 2.6 to 2.9% per year, although urban populations are growing at rates twice national averages. According to FAO, the active population, as a percent of total, varies from about 30% for Mauritania and Niger to 55% for Mali and Upper Volta (5).

Population densities in the countries range from 1.3 persons per km^2 in Mauritania to over 22.0 persons per km^2 in Senegal and Upper Volta. Population distribution is shown in figure 4. The highest densities occur in Senegal and Upper Volta, which have no land area within the desert zone. The lowest population density is encountered in Mauritania, which has the greatest portion of land in the desert zone.

Regional Cereal Requirements

Millet and sorghum are the primary cereals eaten in all the countries. Rice is a major food staple only in Senegal, where it accounts for about 35% of total cereal demand. Estimated per capita and total demand for the major cereals in the region are shown in table 5. In 1975 the estimated consumptive demand was 3.6 million mt of millet and sorghum, 445 thousand mt of rice, and 254 thousand mt of maize.

Table 1. Per Capita Income and Gross Domestic Product of Countries in the Sahelian Region (4, 5)

Income or GDP	Chad		Mali		Mauritania		Niger		Senegal		Upper Volta	
	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970
Per capita income, (total), $	84	66	55	46	90	152	78	86	217	189	38	56
Per capita income, (farmer), $	48	36	34	22	60	58	56	54	101	73	27	28
Per capita income, (nonfarmer), $	774	373	241	300	364	830	378	422	583	602	131	274
GDP (1974), million $	300		400		300		400		1,100		400	

Table 2. Recent Evolution of Commercial Balance, 1970-74 (5)

	Chad		Mali		Mauritania		Niger		Senegal		Upper Volta	
	1970	1974	1970	1974	1970	1974	1970	1974	1970	1974	1970	1974
Exports, million $	39.8	62.3	32.8	59.4	117.3	199.0	46.7	73.3	222.0	397.7	24.6	58.7
Imports, million $	66.3	104.3	47.3	180.8	106.6	185.5	68.8	161.7	310.9	540.1	54.4	202.7
Food imports, %	20.5	31.5	4.2	41.5	14.6	24.1	7.3	8.2	22.2	31.5	23.1	45.4
Balance, million $	-26.5	-42.0	-14.5	-121.4	+10.7	+13.5	-22.1	-88.4	-88.9	-142.4	-29.8	-144.0

Table 3. Imports and Exports of Agricultural Products (6)

Country		Value, $1,000					
		1969	1970	1971	1972	1973	1974
Chad	Imports	10,510	13,440	12,080	15,350	19,260	28,180
	Exports	36,720	35,530	36,740	44,280	51,160	59,440
Mali	Imports	14,290	12,420	18,460	21,000	39,970	72,830
	Exports	21,930	31,730	32,300	40,820	40,050	42,680
Mauritania	Imports	12,030	12,700	14,220	16,180	21,760	39,230
	Exports	17,520	18,600	17,600	19,110	18,320	19,930
Niger	Imports	6,880	7,480	7,190	10,380	13,500	42,940
	Exports	34,990	41,000	37,330	49,890	36,650	25,310
Senegal	Imports	82,410	68,950	76,200	82,980	139,960	211,080
	Exports	77,740	90,370	55,250	126,950	91,300	145,180
Upper Volta	Imports	11,980	12,880	11,890	15,120	17,730	26,330
	Exports	24,040	24,130	21,530	22,870	27,840	39,180

Table 4. Estimated Population, Characteristics in the Six Sahelian Countries (5)

	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta
Population density, person/km^2	3.3	4.6	1.3	3.6	22.7	22.1
1975 population						
Total, 1,000 persons	4,199	5,668	1,330	4,579	4,452	6,058
Rural, % of total	86.1	86.5	89.0	90.6	71.6	91.7
Urban, % of total	13.9	13.5	11.0	9.4	28.4	8.3
Agricultural, % of total	89.3	89.6	85.9	88.5	75.0	87.1
1975-80 growth rate, % year						
Total	2.9	2.7	2.7	2.9	2.7	2.6
Rural	2.2	2.4	2.3	2.6	2.0	2.3
Urban	6.7	4.9	5.6	5.6	4.4	5.4
Agricultural	2.4	2.3	2.2	2.2	1.8	2.0
Nonagricultural	7.0	6.0	5.8	7.9	5.4	6.0
1975 active population						
Active total, 1,000 persons	1,475	3,097	409	1,429	1,903	3,299
Active total, % of total	35.1	54.6	30.8	31.2	42.7	54.5

1974 ESTIMATED POPULATION DENSITY

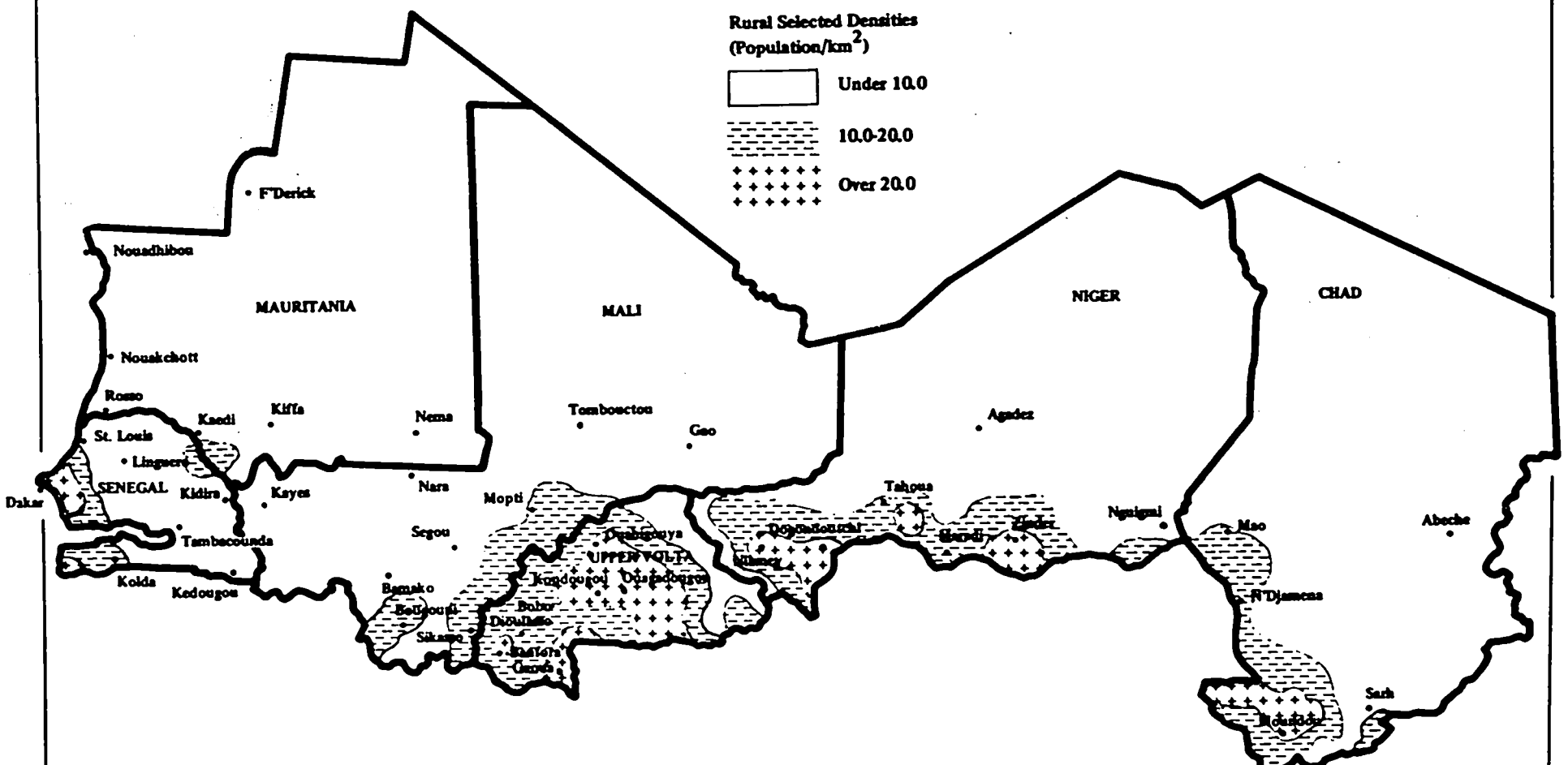


Figure 4

Table 5. Estimated 1970 and Projected (1975-90) Demand for Major Cereals in the Six Sahel Countries (5)

Country	Per Capita Demand, kg/person					Total Demand, 1,000 mt				
	1970	1975	1980	1985	1990	1970	1975	1980	1985	1990
					Millet/Sorghum					
Chad	157.7	158.8	157.6	154.3	148.9	574	667	763	860	956
Mali	143.1	144.1	144.4	144.0	142.9	722	817	937	1,083	1,251
Mauritania	99.9	100.8	101.5	102.0	102.3	117	134	154	178	206
Niger	166.6	167.4	166.5	164.2	160.4	669	766	880	1,010	1,154
Senegal	94.3	95.2	96.1	97.1	98.0	370	424	489	566	657
Upper Volta	129.8	130.8	131.0	130.7	129.7	699	792	902	1,026	1,166
Total						3,151	3,600	4,125	4,723	5,390
					Rice (milled)					
Chad	7.1	7.5	8.0	8.4	8.9	26	32	39	47	57
Mali	14.9	15.5	16.0	16.6	17.2	75	88	104	125	151
Mauritania	17.1	18.0	18.9	19.8	20.8	20	24	29	35	42
Niger	4.7	5.0	5.2	5.5	5.8	19	23	28	34	42
Senegal	55.8	56.9	58.0	59.1	60.2	219	253	295	345	404
Upper Volta	4.1	4.3	4.5	4.7	4.9	22	26	31	37	44
Total						381	446	526	623	740
					Maize					
Chad	2.2	2.2	2.3	2.3	2.3	8	10	11	13	15
Mali	17.4	17.6	17.8	18.0	18.1	88	100	115	135	159
Mauritania	3.4	3.5	3.5	3.6	3.6	4	5	5	6	7
Niger	0.5	0.5	0.5	0.5	0.5	2	2	3	3	4
Senegal	15.8	16.0	16.1	16.3	16.4	62	71	82	95	110
Upper Volta	10.8	11.0	11.2	11.6	11.8	58	67	78	91	106
Total						255	254	294	343	401

FAO projections on estimated increases in demand for the major cereals in 1980, 1985, and 1990, are shown in table 6. The projected growth in demand for millet and sorghum over 1975 demand is expected to increase by 1.8 million mt by 1990. An additional 294 thousand mt of rice and 147 thousand mt of maize over 1975 demand is also projected by 1990.

Rural and Urban Cereal Requirements

Under normal cropping conditions, rural populations will produce sufficient cereals to feed themselves, albeit at a subsistence level. Urban population, however, must depend upon commercial production (domestic or import) to supply demand. Thus, it is the urban demand that determines market demand.

Estimates of urban demand for major cereals were based upon FAO urban population projections and national per capita levels of consumption; these projections are shown in table 7. Urban diet preferences are likely different from rural, however, no information was available on such differences for these countries.

Urban demand for millet and sorghum is projected to increase to 620,000, 800,000, and 1,000,000 mt by 1980, 1985, and 1990, respectively. Urban demand for maize and milled rice is projected to be 175,000, 230,000, and 290,000 mt by 1980, 1985, and 1990, respectively.

Overall projected rural and urban food requirements, as shown in table 5, are 5.4 to 6.8 times greater than projected urban food demand, as shown in table 7. Urban food demand is probably a more realistic indicator of potential deficits since rural populations, as mentioned previously, tend to produce subsistence food requirements in normal years.

Cereal Supply Situation

The distribution of areas of cereal deficit and surplus is shown in figure 5. Food deficit areas are found in northern Senegal extending inland from the coast; in most of Mauritania; northern Mali; most of Niger; and western Chad extending eastward from Lake Chad.

Table 6. Estimated Increased Demand for Major Cereals Over 1975 Estimated Demand (5)

	Increase over 1975, 1,000 mt						
Year	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Total
				Millet/Sorghum			
1980	96	120	20	114	65	110	525
1985	193	266	44	244	142	234	1,123
1990	289	434	72	386	233	374	1,788
				Rice (milled)			
1980	7	17	5	5	42	5	81
1985	15	38	11	11	92	11	178
1990	25	63	18	19	151	18	294
				Maize			
1980	2	16	1	-	11	11	41
1985	3	35	2	1	24	24	89
1990	6	59	3	2	39	40	149

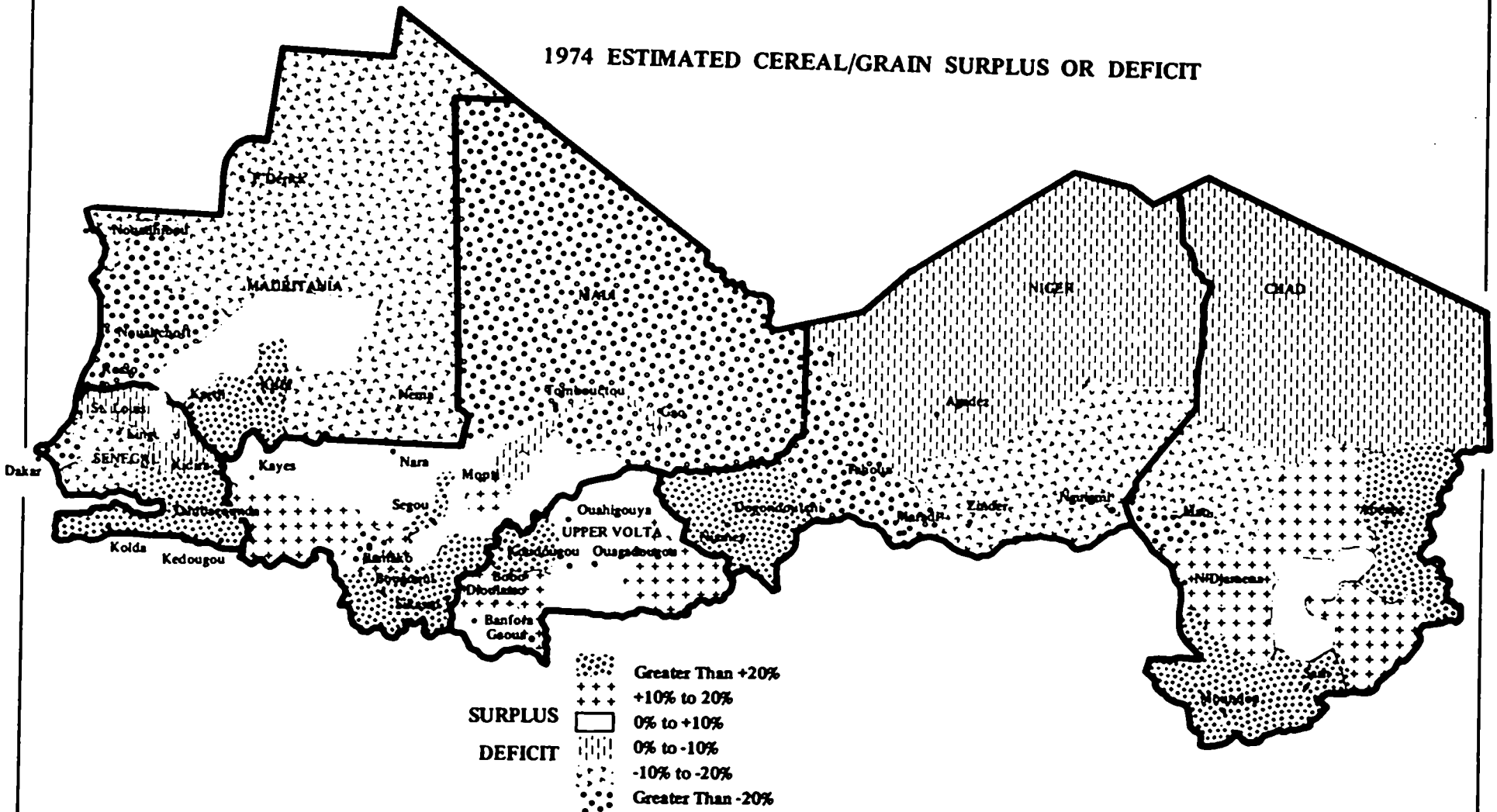

1974 ESTIMATED CEREAL/GRAIN SURPLUS OR DEFICIT
MAURITANIA
MALI
NIGER
CHAD
SENEGAL
UPPER VOLTA
Dakar
Kayes
Nara
Mopti
Segou
Kolda
Kedougou
Ouahigouya
Bobo
Banfora
Geouf
Tombouctou
Agadez
Tahoua
Zinder
Nouakchott
SURPLUS
DEFICIT
Greater Than +20%
+10% to 20%
0% to +10%
0% to -10%
-10% to -20%
Greater Than -20%

Figure 5

Recent cereal production and potential deficits over 1974 production levels for total population are shown in table 8. Deficits for 1976 are less than indicated, since it was generally reported that 1975 production of millet and sorghum had reached the levels experienced in years prior to the drought.

Table 7. Estimated Urban Demand for Major Cereals, 1975-1990[a]

Year	Estimated Urban Demand, 1,000 mt						
	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Total
				Millet/Sorghum			
1975	92.6	109.8	14.7	71.8	120.1	65.7	474.7
1980	127.3	140.1	19.5	93.7	150.6	85.7	616.9
1985	169.1	180.3	25.7	122.0	189.6	111.2	797.9
1990	216.8	231.6	33.8	157.4	239.0	143.6	1,022.2
				Rice (milled)			
1975	4.4	11.8	2.6	2.1	71.8	2.2	94.9
1980	6.5	15.5	3.6	2.9	90.9	2.9	122.3
1985	9.2	20.8	5.0	4.1	115.4	4.0	158.5
1990	12.9	27.9	6.9	5.7	146.8	5.4	205.6
				Maize			
1975	1.3	13.4	0.5	0.2	20.2	5.5	41.1
1980	1.9	17.3	0.7	0.3	25.2	7.3	52.7
1985	2.5	22.5	0.9	0.4	31.8	9.9	68.0
1990	3.3	29.3	1.2	0.5	40.0	13.1	87.4

[a]Calculated from reference 5.

FOOD PRODUCTION

Estimated cereal production per capita in 1974 ranged from 25 kg in Mauritania to 185 kg in Niger; it was 136-156 kg per person in Chad, Mali, and Senegal. Average yield of millet and sorghum generally is less than 500 kg per ha and yield of rice less than 1 mt per ha (table 9). Some of the constraints on productivity are low levels of use of animal traction, fertilizers, improved seed, and good cultural practices.

Land Use

Most crop production in the region follows a pattern of modified shifting cultivation. Villages are rather permanent and crops are grown continuously on land nearest villages. Land farther from villages is cleared and cultivated for 4 to 5 years, then fallowed for 5 to 15 years depending upon population pressures.

Table 8. Production and Potential Deficits of Major Cereals in the Sahelian Countries Based Upon 1970 Per Capita Consumption (5, 7)

Country	Average Production, 1,000 mt			Increases Over 1974 Production Needed to Meet Population Requirements, 1,000 mt		
	1961-65	1970-74	1974	1980	1985	1990
			Millet/Sorghum			
Chad	895	497	528	321	449	596
Mali	782	645	600	431	595	791
Mauritania	93	53	30	139	164	193
Niger	830	766	800	179	339	532
Senegal	482	459	500	33	111	202
Upper Volta	814	769	620	373	512	677
Total	3,896	3,189	3,078	1,476	2,170	2,991
			Rice (Paddy)			
Chad	29	37	37	22	31	41
Mali	170	161	200	-	-	22
Mauritania	1	1	1	43	50	58
Niger	11	37	43	-	7	15
Senegal	100	79	95	390	461	545
Upper Volta	34	32	25	23	30	38
Total	345	347	401	478	579	719
			Maize			
Chad	11	7	7	5	7	9
Mali	80	77	87	39	59	83
Mauritania	4	4	3	3	4	5
Niger	3	2	3	-	-	1
Senegal	32	34	40	49	62	78
Upper Volta	100	58	50	32	46	58
Total	230	182	190	128	178	234

Table 9. Average Crop Yields, 1970-1974 (7)

Crop	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta
	kg/ha					
Wheat	1,684	1,333	287	878	-	-
Rice paddy	732	953	951	2,056	1,097	889
Maize	946	819	571	588	849	686
Millet	534	551	254	390	474	382
Sorghum	-	-	-	466	-	476
Cowpeas	-	-	281	106	282	254
Peanut in shell	588	602	500	559	719	439
Seed cotton	370	808	-	456	1,088	377

Little land is individually owned. Most is controlled by village chiefs or heads of extended families. The village or family food supply and cash for essentials are assured through joint cultivation. Individuals may then cultivate additional land on their own.

Normally, a single individual can cultivate from 0.8 to 1.2 ha by hand or 2 to 3 ha with animal traction. Use of animal traction is very low in most of the region. Yet, on many soils plowing can increase yields by 20-30% (1).

The region has about 62 million ha of potentially agricultural land but only about 18% is in crops (table 10). More than 48 million ha receive above 350 mm of rainfall per year (5). Land area under cultivation per farmer is likely near maximum using the present methods of cultivation (primarily manual).

To achieve greater self-sufficiency in food production, productivity per worker must be increased. This can be accomplished by either increased land area per worker or by increased production per unit of land (or both). It appears that the reasonable approach is to increase both through the use of a variety of inputs, that is, a combination of greater animal traction, increased fertilizer use, improved seed, and pest control.

Increased fertilizer use can play a key role in such a development strategy. Maximum benefit from fertilizer, however, requires that it be used in combination with other improved crop production practices.

An analysis of the social and economic costs and benefits of increasing land area in crops versus increasing productivity per unit area is needed in each country to objectively determine the emphasis which should be placed on each strategy.

Agricultural Policy

A greater understanding is needed in all six countries of the effects various price stabilization and equalization programs have had on national and regional economies. Policies relating to crop production in the Sahelian countries generally have favored the export crops of cotton and peanuts, although, at times, prices and tax levies have even discouraged production of these crops.

Table 10. Land Area and Agricultural Potential (5, 7)

	Chad	Mali	Mauritania	Niger	Senegal	Upper Volt.
Land area (1,000 km^2)	1,284	1,240	1,031	1,267	196	27
Agriculture Potential (1,000 ha)	19,778	14,198	2,127	10,776	6,329	8,88
Zone A (Isohyet < 350 mm)	3,196	2,640	1,346	5,116	742	37
Zone B (Isohyet 350-600 mm)	3,222	4,179	749	5,131	2,106	2,48
Zone C (Isohyet 600-800 mm)	7,569	1,940	32	529	1,181	2,58
Zone D (Isohyet > 800 mm)	5,791	5,439	-	-	2,300	3,44
Irrigation Potential (1,000 ha)	180	2,040	140	160	390	19
Cultivated area (1,000 ha)[a]	1,447	1,782	257	3,311	2,260	2,40
% of potential	7	13	12	31	36	2

[a]Five year average 1970-1974.

Availability of adequate markets to growers influences real commodity prices. Unpredictable market demand has increased uncertainty and thus hindered the development of commercial agriculture in food crops.

Since 1974, all six countries have increased the priority on food crop production. All of the countries now have food crop production projects and most have reoriented cotton and peanut production projects to include more emphasis on food crops.

Supply of credit and other inputs, as well as crop marketing, is channeled through cooperatives in Senegal and Niger and largely through administrative agricultural development districts in the other countries.

Fertilizer prices to farmers are subsidized in all six countries. Levels of subsidy vary widely among countries and among types of fertilizer. Most countries have a central organization responsible for supplying fertilizers to farmers through cooperatives, project managements, and development companies.

Details on marketing and prices of inputs and commodities are found in individual country reports (volumes 2-7).

Regional Organizations

A variety of regional organizations exists to promote agricultural and economic development in the Sahelian region:

CEAO--The West African Economic Community (CEAO) was started in 1974 and has operated through a Commission of the heads of member states; a Council of Ministers of member states; and committees of local experts. CEAO has only recently been fully organized and there are no operational projects at the present time. Regional activities will be planned by the group. CEAO has placed the highest priority upon projects involving energy, water, and communications.

CILSS--The Permanent Interstate Committee for Drought Control in the Sahel (CILSS) was created in September 1973. Its objective is to promote the rural development in the region, including water supplies, reforestation, cattle, and agricultural production. Eight country members are: Cape Verde, Gambia, Upper Volta, Mali, Mauritania, Niger, Senegal, and Chad. Development strategy is agreed upon by the Council of Ministers of the CILSS countries.

Club des Amis du Sahel--The Club des Amis du Sahel was created in March 1976 to support the medium- and long-term rehabilitation efforts of the Sahel. The club is jointly sponsored by CILSS member countries, certain donor countries, and international organizations. The Club will support work of CILSS; foster increased cooperation among donors; and provide a forum for discussing potential development projects. Working groups, under the chairmanship of the CILSS coordinator, will be established to explore specific issues. The club will meet at least once a year.

OMVS--The Organization for the Development of the Senegal River (OMVS) was created in 1972 to develop river transport, hydroelectric power, irrigation, and port facilities of the region. Members of OMVS are Mali, Mauritania, and Senegal. The organization consists of (1) the Conference of Heads of State; (2) the Council of Ministers with one Minister from each state, meeting at least once a year and in extraordinary sessions; and (3) the General Secretariat, based in Dakar. Projects in the first phase include construction of dams at Manantali, Mali, and near Saint Louis, Senegal, and development of ports at Saint Louis and at Kayes, Mali. Subsequent projects will deal with irrigation, industry, mining, land transportation, and extension of electric power supply.

Liptako-Gourma Authority--Liptako-Gourma Authority was created in December 1970 by three Chiefs of

State of the Republics of Upper Volta, Mali, and Niger to promote, under a regional structure, the development of mining, energy, hydraulic, agricultural, range, and forest resources of the Liptako-Gourma region covering an area of 470,000 km^2. The headquarters is located in Ouagadougou, Upper Volta. The policy making body of the Authority is the Council of Ministers, with a general Directorate in charge of project implementation.

WARDA--West Africa Rice Development Association (WARDA) was founded in 1970 and started to function in December 1971 to work toward self-sufficiency in rice within the region. Members of this intergovernmental organization consist of Benin, Gambia, Ghana, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo. The headquarters of WARDA is based in Monrovia, Liberia. Each member state has one representative in the Governing Council which is the policy making body. Work programs are reviewed by the Scientific and Technical Committee. Financial and programming aspects of the projects are studied by an Advisory Committee. The Council and its committees meet once a year. The administrative budget of WARDA is financed by member countries. Research and development projects are financed by cooperating countries and international organizations, namely France, the Netherlands, United Kingdom, United States, Ford Foundation, and the UNDP. All the WARDA activities are coordinated by the Executive Secretary.

AGRICULTURAL RESEARCH

Research on crop variety improvement and selection, cultural practices, fertilization, and plant protection is conducted at the national level on experiment stations with technical assistance from French research groups. French institutes providing assistance are: Research Institute for Tropical Agronomy (IRAT), Research Institute of Cotton and Textile Fibers (IRCT), Research Institute of Oil and Oil Crops (IRHO), and Research Institute for Overseas Fruits (IFAC).

USAID has funded a project of Semi-Arid Food Grain Research and Development (SAFGRAD) oriented toward regional research; development of technological packages; and assistance in national field testing.

The Institute for Crop Research in the Semi-Arid Tropics (ICRISAT) and the International Institute for Tropical Agriculture (IITA) will have primary roles in the regional research and training activities. The National Center of Agronomic Research (CNRA) at Bambey, Senegal, and the Institute for Agricultural Research (IAR) at Samaru, Nigeria, serve as regional research centers.

Crop Response to Fertilizer

Research at experiment stations in the region shows response of cereals to N and P. At application levels of 30-50 kg of nutrients per ha, a response of 10-30 kg of cereals per kg of nutrient is often obtained. In some research trials, a response to K and S is obtained under intensive continuous cultivation.

Factors influencing crop response to fertilizers are: variety and quality of seed; planting date; soil

tillage; weed, disease, and insect control; as well as soil fertility. Typically, crop response to fertilizer in farmers' fields is less than on experiment stations because cultural practices are less well controlled on farms than research stations.

Little farm level data are available for crop response to fertilizer. Limited data indicate responses of 8-12 kg of millet or sorghum and 12-18 kg of rice per kg of nutrient when 30-50 kg of N and P_2O_5 are applied per ha. Thus, when crop production factors are reasonably controlled, 10 kg of cereals may be obtained per kg of nutrient under farm conditions. However, such findings are tentative and more crop response data under farm conditions are needed in all six countries.

At 1976 farm prices, the ratio of nutrient cost to the price of millet and sorghum (cost:price ratio) is about 1-2 in Senegal; 2.5-3.0 in Niger; 3-4 in Upper Volta; 5-6 in Mali, and 7-12 in Chad. Provided a response of 10 kg of grain is obtained from each kg of nutrient, the average value of increased yield is about 6.5 times the cost of fertilizer in Senegal; 3-4 in Niger and Upper Volta; 1.7 in Mali; and 1 in Chad.

The cost:price ratio appears adequate to encourage fertilizer use for millet and sorghum in Senegal, Niger, and Upper Volta, although the ratio is generally unfavorable in Chad and Mali. In all of the countries, commodity price and cost relationships are more favorable for rice, cotton, and peanut than for millet and sorghum. Details of agro-economic investigations on response of crops to fertilizer are found in individual country reports (volumes 2-7).

Phosphate Rocks as Sources of P

Ground phosphate rock (PR) from many deposits is an effective source of P for crops, particularly on acid soils. PR from various deposits differs in agronomic effectiveness because of different chemistry and mineralogy of the rocks. Ground PR from Taiba, Senegal; Tilemsi Valley, Mali; and Tahoua, Niger, is relatively effective as sources of P for crops. PHOS-PAL, a thermally treated aluminum phosphate from Thies, Senegal, is also effective.

Available crop response data are insufficient to permit a good economic analysis of the value of PR sources relative to soluble phosphates. However, because of the high cost of imported soluble phosphate fertilizers in the landlocked countries, the development and use of indigenous PR for direct application seem probable in Mali and Niger, provided the Tahoua deposits can be processed at reasonable costs. Greater use of PHOS-PAL and ground PR from Taiba for direct application appears justified in Senegal and may also be agronomically and economically feasible in Mauritania.

The PR deposits in eastern Upper Volta contain very small phosphorite pellets and high quantities of silica, at least partially in the form of chert, which may physically surround phosphorite pellets even after grinding. Phosphorite in a sample from Kodjari examined by IFDC shows less carbonate substitution for phosphate than more reactive PR. These factors may render the Upper Volta PR less available to crops than PR from the Tilemsi Valley in Mali. Deposits in *Parc W* area of Niger apparently are similar to the deposits in eastern Upper Volta. Although no direct comparisons were made, limited agronomic tests indicate PR from Arli, Upper Volta, may be less effective than PR from Tilemsi Valley. Additional agronomic testing is needed for all of the PR in the region.

Crop Response to Soil Tillage

Charreau (1) summarized the results of many soil tillage experiments in dry tropical west Africa. Several experiments have shown that crop response to fertilizer is sig-

nificantly greater with plowing than with no soil tillage. Effects of plowing upon crop yields are generally seen for 3 years.

In 74 experiments for millet, sorghum, and maize, plowing resulted in yield increases of 20 to 30%. In Senegal, 18 experiments showed about 60% yield increase for millet and sorghum as a result of superficial tillage with horse traction and light fertilization. Plowing with oxen and heavier fertilization gave yields twice as large as yields on cropland receiving no tillage or fertilization.

FERTILIZER USE AND POTENTIAL

Fertilizer Use

The level of fertilizer use is low in all six countries. Senegal consumes about 66% of all fertilizer nutrients used in the region, although consumption in Senegal still only averages about 16.5 kg per ha of cropland. Nutrient consumption in Mauritania averages about 10 kg per ha. Average nutrient consumption in the other four countries is less than 5 kg per ha. It appears that export crops (primarily peanuts and cotton) account for more than 60% of nutrients currently used. In Chad, cotton accounts for approximately 90% of nutrients used.

The six Sahelian countries consume about 30% of the N; 45% of the P_2O_5; and 30% of the K_2O that is used in 21 countries of west Africa south of the Sahara. The four countries of Cameroon, Ivory Coast, Nigeria, and Senegal consume more than 65% of the nutrients used in the entire region.

Estimated fertilizer nutrient use in 1975 was about 56,000 mt in the six countries (table 11). The ratio of $N:P_2O_5:K_2O$ was about 4:4:3. In Senegal the ratio was about 1:1:1. Mali, Mauritania, and Niger use almost no K_2O. In Mauritania, N accounts for more than 90% of the nutrient use. In Mali, Niger, Senegal, and Upper Volta, use of P_2O_5 is greater than other nutrients.

Potential Fertilizer Use

Projected fertilizer use in 1980 and 1985 for the Sahelian region is shown in table 11. The estimates are that fertilizer consumption for the region will increase by about 60,000 mt of nutrients in each period, 1975-80 and 1980-85. These calculations were based on: present use; government plans for crop production programs; crop response data; and the assumption that incentives will be established to promote increased use of fertilizer for food crop production.

Senegal will continue to be the primary user of fertilizer nutrients and will likely still account for 65% of the region's consumption in 1985. Levels of use are projected to increase by 200 to 400% in the individual countries which are presently using more than 1,000 mt of nutrients per year (all except Niger). The greatest percentage increase of the five countries is projected for Mali and Upper Volta.

Assuming a 2% per year growth in cropped area (similar to agricultural population growth rate), 22% more land will be cropped in 1985 than in 1975. The average rate of nutrient use in 1985 will range from 1 kg per cropped ha in Niger to 41 kg in Senegal. Mali will be using an average of 12 kg of nutrient per cropped ha, Chad about 9, and Upper Volta slightly over 4.

Table 11. Fertilizer Use in 1975 and Projected Use in 1980 and 1985 of Six Sahel Countries

	1975				1980				1985			
	N	P_2O_5	K_2O	Total	N	P_2O_5	K_2O	Total	N	P_2O_5	K_2O	Total
	1,000 mt of nutrient											
Chad	2.8	1.8	1.4	6.0	4.6	2.8	3.9	11.3	6.5	3.8	5.2	15.5
Mali	2.2	4.3	-	6.5	7.8	7.6	2.2	17.6	12.5	10.6	3.5	26.6
Mauritania	2.4	0.1	0.1	2.6	3.1	0.4	0.2	3.7	4.1	0.7	0.4	5.2
Niger	0.1	0.2	-	0.3	1.0	1.0	0.3	2.3	2.1	2.0	0.4	4.5
Senegal	11.0	13.4	13.0	37.4	24.6	26.6	26.5	77.7	39.6	39.1	35.5	114.2
Upper Volta	1.0	1.7	0.4	3.1	1.9	3.4	0.2	5.5	3.8	5.8	2.9	12.5
Total	19.5	21.5	14.9	55.9	43.0	41.8	33.3	118.1	68.6	62.0	47.9	178.5

The ratio of nutrient consumption for the region is projected to remain about 4:4:3 through 1985, but N will have surpassed P_2O_5 by a slight margin. Senegal will still be using about 75% of the K_2O in the region. Chad, Mali, and Upper Volta each will be using 3,000 to 5,000 mt of K_2O by 1985.

FERTILIZER SUPPLY

Supply and Demand in West Africa

The 21 countries in the region of west Africa south of the Sahara are net importers of N and P_2O_5 in finished fertilizers but net exporters of K_2O (table 12). The region is a net exporter of PR and will produce as much finished P_2O_5 as it consumes by 1977. While Ivory Coast and Senegal produce fertilizer containing N, they are totally dependent upon imported ammonia. Both of these countries use Senegal PR for production of phosphate fertilizers. All potash production in the region is in the Republic of the Congo.

Of the six Sahelian countries, only Senegal presently has fertilizer production facilities. Senegal has ample phosphate rock for both domestic needs and export. Domestic demand is nearly equal to production capacities for sulfuric acid, phosphoric acid, single and triple superphosphates, and NPK fertilizers. All sulfur, potash, ammonia, and urea are imported. Senegal's exports of finished fertilizers are primarily to other west African countries.

Senegal also produces an aluminum phosphate ore at Thies which is calcined and small quantities are ground for direct application. The calcined ore has a high P_2O_5 solubility in ammonium citrate solution. The product is called PHOS-PAL and is used in Senegal and neighboring countries, and is exported to France and other European countries. It may be exported in bulk as unground clinker with grinding in the receiving country, or it may be distributed after grinding in bags. The grade (after calcining) is about 34% P_2O_5.

Raw Materials For Fertilizers

Fertilizer raw materials, except PR, are scarce in the six Sahelian countries. Locations of potential fertilizer raw materials are shown in figure 6.

No potash reserves have been identified in the six Sahelian countries. Potash reserves and production capacity exist in the Republic of the Congo to meet the long term needs of west Africa, south of the Sahara. Also, natural gas reserves in Nigeria are sufficient to produce the nitrogen requirement for the entire region for many years. Data on potential fertilizer raw material deposits in west Africa other than the six Sahelian countries are found in appendix I. Similar data for the six Sahelian countries are found in the individual country reports (volumes 2-7).

Nitrogen--At least 90% of the world supply of fertilizer nitrogen is derived from synthetic ammonia. Natural gas is the preferred feedstock for producing ammonia. Other petroleum products such as LPG, naphtha, and heavy fuel oil are also used. Table 13 shows the estimated amount of natural gas flared in 1972 in Algeria, Libya, and Nigeria.

Table 12. Fertilizer Production, Export and Consumption in Countries of West Africa South of the Sahara, 1975[a]

Country or Region	Production, 1,000 mt		
	N	P_2O_5	K_2O
Congo Republic	0	0	285.2
Ivory Coast	6.0	7.4	0
Senegal	5.0	22.0	0
Total	11.0	29.4	285.2

Country	Exports, 1,000 mt		
	N	P_2O_5	K_2O
Congo Republic	0	0	281.2
Ivory Coast	1.9	2.4	0
Senegal	2.2	13.0	0
Total	4.1	15.4	281.2

Sahelian Countries	Consumption, 1,000 mt		
	N	P_2O_5	K_2O
Chad	2.8	1.8	1.4
Mali	2.2	4.3	0.4
Mauritania	2.4	0.1	0.1
Niger	0.1	0.2	0
Senegal	11.0	13.4	13.0
Upper Volta	1.0	1.7	0.4
Subtotal	19.5	21.5	15.3
Others			
Cameroon	9.3	2.1	4.8
Central African Republic	1.8	0.5	0.7
Congo Republic	0.2	0.1	4.0
Benin (Dahomey)	2.6	1.8	1.4
Gabon	0.1	0	0
Gambia	0.5	0.7	0
Ghana	3.8	3.2	2.7
Guinea Bissau	0.3	0.1	0.1
Guinea	0.7	0.5	0.7
Equatorial Guinea	0.1	0	0
Ivory Coast	7.8	4.5	18.6
Liberia	1.2	0.8	1.3
Nigeria	13.2	10.7	3.0
Sierra Leone	1.0	1.0	1.3
Togo	0.3	0.3	0.4
Subtotal	42.9	26.3	39.0
TOTAL--Consumption	62.4	47.8	54.3

[a]TVA preliminary data except for Sahelian countries.

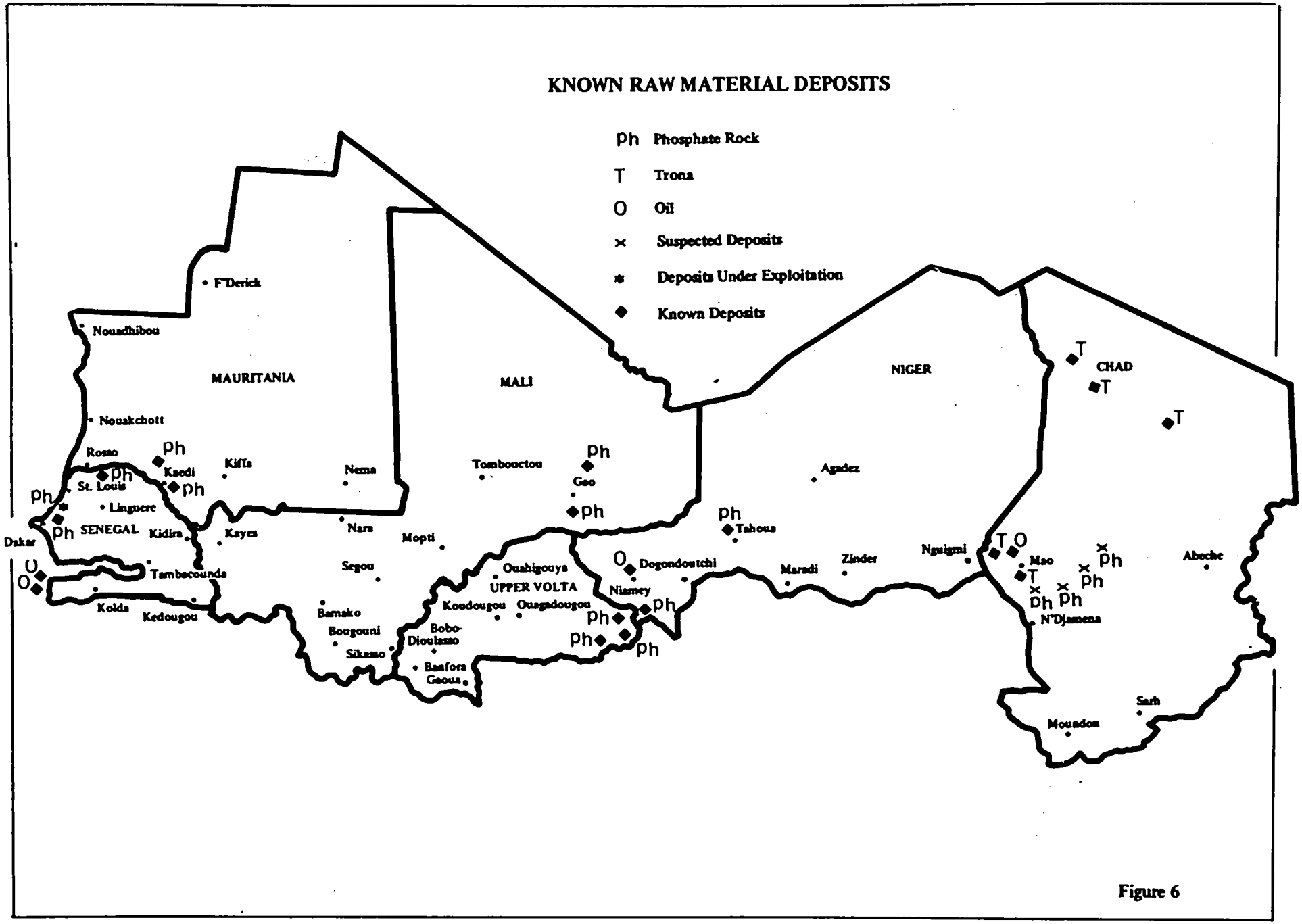

KNOWN RAW MATERIAL DEPOSITS
Ph Phosphate Rock
T Trona
O Oil
× Suspected Deposits
✱ Deposits Under Exploitation
◆ Known Deposits
MAURITANIA
MALI
NIGER
CHAD
SENEGAL
UPPER VOLTA
F'Derick
Nouadhibou
Nouakchott
Rosso
St. Louis
Linguere
Kaedi
Kiffa
Nema
Kidira
Kayes
Dakar
Tambacounda
Kolda
Kedougou
Nara
Segou
Mopti
Bamako
Bougouni
Sikasso
Bobo-Dioulasso
Banfora
Gaoua
Koudougou
Ouagadougou
Oushigouya
Tombouctou
Gao
Niamey
Dogondoutchi
Tahoua
Agadez
Maradi
Zinder
Nguigmi
Mao
N'Djamena
Abeche
Sarh
Moundou

Figure 6

Table 13. Estimated Natural Gas Flared in African Countries

Country	Gas flared 1972, million m^3
Algeria	8,625
Libya	6,234
Nigeria	16,849

The petroleum and natural gas statistics for Africa are summarized in table 14. As an indication of the adequacy of each country's natural gas reserves to support an economical scale of ammonia production, the potential ammonia production has been calculated.

The results of the calculations are shown in table 15. The last column of this table shows the number of 1,000 mt/day ammonia plants that the country's gas reserves would support under the assumed conditions. Several cautions should be taken into account in considering these projections: First, in some countries there are many competing uses for natural gas; in other countries there are few. In most countries the accuracy of estimates of known reserves are questionable. Active exploration is now in progress which may discover new reserves.

No promising feedstock for nitrogen fertilizer production has been identified by this survey in the six Sahelian countries with the possible exception of Chad where oil discovery has been reported but not evaluated. Unless feedstocks are found it must be presumed that all nitrogen fertilizer must be imported. Planned production in Nigeria and Gabon should be sufficient to meet expected regional demand in the near future.

Phosphate Rock--Africa is a large exporter of PR. In 1974, African countries produced 32.9 million mt of PR (9) (table 16). Exports were 28.1 million mt, indicating an apparent consumption of 4.8 million tons.

Table 14. African Petroleum and Natural Gas Reserves and 1974 Production (8)

Country	Petroleum, million mt		Natural Gas, billion m^3	
	Reserves, January 1, 1975	Production, 1974	Reserves, January 1, 1975	Production,[a] 1974
Algeria	1,042	48.6	6,485	0.583
Angola	159	8.3	40	1.152
Congo	660	1.6	28	0.173
Egypt	501	7.1	99	1.407
Gabon	237	8.7	198	0.430
Libya	3,599	73.5	750	1.160
Morocco	-	-	1	0.821
Nigeria	2,828	111.2	1,274	1.698
Tunisia	149	4.3	42	0.586
Zaire Republic	68	-	1	-
Total	9,243	263.3	8,918	8.010

[a]Production in most cases is gas utilized; does not include gas flared.

Note: About 1,090 m^3 of gas is required for production of 1 ton of ammonia, hence reserves of 5.4×10^9 m^3 are required for a 1,000 ton/day ammonia plant for 15 years operation.

Table 15. Adequacy of Natural Gas Reserves for Ammonia Production

	Reserves, January 1, 1975	Rate of depletion	Life at present depletion rate	Potential, using 25% of gas reserves over a 20-year period[d, e]
		billion m^3/yr	years	1,000 mt NH_3/day
Algeria	6,485	9.208[a]	704	225
Angola	40	1.152[b]	35	1.4
Congo	28	.173[b]	162	0.9
Egypt	99	1.407[b]	70	3.4
Gabon	198	.430[b]	460	6.9
Libya	750	7.394[a]	101	26.1
Morocco	1	.821[b]	-	c
Nigeria	1,274	18.547[a]	69	44.3
Zaire	1	-	-	c

[a]Includes gas flared if available.
[b]Does not include gas flared, if any.
[c]Known reserves will not last 20 years at present use rates.
[d]Natural gas requirement is 1,090 m^3/ton of ammonia.
[e]Ammonia plants will operate at rated capacity 330 days/year.

Table 16. African Rock Production by Country, 1974 (9)

Country	Production, 1,000 mt	Apparent Consumption 1,000 mt
Algeria	802	356
Arab Republic of Egypt	550	500
Ivory Coast	-	5
Morocco	19,327	618
Mozambique	-	3
Rhodesia	130	130
Senegal	1,702	198
South Africa	1,550	1,550
Spanish Sahara	2,385	-
Tanzania	-	80
Togo	2,553	-
Tunisia	3,903	1,324
Uganda	11	11
Total	32,913	4,775

Morocco accounted for about 19.3 million mt or approximately 60% of the total African production. Senegal produced 1.7 million mt in 1974, most of which was exported.

There are a number of deposits of more than 100 million mt in west Africa south of the Sahara (table 17). These are located in Niger, Senegal, Upper Volta, and Togo. Only the deposits in Senegal and Togo are being mined.

Nearly all of the countries producing phosphate rock in Africa have direct access to ocean shipment. It is reasonable to assume that transport costs from the mine site to an ocean port would exclude export development of the deposits of landlocked countries. Also, there is little opportunity for lateral movement of any commodities between the countries because of inadequate transportation facilities linking the landlocked countries. Therefore, any development of the phosphate deposits

Table 17. Phosphate Deposits of West Africa, South of the Sahara

Country	Estimated Reserves, millions mt	Grade % P_2O_5	Production (1974), 1,000 mt
Six Sahel Countries			
Chad	Unknown[a]	Unknown	
Mali	20	30	
Mauritania[b]	5	23-32	
Niger	No Estimate (Tahoua)	23-26	
	100 Tapoa	23 (aluminum phosphate)	
Senegal	140 Taiba	25	
	50 Thies	28-30[c]	{ 1,702
Upper Volta	30 Kodjari	26	
	3 (D'Arli)	31	
	50-100 D'Aloub Djouna	29-32	
Other West African Countries, South of the Sahara			
Angola	42	20-36	
Cameroon	Small	3-18	
Central African Republic	High phosphate uranium deposit reported		
Congo	?		
Dahomey (Benin)	No Estimate	23	
Gabon	No Estimate	?	
Ghana	-		
Liberia	No Estimate	33[c] (one sample)	
Ivory Coast	-		
Nigeria	1	22-23	
Togo	150	30	2,553
Zaire	83	14-33	

[a]Presence of phosphate ore reported by Chadian Ambassador to the United States.
[b]Mauritania also has an interest in Spanish Sahara deposits. Also new discoveries in Mauritania have not been evaluated.
[c]Aluminum phosphate ore.

Table 18. World Phosphate Rock List Prices

Date	Florida f.o.b. vessel, Grade, BPL 77/76	75/74	73/72	72/70	68/66	66/64	Morocco f.a.s. Casablanca, Grade, BPL 80	77	75	72
	$/long ton or mt[a]									
July 1972	12.28	11.18	10.30	10.02	8.70	8.37	-	-	-	-
Mar. 1973	14.50	13.10	12.00	11.50	9.90	9.40	Approximately 14.80	-	12.50	11.00
Jan. 1974	30.00	27.50	25.50	24.00	18.00	16.00	Published 50.00	47.45	42.00	40.00
July 1974	47.50	42.00	38.00	36.00	30.00	27.50	75.00	71.00	63.00	60.00
Jan. 1975	62.00	55.00	-	48.00	39.00	36.00	80.00	76.50	68.00[b]	65.00
Jan. 1976	-	47.00	-	41.00	33.00	30.00	54.00	51.50	48.50[b]	46.00

[a]Florida prices are quoted in $/long ton through July 1974, and $/metric ton thereafter; Morocco prices are all in $/metric ton.
[b]Actual $54-60 in second half of 1975 and $38-45 in January 1976.

Table 19. Phosphate Rock Deliveries and Supply Potential (10)

Region	Actual Deliveries, 1,000 mt 1972	1973	1974	1975	Forecasted Supply Potential, 1,000 mt 1975	1976	1977	1978	1979
West Europe	108.2	128.0	105.0	100	90[E]	90[E]	90[E]	90[E]	90[E]
East Europe	19,722.0	21,580.0	22,505.0	22,200	23,500[E]	25,000[E]	26,500[E]	28,000[E]	29,500[E]
North America	39,807.9	40,421.6	43,039.3	40,300	42,750	48,600	54,000	57,600	62,100
Oceania	2,927.2	4,563.8	4,649.7	3,460	3,725	5,325	5,825	5,745	5,225
Latin America	414.4	430.1	549.2	550	690	830	2,540	2,860	3,670
Northwest Africa	18,200.4	21,414.4	25,934.7	20,500	27,600	32,850	36,550	40,450	43,950
Near East	2,191.1	2,438.8	3,698.6	2,600	5,160	7,666	10,700	13,060	13,560
Africa (Except NW)	5,044.3	5,513.1	5,773.1	6,130	6,225	6,475	7,485	7,935	7,935
South Asia	217.0	136.0	326.4	300	390	650	740	840	900
Socialist Asia	3,180.0	3,860.0	4,600.0	4,500	5,200[E]	5,800[E]	6,400[E]	7,200[E]	8,500[E]
World	91,812.5	100,485.8	111,181.0	100,640	115,330	133,286	150,830	163,780	175,430

E - Estimated.

is not likely to be economical for any use other than for local agriculture although the establishment of small plants based on local phosphate deposits cannot be completely ruled out.

Use of the rock after grinding for direct application is likely to be more economical than importation of rock or finished fertilizers. Upper Volta and Niger have plans to begin mining and grinding of PR on a small scale for direct application. Equipment was ordered in early 1976 for the facilities in Upper Volta. Mali is interested in establishing facilities for mining and grinding of domestic PR.

World Phosphate Demand--Beginning in 1973 and particularly in 1974, PR was in short supply throughout the world and prices increased drastically. Table 18 lists posted Florida and Morocco rock prices for several periods beginning in 1972 and ending in 1976. Current posted prices are subject to various discounts and concessions, and thus have little meaning at face value.

The demand for phosphate fertilizers declined in 1975 due to high prices and overstocking by merchants, developing countries, and farmers, and the consumption of PR likewise decreased, creating a surplus. Forecasts indicate that PR mining capacity will continue to increase faster than demand, which will result in growing surpluses, or operation of mining facilities well below capacity. Nevertheless, as long as PR prices remain at much higher levels than 1972-73, countries that have indigenous deposits will continue to be interested in utilizing them for domestic fertilizer production.

Table 19 shows actual or estimated deliveries of PR in 1972 through 1975, and forecasted supply potential for 1975 through 1979. It will be noted that 1975 estimated deliveries were 10% below 1974, and 15% below supply (10). World PR capacity as estimated by U.S. Bureau of Mines is given in table 20. The world production capacity in 1973 was estimated at 104.3 million mt in 1973 with actual production estimated at 98 million mt. The production capacity was expected to nearly double to 173 million mt by 1980.

The African region accounted for 27.5 million mt of capacity in 1973 or 28% of the world's capacity. The African capacity was expected to increase to 53.8 million mt or 31% of the world capacity by 1980. This trend may continue beyond 1980 since the African countries possess the majority (72%) of the proven world reserves and 79% of the world resources of PR. However, in view of the present and potential surplus and the desire of other countries to develop and use indigenous deposits, the trends expected in 1973 may not materialize.

Sulfur--No documented sulfur reserves are known to exist in the six Sahelian countries. However, by 1977 Mauritania is expected to have 100,000 mt/year of sulfuric acid as a by-product from copper refining.

Potash--The only potash deposit now being mined in west Africa is in the Congo. Production in the years 1972/1973, 1973/1974, 1974/1975 was listed by British Sulfur Corporation to be 283,000, 263,000, and 263,000 mt, respectively. This deposit is located on a railroad from Brazzaville to Point Noire approximately 50 km inland. Estimated potash reserves in west Africa south of the Sahara are listed in table 21.

Summary--All of the six Sahelian countries with the exception of Chad have identified PR deposits and a deposit is presumed in Chad (figure 6). Except for Senegal, more information is needed about quantity, quality, and prospective cost of mining and beneficiation (if necessary) to determine the potential of PR deposits for fertilizers. Needed information includes rock characteri-

Table 20. World Phosphate Rock Production and Capacity (11)

Country	1973 Production 1,000 mt	Capacity, (1,000 mt) 1973	1974	1980
North America:				
United States	38,236	40,254	40,835	62,613
Other	162	236	272	91
Total	38,398	40,490	41,107	62,704
South America	330	348	363	1,815
Europe:				
USSR	21,234	22,350	22,777	32,668
Other	129	136	136	136
Total	21,363	22,486	22,913	32,804
Africa:				
Algeria	644	680	907	1,815
Morocco	16,569	17,441	19,056	27,223
Senegal	1,693	1,779	1,815	2,269
South Africa	1,366	1,434	1,633	3,176
Spanish Sahara	697	1,815	1,815	9,074
Togo	2,293	2,414	2,450	2,995
Tunisia	3,474	3,657	3,630	5,898
Other	722	762	817	1,361
Total	27,458	29,982	32,123	53,811
Asia:				
China, People's Republic of	2,995	3,176	3,176	6,352
Christmas Island	1,538	1,615	1,633	1,996
Israel	633	672	907	1,815
Jordan	1,106	1,162	1,180	2,722
Vietnam, North	499	526	817	1,361
Other	662	699	907	1,815
Total	7,433	7,850	8,620	16,061
Oceania:				
Nauru	2,324	2,450	2,450	2,450
Ocean Island	744	780	817	-
Other	5	6	6	3,630
Total	3,073	3,236	3,273	6,080
World Total	98,055	104,392	108,399	173,275

Table 21. Potash Reserves–West African Countries, South of the Sahara (12)

Country	Mineralogical Ore Types	Grade % K_2O	Depth, m	Recoverable
Mali	Sulfates	-	-	Potential
Niger	Brine	2.4-6.0	NA	Potential
Gabon-Congo	Carnallite and Sylvinite	16-38	200-900	Potential[a]
Nigeria	Brine	2.4-6.0	NA	Potential

[a]"Industrial Minerals and Rocks" -4th Edition (1975) shows 134 x 10^6 short tons K_2O. Production 1974/1975--263,000 metric tons.

zation studies to determine suitability for direct application or for use in various processes. Such studies involve detailed chemical and mineralogical examinations of the rock or a concentrate obtained by beneficiation followed by actual field testing.

None of the six Sahelian countries have commercially available feedstock for ammonia production, although significant amounts of oil have been reported from two wells in Chad. Unless further search reveals such resources, all nitrogen fertilizer will have to be imported or manufactured from imported feedstock.

Additional information is needed about sulfur sources; only Mauritania is said to have sulfur deposits and little is known about these reserves.

There are few potash resources in the six Sahelian countries. However, there is not likely to be much need for potash in most of the area.

Only Chad is known to have a minable trona deposit, a potential raw material for making Rhenania phosphate. Information about the quality, quantity, and cost of the Chad material is given in the Chad country report (volume 6).

Very little information has been found about fuel or energy sources in the six Sahelian countries. Energy will be an important factor in determining which fertilizer manufacturing processes can be economically used.

Production and Plans

Operational and planned production facilities for sulfuric acid and fertilizers are shown in tables 22 and 23 for the region of west Africa south of the Sahara.

Senegal--Of the six Sahelian countries, Senegal is the only one producing processed fertilizers. Production capacities for PR and processed fertilizers are shown in table 24. The Societe Industrielle des Engrais du Senegal (SIES) has capacities for production of 90,000 mt/year of superphosphates and 130,000 mt/year of DAP plus granular NPK fertilizers.

Domestic consumption of DAP and granular NPK fertilizers is approaching present plant capacity. SIES plans to expand facilities to produce sufficient sulfuric and phosphoric acids to process an additional 400 mt of P_2O_5 per day and increase granulation capacity to 420,000 mt/year. In addition, a newly formed company

Table 22. Sulfuric Acid Production Capacity in West Africa, South of the Sahara

Country	Company	Location	Product	Product Capacity 1,000 mt	Status
Angola	Ammonial Portugues	Caala	Sul. Acid--Sul.	165	Pln. 1977
	Fabril Com. Ultramar	Luanda	Sul. Acid--Sul.	50	Pln. 1977
	S. Estudoes Invest	Luanda	Sul. Acid--Sul.	165	Indf. 1981
Cameroon	Soc. Cam. des Engrais	Douala	Sul. Acid--Sul.	60	Pln. 1977
Gabon	Mines D'Uranium	Mounana	Sul. Acid--Sul.	4	Opr. 1967
Ivory Coast	Ivoirienne d'Engrais	Abidjan	Sul. Acid--Sul.	30	Opr. 1971
Niger	Niger Government	D'Arli	Sul. Acid--Sul.	59	Opr. 1972
Nigeria	Nigerian Government	Kaduna	Sul. Acid--Sul.	38	Ctr. 1975
Senegal	S. Ind. Engrais	Rufisque	Sul. Acid--Sul.	66	Opr. 1967
			Sul. Acid--Sul.	363	Pln. 1977
Togo	Togo Government	Lome	Sul. Acid--Sul.	132	Pln. 1978
	Togo Government	Lome	Sul. Acid--Sul.	7	Opr. 1967
			Sul. Acid--Sul.	363	Pln. 1981
Zaire	Soc. Gen. Ind. & Chem	Jadotville	Sul. Acid--Other	132	Opr. 1967
			Sulfur (Pyr.)	43	Opr. 1967

Table 23. Fertilizer Production Capacity in West Africa, South of the Sahara

Country	Company	Location	Product	Product Capacity	Status
				1,000 mt/yr	
Cameroon	Soc. Cam. des Engrais	Douala	Am. Sul. Prime	39	Pln. 1977
			Normal Super	19	Pln. 1977
			NPK	27	Pln. 1977
Congo	Compania des Potasse	St. Paul	Potash	800	Opr. 1969
Ivory Coast	Ivoirienne d'Engrais	Abidjan	Am. Sul. Prime	20	Opr. 1971
			Am. Phosphate and NPK	60	Opr. 1971
			Normal Super	25	Opr. 1971
Nigeria	ICI & Colonial Dev Cor	Port Harcourt	Ammonia	320	Indf. 1981
			Urea	350	Indf. 1981
	Nigeria Government	Kaduna	Normal Super	90	Uct. 1976
Senegal	Cie. Sen. Phos. Taiba	Taiba	Phos. Rock	1200	Opr. 1967
			Phos. Rock	300	Opr. 1971
	Ste. Sen. Phos. Thies	Thies	Phos. Rock	1000	Opr. 1967
	Senegal, Iran, & Brazil	Tobemi	Phos. Rock	2000	Pln. 1977
	Soc. Ind. Engrais	Rufisque	Am. Phosphate and NPK	130	Opr. 1969
			Normal Super	90	Opr. 1968
			Conc. Super	...	Opr. 1967
			Phos. Acid W.P.	40	Opr. 1969
Spanish Sahara	Fosfatos del Sahara	Bu-Craa	Phos. Rock	3300	Uct. 1973
			Phos. Rock	2300	Exp. 1975
Togo	Cie Togo des Mines	Hahatoe	Phos. Rock	1200	Cls. 1973
			Phos. Rock	400	Cls. 1973
			Phos. Rock	200	Cls. 1973
	Unknown	Lome	Am. Sul. Prime	...	Indf. 1981
			Urea	...	Indf. 1981
			Nitricphos	140	Indf. 1981
			Conc. Super	...	Indf. 1981
			Phos. Acid W.P.	330	Indf. 1981
Zaire	Zaire Government	Unknown	Ammonia	...	Indf. 1981
			Am. Nitrate	90	Indf. 1981

Table 24. Capacity of Fertilizer Production Facilities in Senegal, 1976

Material	Capacity, mt/year
Aluminum phosphate rock (Thies)	700,000
Calcined aluminum phosphate clinker	350,000
Ground calcined aluminum phosphate	15,000
Phosphate rock--34% P_2O_5 (Thies)	100,000
Phosphate rock--37.3% P_2O_5 (Taiba)	1,600,000
Normal and triple superphosphate	90,000
Granular NPK and ammonium phosphate	130,000

(FERTISEN) plans to build ammonia and urea plants with capacities of 300 and 230 mt/day, respectively. These plants will use gases from a planned oil refinery to be built in the free zone of Dakar.

Cameroon--A new fertilizer complex being constructed by the Cameroon Fertilizer Company at Douala is nearly ready for startup. The shareholders of the company are Cameroonian Company for Industrial Investment (25.5%), Klockner Industrie-Anlagen GmbH., Duisburg/West Germany (25.5%), and Government of Cameroon (49.0%). The rated yearly capacities are 39,000 mt of ammonium sulfate, 19,000 mt of single superphosphate, and 27,000 mt of mixed fertilizers.

Company maragement expects the total production to be 60,000 mt in 1977, and expects to exceed the total design capacity of 85,000 during subsequent years. Sulfur and ammonia for the complex will be purchased on the open market. Phosphate rock will probably come from Togo and potash from the Congo.

Ivory Coast--The Societe Ivoirienne D'Engrais (SIVENG) has a facility in Abidjan which is designed to produce 30,000 mt/year of sulfuric acid, 25,000 mt/year of nongranular normal superphosphate, and 150 to 250 mt/day of granular NPK fertilizers (actual production depends on the grade). Crystalline ammonium sulfate is also produced in relation to demand. Sulfur, ammonia, phosphate rock, and KCl are imported.

Projects exist for expansion of the SIVENG facility to produce more granular products and also phosphoric acid. However, definite decisions concerning the projects have been delayed until 1978 after there is a better understanding on consumption and the market.

Nigeria--A SSP plant is in the process of starting up at Kaduna. The complex contains a sulfuric acid plant with a capacity of 41,000 mt/year and a 100,000 mt/year normal super plant. Sulfur for the unit is imported and phosphate rock is brought in from Togo. The plant is expected to produce 50,000 mt in 1977 and be close to full production late in 1978.

Plans are for all the production to be used internally in Nigeria with the major portion being used on groundnuts, which is the reason the plant was located in Kaduna.

Plans have been announced to construct a large ammonia-urea complex near Port Harcourt with a total capacity of 350,000 mt/year of urea.

Togo--Definite plans exist for producing 1,000 mt/day of phosphoric acid. Half of the P_2O_5 would be used to produce TSP, DAP, and MAP and the remaining 500 mt/day would be marketed in the international market as phosphoric acid. Although these plans are said to be firm, financing plans are not yet clear.

TRANSPORTATION

International Transportation

The existing transportation infrastructure in west Africa appears adequate to serve the populated regions of the six Sahelian countries--Chad, Niger, Mali, Upper Volta, Mauritania, and Senegal (13, 14). Each of the four landlocked countries has access routes to the sea, however, the transportation cost involved in international trade is very high, thus greatly inflating the delivered cost of imports. In general, transportation costs are determined by the freight charges levied by those countries through which the Sahelian countries import. Two of the Sahelian countries, Mauritania and Senegal, have coastlines, but only Senegal has well-developed port facilities. Mauritanian and Malian import/export activities commonly rely on Senegal's port of Dakar. Nearly all of the international traffic in the remainder of the region flows in a north-south direction. Most of the Sahelian countries produce and consume the same commodities, therefore the incentive of inter-country transportation routes (east-west movement) is significantly reduced.

The principal transportation routes for each of the primary countries are shown in figure 7. A description of the international transportation routes available to each of the Sahelian countries is included in volumes 2-7. A series of tables containing estimates of freight rates and other costs of imported fertilizers and fertilizer raw materials is available in appendix III.

A brief summary of the facilities available at the ports used by the six Sahelian countries is given in table 25.

Domestic Transportation

The domestic infrastructure of the six countries consists of roads, seasonably navigable rivers, and railways primarily devoted to international trade (only Niger and Chad do not have rail facilities). Most of the road network lies to the south of the desert areas. The existing road network can serve populated areas, although movement may be hampered during the rainy season as many of the nonpaved surfaces become impassable. The predominance of road transportation in the six countries is largely due to the small volume of domestic freight movement and the relatively short distance required to access most market areas. Currently, there is insufficient justification for major developments in rail and water transportation.

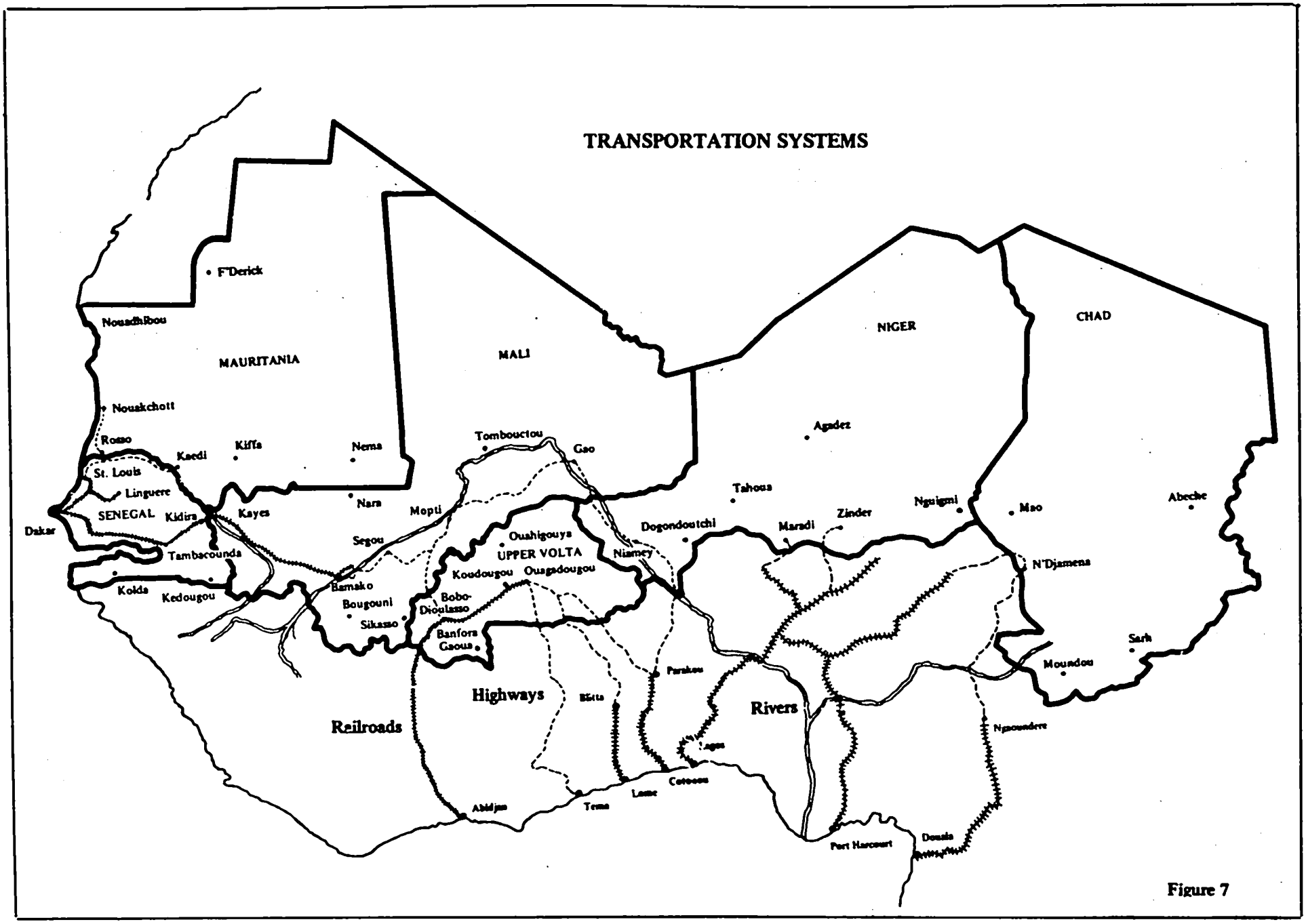

TRANSPORTATION SYSTEMS
F'Derick
Nouadhibou
MAURITANIA
MALI
NIGER
CHAD
Nouakchott
Rosso
Kaedi
Kiffa
Nema
Tombouctou
Gao
Agadez
St. Louis
Linguere
SENEGAL
Kidira
Kayes
Nara
Mopti
Tahoua
Zinder
Nguigmi
Mao
Abeche
Dakar
Tambacounda
Segou
Ouahigouya
UPPER VOLTA
Niamey
Dogondoutchi
Maradi
N'Djamena
Koudougou
Ouagadougou
Kolda
Kedougou
Bamako
Bougouni
Bobo-Dioulasso
Sikasso
Banfora
Gaoua
Sarh
Mouadou
Parakou
Highways
Rivers
Reilroads
Ngaoundere
Lagos
Cotonou
Lome
Tema
Abidjan
Port Harcourt
Douala

Figure 7

Table 25. Ports Used by the Six Sahelian Countries in Accessing World Markets (15)

Country	Port	Description
Senegal	Dakar	The port of Dakar is located at latitude 140° 40'N and 17°24'W. A safe harbor provides good anchorage; depth at entrance is 34 feet. The port of Dakar has 21 berths for general cargoes; water depth alongside ranges from 6-1/2 to 10 m.
	Kaolack	The water depth at the port entrance is 3 m. There is one concrete wharf, 630 m long with a depth of 4 m alongside. The port has little mechanical equipment for handling.
	Ziguinchor	The port is located on the Casamance River. Depth on the bar is varied, maximum depth is now 17 ft but is being dredged to 30 ft. Vessels load and discharge alongside private and government jetties; depth at the jetties is 17 ft. There are also 3 berths with a depth alongside at 27 ft.
Cameroon	Douala	The port of Douala is located at latitude 4°N and longitude 9°40'E. There are 11 berths for handling general cargoes with the depth alongside at 7 m at low water. The railway system is connected to the quays.
Congo (Popular Republic of)	Pointe Noire	The port is located at latitude 4°47'5"S and longitude 11°50'E. The harbor provides a good anchorage in 11-12 m water. There are 7 general cargo berths with alongside depths ranging from 25-29 ft. A railway extends from Point Noire to Brazzaville.
Dahomey	Cotonou	The port is located at latitude 6°21'N and longitude 2°27'E. The maximum water depth is 34 ft. There are no quay cranes as loading/unloading is done by the ships' derricks. There is one quay with a total length of 650 m.
Ghana	Tema	Located at latitude 5°38'N and longitude 0°1'E, the port of Tema is about 28 km east of Accra. Water depth at the entrance is 32 ft at mean low water. There are 2 main quays (finger and marginal) having a total of 12 berths. The depth alongside ranges from 26-32 ft, at mean low water.
Ivory Coast	Abidjan	The port is located at latitude 5°18'N and longitude 4°00'W. Water depth at the entrance is 10 m. The main quay is 3,130 m long with 10 m water depth alongside and 640 m with 11 m alongside. Several other quays are available but devoted to specific product classifications.

(continued)

Country	Port	Description
Togo	Lome	Located at latitude 6°7'N and longitude 1°13'E, the port consists of the following: one principal jetty, 1,720 m long and one mole 366.50 m long and 71.50 m wide. Depth alongside the mole ranges from 5.5-10 m. Rail and road facilities serve the port.
Nigeria	Lagos	The port is located at latitude 6°27'N and longitude 3°24'E. Quays available include the (a) Apapa Quay, 5,000 ft in length will berth vessels with a maximum draft of 27 ft. There are ample cranes and all berths have access to sail service; (b) Custom quay can simultaneously handle three vessels of up to 500 ft in length. Maximum vessel depth allowed at the 3 berths is 19.5 ft, 21.5 ft, and 22.5 ft. These berths are not directly served by rail; (c) other quays are available for specific cargoes.
Nigeria	Port Harcourt	The port is located at latitude 4°46'N and longitude 7°E. The water depth at the port entrance is 18 ft plus the rise of tide. Total quay length is 3,500 ft with a 27 ft depth alongside. All berths have rail and road access. The possibility of providing a deeper entrance channel is being investigated.
Nigeria	Warri	The port is located at latitude 5°32'N and longitude 5°46'E on the Warri River. Bar depth is currently 14.5 ft but is being dredged to 21 ft. The main wharf is 525 ft in length with 18 ft water depth alongside. There is a coaster wharf of 150 ft in length and 14 ft water depth alongside and a government lighter wharf, 170 ft in length. Mooring buoy berths for 3 oceangoing vessels are also available.

ALTERNATE SUPPLY SCHEMES

Because of the extremely high cost of transporting raw materials used in fertilizer production to the interior of the landlocked countries, consideration should be given to the utilization of any indigenous resources found in these countries. The difficult transportation situation would tend to restrict any fertilizer production facility located deep in the interior to serving only a local market.

Since the present and prospective demand for fertilizer in local areas is small, potential plants need to be quite small, eliminating from consideration highly sophisticated processes that depend on economies of scale. Still, small-scale, "low-technology" processing plants using local raw materials may have economic merit for interior markets.

Possibilities which may be considered in the future include: (1) grinding local rock for direct application; (2) small superphosphate plants using local rock and imported sulfur or sulfuric acid (the latter could be made at a central plant or recovered from smelter operations); (3) small triple superphosphate plants based on local rock and phosphoric acid made at a central plant; (4) Rhenania phosphate based on local rock and natron deposits; (5) calcined, ground aluminous phosphate rock. A dual purpose plant to make Rhenania phosphate and cement could be considered since the two products can be made in the same plant (not simultaneously but in campaigns); and (6) bulk blending of semi-bulk import shipments.

Depending on future finding on location and quality of raw materials, other alternates may develop. Current usage levels in the landlocked countries preclude immediate consideration of more capital intensive plants producing superphosphate (normal or triple), calcined aluminum phosphates, and Rhenania phosphates. Local grinding of phosphate rock and bulk blending from imported semi-bulk materials appears to be feasible in several of the countries.

Senegal presently produces fertilizers for domestic use as well as some exports and plans to expand production facilities. No alternate supply system is suggested for Senegal.

Mauritania uses very little fertilizer and only in the production areas bordering Senegal. Mauritania's fertilizer supply comes through Senegal. This relationship will continue, at least in the near future.

The immediate recommended changes in supply schemes involve Chad, Mali, and Upper Volta. These countries have sufficient fertilizer demand for mixed grades to warrant installation of simple bulk-blending facilities.

Mali, Niger, and Upper Volta have known reserves of PR. Those of Mali and the Tahoua deposits of Niger have been shown to give relatively good agronomic responses. Upper Voltan PR has lower citrate solubility and little agronomic data is available. The *Parc W* deposits of Niger are assumed to be similar to the Upper Voltan deposits. Previous studies indicate the feasibility of mining and grinding the Malian PR, but the feasibility is yet to be determined for PR in Niger and Upper Volta.

A bulk-blending system for all three countries and a PR mining and grinding system for Mali are discussed below as well as in individual country reports (volumes 2-7).

Bulk Blending of NPK Fertilizers

Since the east-west transportation structure is limited and costs are high, most fertilizer production facilities located in the landlocked countries can only serve a local market. However, a bulk-blending facility located at Bobo-Dioulasso could serve major portions of the fertilizer market in Upper Volta and Mali.

The system from the receiving port through the blending and bagging operation is shown schematically in figure 8 and illustrations of handling and filling the 1-mt containers are shown in figures 9-12. Hopefully, the 1-mt container will prove to be a major cost-reducing component of the supply scheme.

The facility would contain a 3-mt mixer and consist of equipment capable of producing 12 mt/hour. The raw materials received at Bobo-Dioulasso 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 under a shed, in an existing building, or even outside. This very simple operation is estimated to require a capital investment of about $172,000.

Estimations were made of the raw materials and operating costs for producing 6,000 mt/year of 18-35-0-7S grade for use in Upper Volta and 12,000 mt/year of 19-31-0-8S grade for use in Mali. A summary of these calculations is presented in table 26.

The Upper Volta grade could be produced for approximately $217/mt. For comparison purposes, the same imported grade, delivered at Bobo-Dioulasso for the 1976/77 season cost $313/mt or an additional $96/mt. The Mali grade could be produced and delivered to Sikasso for approximately $230/mt. The current delivered cost via Abidjan and Bobo-Dioulasso of the same grade is about $330/mt or $100/mt more.

It is evident that a bulk-blending facility at Bobo-Dioulasso to produce mixed grades for Mali and Upper Volta can be justified. Separate facilities in Upper Volta and Mali can also be justified, although lesser savings could be realized. A similar system is recommended for supplying fertilizers to Chad. Estimated cost savings over the present supply system are similar to those for Mali and Upper Volta.

PR Mining and Grinding

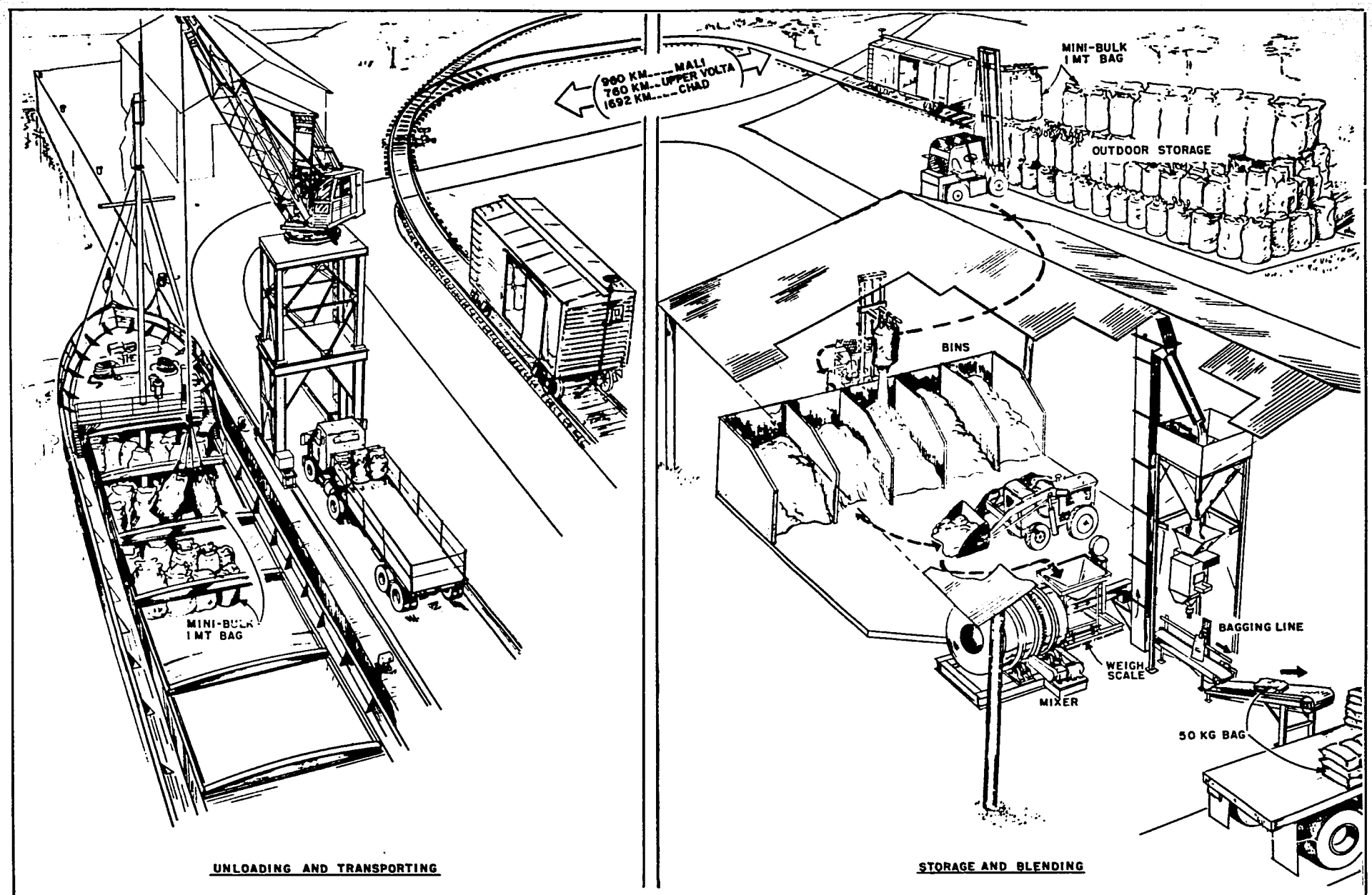
Mining and grinding of Malian PR should be considered. Feasibility studies are needed to determine the practicality of mining and grinding of domestic PR in Niger and Upper Volta. In addition more agronomic information is needed for the Upper Voltan rock.

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

Table 26. Bulk Blending in Upper Volta

Plant Location	Bobo-Dioulasso	
Operating Rate, mt/yr	18,000	
	12,000	6,000
Investment, $	172,000	
Working Capital (Cost of 1/2 of annual production), $ MM	1/2	0.6
Grade	19-31-0	18-35-0
Raw Materials	$/mt	$/mt
18-46-0, $216.28/mt at Bobo-Dioulasso	145.77	164.59
AS, $121.77/mt at Bobo-Dioulasso	39.45	24.96
Sub-total	185.22	189.55
Fixed and Variable Costs		
Electricity, gasoline, etc.	0.15	0.15
Operating Labor	0.70	0.70
Maintenance (5% of equipment cost)	0.35	0.35
Depreciation (15 years)	0.64	0.64
Taxes and insurance (2% of investment)	0.19	0.19
Supplies (20% of mtce.)	0.07	0.07
Overhead (100% of Labor)	0.70	0.70
Interest (8.5% of 1/2 investment)	0.41	0.41
Bags	10.00	10.00
Product loss (2% of raw materials)	3.70	3.79
Sub-Total	16.91	17.00
Total Production Cost	202.13	206.55
Interest on W.C. (8.5%)	8.50	8.50
Ex-Factory Cost	210.63	215.05
With 20% ROI	212.54	216.96
Freight to Sikasso	17.10	
	229.64	

NOTES: 1. AS = Ammonium sulfate
2. ROI = Return on investment



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

Figure 8.

Figure 9. Attaching Hooks to Bags in Ship's Hold

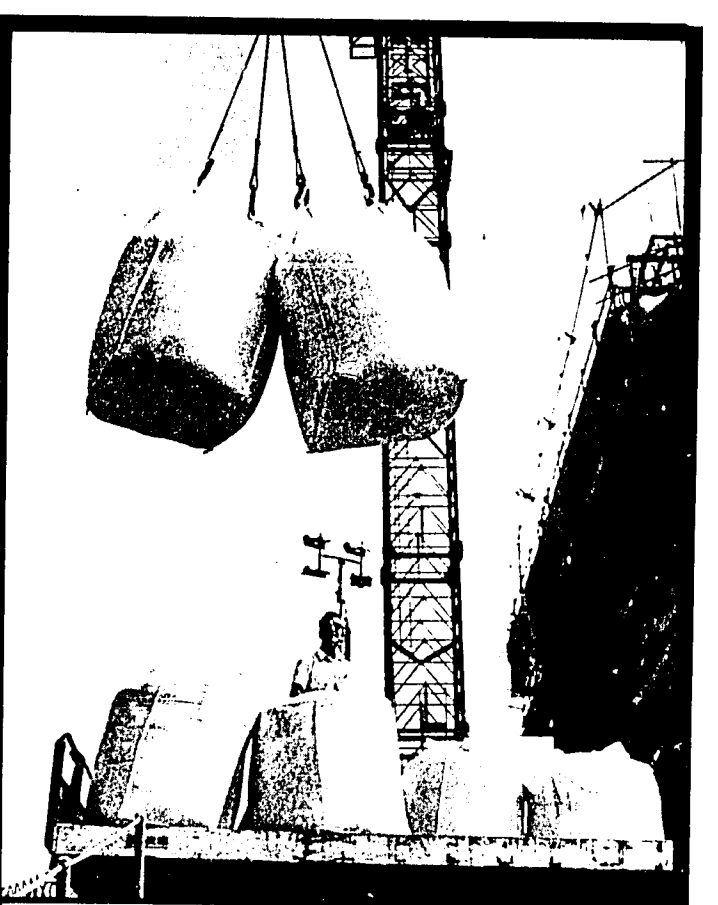


Figure 10. Transferring 1-mt Bags to Truck

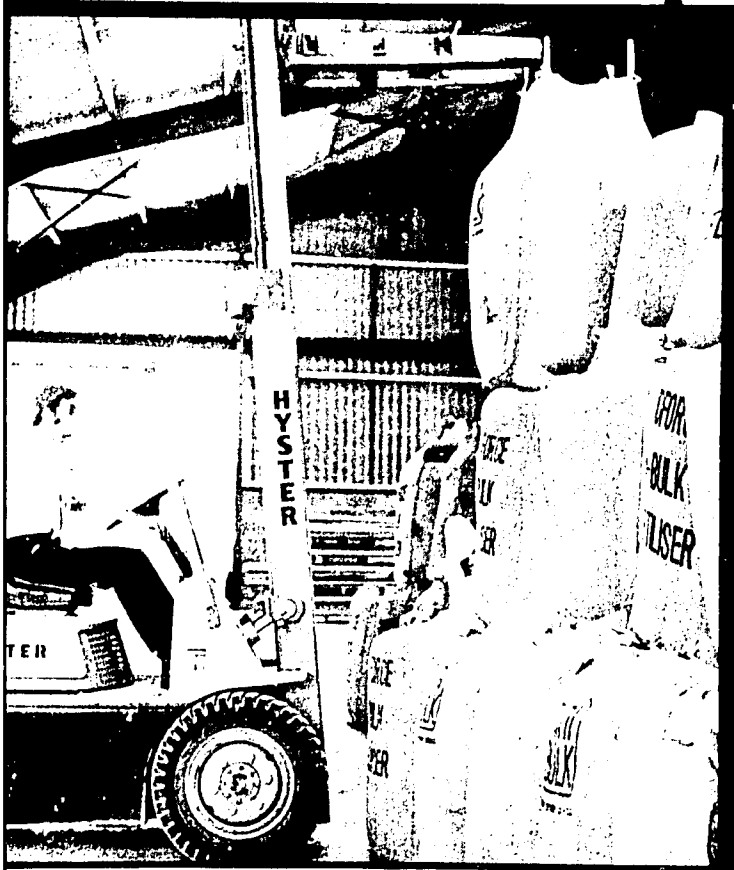


Figure 11 Stacking 1-mt Bags in Storage Area

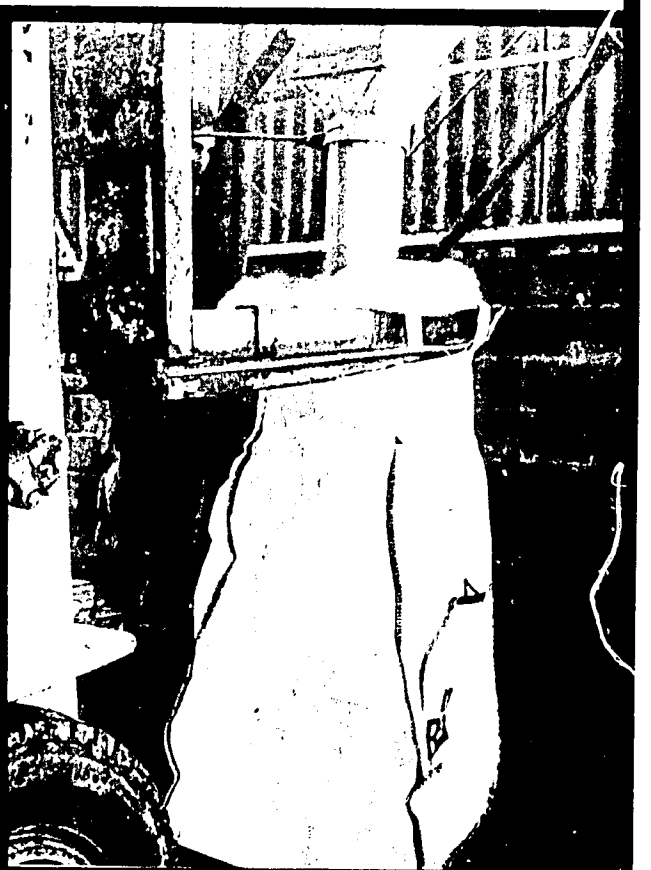


Figure 12. Filling 1-mt Bags from Bulk Shipment

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.

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.

Approximate investment required for 12,000 to 25,000 mt/year (3.5 mt/hour) of mining, grinding, and bagging capacity is $1.1 million. The equipment required is the same for either a 12,000 or 25,000 mt/year 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/year (table 27). Delivered cost would be $69.39/mt ($220.29/mt of P_2O_5 at Mopti) or $99.49/mt ($315.84/mt of P_2O_5) at Sikasso. This should be

Table 27. 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/yr)

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

compared with IFDC estimates for TSP of $250/mt or $556/mt of P_2O_5 delivered to Sikasso via Dakar-Bamako (actual costs were $286/mt of TSP or $622/mt of P_2O_5 as quoted by SCAER). Although the effectiveness of Tilemsi PR needs to be verified, it appears that the use of PR over TSP is economically justifiable.

Manufacturing Prospects

The greatest prospect for manufacturing processed fertilizers in the landlocked Sahelian countries at the present time appears to be in Mali. Production in Chad, Niger, and Upper Volta should be reconsidered if PR deposits are confirmed in Chad and after PR deposits of eastern Upper Volta and *Parc W* area of Niger are characterized.

In Mali a techno-economic study of the feasibility of producing materials ranging from PR to SSP, TSP, and NPK fertilizers was made in 1969 by Klockner Industries (16). They found that manufacturing of chemical fertilizers in Mali was not feasible. In 1976 IFAGRARIA (17), an Italian firm, recommended establishing a SSP and bulk-blending plant. The economic justification underlying its recommendation, however, used inflated costs for imported SSP to justify installation of domestic manufacturing capabilities.

The IFDC study team recalculated preliminary cost estimates of producing SSP at Bamako in a plant with capacity of 33,000 mt/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 28. 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.

Table 28. 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.

At 50% of design capacity the costs were $156.23 per mt of SSP and $867.94 per mt of P_2O_5.

The present c.i.f. Bamako cost of imported TSP is $250/mt or $556/mt of P_2O_5 (SCAER). Therefore, one mt 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 Malian 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 agronomic 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.

Other Relevant Studies

CILSS is undertaking a study of fertilizer and pesticide needs of the region and will make recommendations on how best to supply those needs. The study is expected to start in July 1976 with UNIDO assistance. Primary emphasis of the study will be on the use of regionally available raw materials and regional bulk-handling and bulk-blending schemes. Consideration will also be given to promotion of fertilizer use through extension activities.

POTENTIAL PROJECTS

All six Sahelian countries have land resources to achieve greater self-sufficiency in food production for their people. Since most current cultivation is manual, the main constraint on increasing land use appears to be labor. Expansing animal traction could greatly increase crop area. The productivity per worker can be significantly increased through the use of improved production practices on current cropland.

Project recommendations discussed below are aimed at increasing food production through fertilizer use. It is fully recognized that the benefits from using fertilizer depend upon the use of other improved crop production practices.

Recommended projects cover a range of activities which influence fertilizer use including public policy, agricultural research and extension, and fertilizer supply. Each project is discussed in greater detail in the individual country reports (volumes 2-7).

Soil Fertility

Data on actual yield responses to fertilizer under farmer conditions are lacking in all of the six countries. Some data of this type exist in Senegal and a project is under way to obtain additional data. Discussions are under way between FAO and the Government of Upper Volta to consider

a fertilizer trial and demonstration program. Response data are needed for major crops at various levels of management on farms but concentrating on higher levels of management. Levels of various management factors which influence crop response to fertilizer are: method of land preparation and tillage; varieties and plant population; timing of seeding, weeding, and harvesting; soil type and soil moisture should be recorded for all test sites. Varietal responses, effect of crop rotations, and value of residual fertilizer should also be studied.

In addition to Senegal where commercial mining is active, easily minable PR deposits exist in Upper Volta, Mauritania, Mali, and Niger. While limited agronomic tests comparing PR with soluble phosphates have not given as good response as soluble P fertilizer in the first year, basal applications of PR followed by small annual doses of soluble P fertilizers do show promise. The indigenous PR should be tested in comparisons with other standard PR and soluble P fertilizers. The effectiveness of these rocks need to be determined for the major crops under varying soil and moisture conditions. The residual value should be noted in all cases. The effect of placement and incorporation (within practical limits) should be determined for the PR.

Level of fertilizer use is low in the region. It is speculated that the cost:price relationship of fertilizer and crops, farmer awareness of the value of fertilizer, farmer awareness of other practices needed to maximize response to fertilizer, fertilizer availability, and credit availability contribute to the low demand. A study of the adoption of fertilizer use should be included as a component of the project. The study area should include an area where a crop production project is operating to provide the support services.

A Soil Fertility Project should be established to include all of these components in Chad, Mali, Mauritania, Niger, and Upper Volta. From three to five expatriate crop production specialists and one production economics specialist would be assigned to each country for the crop response components. A sociologist would coordinate and a graduate student perform field work for the fertilizer adoption component. More information on crop response to fertilizer on farms exists in Senegal and IBRD and USAID funded projects are under way to obtain additional data. The Casamance is being studied for potential funding of a crop production project. Relevant portions of this Soil Fertility Project should be included in any crop production project initiated in the Casamance. The Federal Republic of Germany is expected to supply one field trial officer for testing PR in Upper Volta. If that materializes, attempts should be made to include that assistance in the total Soil Fertility Project in Upper Volta. A detailed program should be outlined prior to starting which would permit accomplishment of the above-mentioned objectives. The program should be coordinated among the countries so that complementary data are obtained and transfer of information is accomplished.

An additional component of the project should be training of nationals to conduct and have responsibilities for soil fertility programs. In this connection four national assistants and/or counterparts (depending upon qualifications) should be assigned to each specialist. The assistants should have sufficient technical training to permit an understanding of methods, techniques, and basic theory of conducting field trials. The term of this project should be five years.

PR Mining and Grinding

Reserves of PR are estimated to be 100 million mt in Upper Volta, 20 million mt in Mali, and at least 10 million mt in Niger. Considerable portions of the deposits can be easily

surface mined. All three countries incur high transportation cost because of distances from seaports. Crop responses are obtained to P in all three countries and some degree of response to PR has been demonstrated. Mining and grinding of indigenous PR can result in considerable savings in delivery of P to farmers.

This project would consist of establishing PR mining and grinding facilities, providing technical services for starting the operation, and training personnel for continued operation. The project is applicable to Mali.

Feasibility studies for possible mining and grinding facilities are recommended for Niger and Upper Volta. Assistance from Federal Republic of Germany seems assured for small-scale projects in Niger and Upper Volta. Liaison with technicians from Germany is recommended when conducting feasibility studies for larger-scale facilities.

Bulk Blending

Chad, Mali, and Upper Volta are presently using 10,000, 12,000, and 4,000 mt, respectively, of mixed fertilizer per year. This level of use can support local blending plants using a low level of technology. The mixed fertilizers are imported as special mixtures which are made for individual orders. This results in costs up to $100/mt more than individual materials could be shipped into the countries and blended locally.

The Bulk Blending Project would involve establishing a simple blending system based upon importing materials in 1-mt containers. The project is applicable to Chad, Mali, and Upper Volta.

PR Characterization

PR deposits have been identified and studied for possible use in manufacturing in Mali. Other deposits have been identified in eastern Upper Volta and southern Niger (possibly of the same formation). Little information was obtained on the Niger deposits but the IFDC study team obtained samples of the PR from Kodjari, Upper Volta. The phosphate is of extremely fine texture and exists in a massive cherty matrix. These characteristics necessitate examination before possible uses are identified. A study for characterizing the Upper Volta PR should be conducted.

PR Deposit Identification

Phosphate rock deposits exist in Mauritania along the Senegal River. Small quantities have been mined and used in direct application. Assistance should be granted to Mauritania to survey these deposits, determine the extent and their value for chemical processing and for direct application.

There are fairly good indications of a phosphate deposit in the Bahr-er-Ghazal area northeast of N'Djamena, Chad. This area should be explored by aerial radiometrics to define areas in which prospecting would be most promising. Radiometric work for other minerals has been done in Chad by Polservice, a firm in Poland. That work was funded by UNDP. If the radiometric study so indicates, ground prospecting should proceed to determine the feasibility of mining and grinding phosphate rock for direct application in Chad.

Public Policies Related to Extending Fertilizer Use

All of the countries have some forms of price stabilization and equalization and subsidies. Some country governments depend heavily upon outside funds to maintain the subsidies while at the other extreme some have not only funded subsidies but have held producer prices low and profited from exports of crops at the expense of farmers. The effect, including interactions, of subsidies and taxes could not be examined in

detail within this study. That seems to be a study within itself. Mr. Sauger of ISRA in Senegal expressed an interest in a study of this type. Such a study should be undertaken for each of the six countries at the time national officials are willing and able to address the key issues and make available the appropriate counterparts.

Possibly a detailed case study might be conducted in one country (maybe Senegal) to determine the influences of various forms of subsidy and taxes in the agricultural sector upon the regional and national economy and social development. Alternatives could be delineated and their effects predicted to provide the government with guidelines in making policy decisions. Then, the study might be

Table 29. Summary of Proposed Projects and Budgets

Country	Project[a]	Annual Budget	Project Budget
Chad	Soil fertility (5)	$390,000	$1,950,000
	Bulk blending[b]	-	293,000
	Public policy	-	31,000
	PR identification	-	75,000
			$2,349,000
Mali	Soil fertility (6)	$470,000	$2,350,000
	Bulk blending[b]	-	293,000
	PR grinding[b]	-	1,352,000
	Public policy	-	31,000
			$4,026,000
Mauritania	Soil fertility (2)	$165,000	$ 825,000
	Public policy	-	31,000
			$ 856,000
Niger	Soil fertility (4)	$318,000	$1,590,000
	Feasibility of PR grinding	-	30,000
	Public policy	-	31,000
			$1,651,000
Senegal	Soil fertility (2)	$165,000	$ 825,000
	Public policy	-	31,000
			$ 856,000
Upper Volta	Soil fertility (6)	$470,000	$2,350,000
	Bulk blending[b]	-	293,000
	Feasibility of PR grinding	-	30,000
	Public policy	-	31,000
	PR characterization	-	53,000
			$2,757,000
Grand Total			$12,495,000

[a]Numeral in parentheses refers to the number of expatriate staff.
[b]Greatest portion in capital investment.

less involved in the other countries since many of the cause and effect relationships will likely be similar.

Estimated Budget

The estimated foreign exchange requirements for the budgets for the recommended projects are shown in table 29. The recommended soil fertility projects will require about $2 million/year or about $10 million to complete. Other projects for which budgets were prepared will require about $2.5 million and can be completed in 1 to 2 years. Additional potential projects are mentioned but will require further study to develop.

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14. Finne, Grace W., Sahel Transport Problems, Transport of U.S. Relief to the Drought Region, Mauritania, Mali, Upper Volta, Niger, and Chad. Dept. of Transportation.

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APPENDIX I

FERTILIZER RAW MATERIAL DEPOSITS AND LITERATURE REFERENCES IN SELECTED WEST AFRICAN COUNTRIES

Benin
Cameroon
Gabon
Ghana
Liberia
Nigeria
Spanish Sahara (Rio del Oro)
Togo

Information on raw material deposits in Senegal, Upper Volta, Mali, Niger, Mauritania, and Chad is contained in individual country reports.

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BENIN

References	Composition of Samples	Location	Other Information
Reference 1	The layers mentioned in this paper are too small to be of interest.		
Reference 2	**Nodules** P_2O_5 25-30% Al_2O_3 16 Fe_2O_3 12 CaO 19 SiO_2 13	Pobe	1/2-3/4 m thick Clearly not an apatite
	Raw Mineral P_2O_5 30 Al_2O_3 10 Fe_2O_3 2 CaO 41 SiO_2 9	Hahotoe This refers to the town of this name in Togo.	Simple washing increased the values to BPL of about 80%. (Presumably this is by removal of clays and other aluminous materials). See under Togo.
	Raw Mineral / **Washed Mineral** P_2O_5 29 / 34 Al_2O_3 6.8 / 6.7 Fe_2O_3 1.4 / 1.4 CaO 42 / 48 SiO_2 11 / 3	Lokossa	The bed is a continuation of the Togo deposits but has become reduced in thickness and values. Desliming should lead to further improvement.

BENIN (Continued)

References	Composition of Samples	Location	Other Information
Mines et Metallurgie No. 3.600 Nov. 1965, p. 514-5 Chermette A. and Olory-Togbe G.	Phosphate values Lignite values	North Benin in the valley of the Niger	The paper describes a "mining-research" programme.
Private communication (BRGM 1975)	Seven samples were taken in all and the raw rock analyses were in the ranges P_2O_5 27-32% CaO 36-50 SiO_2 26-34 R_2O_3 1-3	North Benin. Regions D'Arly and Kaabougou. (See also Upper Volta side of the border)	The ore bed is 6-10 m thick. "It is convenient for use in the south of Upper Volta." Reserves large.

References on Raw Material Deposits

1. Sedimentation argileuse et phosphatee au Dahomey. M. Slansky, T. Camez et G. Millot. Bull. Soc. geol. Fr., Ser. 7, 1959, Vol. 1, pp 150-155, fig., photos., refs. (In French).

2. Contribution a l'etude geologique du bassin sedimentaire cotier du Dahomey et du Togo. M. Slansky. Mem. Bur. Rech. geol. min., 1962, No. 11, pp 270, figs., photos., refs., col. geol. map. (In French) Roches phosphatees, pp 197-203.

CAMEROON

References	Composition of Samples	Location	Other Information
Reference 1	A layer of phosphate varying in composition from 5.8% P_2O_5 to a bottom band of 15-18% P_2O_5.	N.E. of Douala	The best layer is 1-2 m thick.
Private communication from the Paris School of Mines	Gas	Bomono, Souellaba and Logbaba	
Private communication and Europe-Outremer 1974, May, p. 55.	Oil	Rio del Ray	Being evaluated by the company Elf-Serepca.

References on Raw Material Deposits

1. Sur la presence d'accumulations phosphatees au Cameroon, au Dahomey, et au Togo. L. D. Visse. C.r. hebd. Seanc. Acad. Sci., Paris, 1953. Vol. 237, No. 19, pp 1171-1173, refs. (In French) Cameroon. p. 1171.

GABON

References	Composition of Samples	Location	Other Information
Reference 1	P_2O_5 8% Al_2O_3 2 Fe_2O_3 1/2 CaO 14 SiO_2 66 Organic 2.7%	Between St. Catherine and Pointe Iguegue	Occurs in calcareous sandstone. Other samples were found in siliceous and bituminous rocks.
Reference 2	No chemical analyses given, but described as calcium phosphate (many bones) held together by siliceous matter.	Between Fernan Vaz and Iguela.	The phosphate layers are intercalated between rocks of quite different composition.
Reference 3	This is almost identical with 2.		
Private communication	Rich phosphate of 81 BPL after desliming.	150 km to S.E. of Port Gentil and 50 km S.E. of d'Omboue.	The bed is 3 m thick and was found in 1973/4 when boring for oil.
Private communication from the Paris School of Mines.	Potassium salts	Lake Azingo	
Ann. Rept. Res. Inst. Afr. Geol. Leeds U. 1975, 19, 83.	Oil	Not given	Described as a large field

References on Raw Material Deposits

1. Observation geologiques dans la Partie Meridionale de l'Afrique Equatoriale Francaise (Bassins du Niari, de la Nyanga, de Djoue et du Haut Ogooue). V. Babet. 154 pp fig., photos., refs., geol. map, col. geol. map. (Paris: Mission Permanente de Recherches Geologiques. Afrique Equatoriale Francaise, 1932.) Gabon phosphate, p 142. (In French).
2. Les roches phosphatees de la cote du Gabon. R. Furon. C.r. hebd. Seanc. Acad. Sci., Paris, 1932, Vol. 194, No. 22, pp 1959-1960. (In French).
3. Observations geologiques sur la cote du Gabon (A.E.F.) (les roches phosphatees). R. Furon. Bull. Soc. geol. Fr., Ser. 5, 1932 Vol. 2, Pt. 5-6-7, pp 505-511, photos., refs. (In French).

LIBERIA

References	Composition of Samples	Location	Other Information
Reference 1	Various iron phosphates	Bomi Hill, 70 km north of Monrovia and Bambuta, 22 miles east of Bomi Hill	The source of phosphates is believed to be bat dung. This has reacted with exposed iron oxide present in this major deposit of iron ore.
Reference 2	32% P_2O_5	Bambuta	Minimum reserves 1 m ton. It is said to be a potential resource. On the surface the rocks are aluminous (variscite and augelite) and lower down mainly ferriferrous (strengite and barrandite).

References on Raw Material Deposits

1. Phosphate mineralization at Bomi Hill and Bambuta, Liberia, West Africa. J. M. Axelrod, M. K. Carron, C. Milton and T. P. Thayer. Am. Miner., 1952, Vol. 37, Nos. 22 and 12, pp 883-909, photos., refs.

2. Mineral-resource investigations. Prof. Pap. No. 750-A, U.S. Geol. Surv. 1971, p 217.

NIGERIA

References	Composition of Samples	Location	Other Information
Reference 2	P_2O_5 30-32% Al_2O_3 4-12% Fe_2O_3 3-6% CaO 32-38% CO_2 2-3%	Ifo Junction	"Unsuitable for acidulation". Not likely to be suitable for direct application. Only 20,000 tons in a bed 1-1/2 meters thick, but contains some intercalated shales. Overburden up to 3 m.
Reference 4 from the Senegal list p. 49 and p. 91	Phosphate rock 55-70 BPL	Oshosun 45 km North of Lagos	Three phosphate layers inter-bedded with clay; thickest is 0.9 m.
Reference 4 from the Senegal list pp. 56-59.	Coal and lignites	Between Port Harcourt and Enugu and near Benin City	Some of this is already mined to produce many hundreds of thousand tons per year.

References on Raw Material Deposits

1. The phosphate deposits of Abeokuta Province. W. Russ. Bull. No. 7, geol. Surv. Nigeria, 1924. 43 pp, figs., photos., refs., maps.

2. Phosphate deposits in Abeokuta Province. H. A. Jones. Rec. geol. Surv. Nigeria, 1964, Vol. 7, pp 5-13, figs., refs.

TOGO

1. Only references 2 and 4 could be easily obtained. But Togo deposits and developments are well known and more up-to-date information exists than is given in these 4. Moreover the deposits mentioned are in the south of Togo and about 500-600 km from the border with Upper Volta. These references are therefore unlikely to be of significance for the West African Study--at least at this stage.

2. The Hahotoe deposit is mentioned under Benin. This is because the reference number 2 covered the whole geographical area, irrespective of the Togo-Benin border.

References on Raw Material Deposits

1. Notice explicative sur la feuille Porto-Novo-Ouest. Carte geol. Reconn. A.O.F. No. NB. 31 N.O.O.9, 1959. P. Aicard and M. Slansky. 32 pp, refs., map. (In French) Phosphates, pp 8, 9, 22.

2. Le demarrage de l'exploitation du gisement de phosphate du Bas-Togo (The commencement of exploitation of the Lower Togo phosphate deposit.) J. Colonna-Cimera. Industr. Trav. Outremer, 1961, Vol. 9, No. 94, pp 651-656, figs., photos. (In French).

3. Contribution a l'etude geologique du bassin sedimentaire cotier du Benin et du Togo. M. Slansky. Mem. No. 11, Bur. Rech. geol. min., 1962. 270 pp, figs., photos., refs., col. geol. map (In French) Togo phosphate, pp 123-125, 201.

4. La mise en valeur des phosphates du Togo (Phosphate deposit development in Togo). M. Robert. Annls Mines, Paris, 1965, No. 3, pp 157-180, figs., photos. (In French. English summary.)

GHANA

1. Phosphatic nodules from the Sekondi Series, Ghana. W.G.C. Austin and A.F.J. Smit. Jnl Niger. Min. Geol. Metall. Soc., 1965, Vol. 2, No. 2, pp 47-56, fig., photo., refs.

SPANISH SAHARA

1. La investigacion de fosfatos en el Sahara (The investigation of phosphates in the Sahara). J. la Vina Villa. Arch. Inst. Estud. afr., Madrid, 1961, Vol. 16, No. 59, pp 65-83, figs. (In Spanish).

2. Phosphate prospecting in the Spanish Sahara. A.J.G. Notholt. Overseas Geol. Miner. Resour., 1965, Vol. 9, No. 4, pp 443-444.

3. Descubrimento, Cubicacion y Evaluacion del Yacimiento di Fosfato de Bu-Craa (Provincia del Sahara). 203 pp, figs., photos., refs., col. geol. maps. (Madrid: Empresa Nacional Minera del Sahara, S.A., 1966.)

4. Exploration of the Bu-Craa deposit, Spanish Sahara. Mineral Resour. Dev. Ser. No. 32, U.N.E.C.A.F.E., 1968, pp 284-291.

5. Bu-Craa--major addition to world phosphate mining capacity. Phosphorus & Potassium. 1973, No. 64, pp 21-27, figs., photos.

APPENDIX II

FERTILIZER AND TRANSPORTATION COSTS FOR WEST AFRICA

The following tables present data for fertilizer prices on the international market, ocean shipping rates, port handling charges, forwarding charges, transportation rates to selected destinations (inland), and estimated delivered costs to several locations in west Africa.

Two important points shown in these tables are: (1) ocean shipment in bulk with bagging at the receiving port can save the importing country about $20-25/mt in comparison to shipping in bags; and (2) freight rates from receiving ports to agricultural areas in the landlocked countries range from about $40/mt for Upper Volta to about $100/mt for Chad.

Table 1. International Market Prices of Fertilizers, Late 1975

Product	f.o.b. Vessel Prices, $/mt[a]		
	Average	High	Low
Bagged			
Urea	130	131	122
Ammonium Sulfate	65	69	61
Triple Superphosphate	133	139	125
Diammonium Phosphate	150	153	146
Bulk with Bags			
Urea	117	124	110
Ammonium Sulfate	44	50	38
Triple Superphosphate	120	126	114
Diammonium Phosphate	140	148	132
Bulk			
Potassium Chloride	60	64	56
Phosphate Rock[b]	30	-	-
Sulfur[c]	50	52	48

[a]IFDC estimate.
[b]Unground, 66 BPL, Tampa (PHOSROCK published price list).
[c]Canadian recovered sulfur.

Table 2. Estimated Freight Rates on Non-U.S. Vessels for Fertilizer Materials (FIO Basis) to Major Receiving Ports in West Africa[a]

Fertilizer Material	Loading Port	Unloading Port	Distance N-Miles	Steaming Time, Days (17 Knots)	Bulk Fertilizers[b] Estimated Freight Charges, $/mt			Bagged Fertilizers[c] Estimated Freight Charges, $/mt		
					Average	Maximum	Minimum	Average	Maximum	Minimum
N, P, K	Tampa	Dakar	3,976	9.8	17.89	40.16	8.75	29.42	42.94	9.14
N, P, K	Tampa	Abidjan	4,973	12.2	22.37	50.23	10.94	36.80	53.71	11.44
N, P, K	Tampa	Lagos	5,457	13.5	24.56	55.12	12.00	40.38	58.94	12.55
N, P, K	Tampa	Port Harcourt	5,676	13.9	25.54	57.32	12.49	42.00	61.30	13.01
N, P, K	Tampa	Douala	5,936	14.6	26.71	59.95	13.06	43.93	64.11	13.65
N	Yokohama	Dakar	11,349	27.8	51.47	114.62	24.97	83.98	122.57	26.10
N	Yokohama	Abidjan	11,200	27.4	50.04	113.12	24.64	82.88	120.96	25.76
N	Yokohama	Lagos	10,876	26.7	48.94	109.84	23.93	80.48	117.46	25.01
N	Yokohama	Port Harcourt	10,657	26.1	47.96	107.64	23.45	78.86	115.10	24.51
N	Yokohama	Douala	10,522	25.8	47.35	106.27	23.15	77.86	113.64	24.20
N, P	Rotterdam	Dakar	2,867	7.0	12.90	28.96	6.31	21.22	30.96	6.59
N, P	Rotterdam	Abidjan	4,032	9.9	18.14	40.72	8.87	29.84	43.55	9.27
N, P	Rotterdam	Lagos	4,468	10.9	20.01	45.13	9.83	33.20	48.25	10.27
N, P	Rotterdam	Port Harcourt	4,686	11.4	21.09	47.33	10.31	34.68	50.61	10.78
N, P	Rotterdam	Douala	4,936	12.1	22.21	49.85	10.86	36.53	53.31	11.35
P	Tunis	Dakar	2,384	5.8	10.73	24.07	5.24	17.64	25.75	5.48
P	Tunis	Abidjan	3,634	8.9	16.35	36.70	7.99	26.89	39.25	8.36
P	Tunis	Lagos	4,020	9.8	18.09	40.60	8.84	29.75	43.41	9.25
P	Tunis	Port Harcourt	4,200	10.3	18.90	42.42	9.24	31.08	45.36	9.66
P	Tunis	Douala	4,485	11.0	20.18	45.30	9.87	33.20	48.44	10.32
P	Casablanca	Dakar	1,396	3.4	6.28	14.10	3.07	10.33	15.07	3.21
P	Casablanca	Abidjan	2,559	6.3	11.52	25.85	5.63	18.94	27.64	5.89
P	Casablanca	Lagos	3,024	7.4	13.61	30.54	6.65	22.38	32.66	6.96
P	Casablanca	Port Harcourt	3,257	7.9	14.66	32.90	7.17	24.10	35.18	7.49
P	Casablanca	Douala	3,452		15.53	34.87	7.59	25.54	37.28	7.94

[a]Based on Maritime Research Report, first six months, 1975.
[b]Average $0.0045/mt mile; maximum, $0.0101/mt mile; minimum, $0.0022/mt mile.
[c]Average $0.0074/mt mile; maximum, $0.0108/mt mile; minimum, $0.0023/mt mile.

Table 3. Estimated Price of Major Fertilizers Shipped in Bulk with Bags to Key West African Ports

Loading Port	c.i.f. Price at Receiving Port, $/mt[a]				
	Abidjan	Dakar	Douala	Apapa	Port Harcourt
			Urea		
Tampa	142.88	138.40	147.22	145.07	146.05
Rotterdam	138.65	133.41	142.72	140.52	141.60
Yokohama	170.55	171.98	167.86	169.45	168.47
			Ammonium Sulfate		
Tampa	67.69	63.21	72.03	68.88	70.86
Rotterdam	63.46	58.22	67.53	65.33	66.41
Yokohama	95.36	96.79	92.67	94.26	93.28
			Triple Superphosphate		
Tampa	145.97	141.49	150.31	148.16	149.14
Casablanca	131.52	126.28	135.94	133.61	134.66
Tunisia	134.33	139.95	143.78	141.69	142.50
			Diammonium Phosphate		
Tampa	166.57	162.09	170.91	168.76	169.74
Rotterdam	162.34	157.10	166.41	164.21	169.74
Casablanca	151.52	146.28	153.61	154.66	155.94

[a]Calculated from tables 1 and 2.

Table 4. Estimated Price of Major Fertilizers Shipped in Bags to Key West African Ports

Loading Port	c.i.f. Price at Receiving Port, $/mt[a]				
	Abidjan	Dakar	Douala	Apapa	Port Harcourt
			Urea		
Tampa	170.70	163.32	177.83	174.28	175.90
Rotterdam	163.74	155.12	170.43	167.10	168.58
Yokohama	216.78	217.88	211.76	214.38	212.76
			Ammonium Sulfate		
Tampa	103.75	96.37	110.88	107.33	108.95
Rotterdam	96.79	88.17	103.48	100.15	101.63
Yokohama	149.83	150.93	144.81	147.43	145.81
			Triple Superphosphate		
Tampa	173.80	166.42	180.93	177.38	179.00
Casablanca	155.94	147.33	163.21	159.38	161.10
Tunisia	163.89	154.64	170.20	166.75	168.08
			Diammonium Phosphate		
Tampa	191.30	183.92	198.43	194.88	196.50
Rotterdam	184.34	175.72	191.03	187.70	189.18
Casablanca	173.44	164.83	180.71	176.88	178.60

[a]Calculated from tables 1 and 2.

Table 5. Estimated Costs in Addition to c.i.f. Receiving Port for Delivery to Selected Destinations--Bulk Fertilizers with Bags

Destination	Receiving Port	Cost, $/mt					Mode
		Stevedore and Port	Bagging	Handling[a]	Internal Freight[a]	Total[b]	
Chad							
N'Djamena	Douala	4.25	4.20	6.99	83.11	98.55	Rail + Road
N'Djamena	Port Harcourt	4.25	4.20	9.13	56.65	74.23	Rail + Road
N'Djamena	Apapa (Lagos)	4.25	4.20	9.13	86.60	104.18	Rail + Road
Niger							
Niamey	Abidjan	4.25	4.20	7.35	78.89	94.69	Rail + Road
Niamey	Cotonou	4.25	4.20	8.00	59.43	75.88	Rail + Road
Maradi	Apapa (Lagos)	4.25	4.20	9.46	39.96	57.87	Rail + Road
Zinder	Apapa (Lagos)	4.25	4.20	9.46	40.47	58.38	Rail + Road
Upper Volta							
Bobo-Dioulasso	Abidjan	4.25	4.20	4.00	28.23	40.68	Rail
Bobo-Dioulasso	Dakar	4.25	4.20	5.51	122.87	136.83	Rail + Road
Ouagadougou	Abidjan	4.25	4.20	4.00	40.42	52.87	Rail
Ouagadougou	Accra	4.25	4.20	4.43	38.61	51.49	Road
Mali							
Bamako	Dakar	4.25	4.20	4.00	65.81	78.26	Rail
Bamako	Abidjan	4.25	4.20	5.51	86.00	99.96	Rail + Road
Gao	Cotonou	4.25	4.20	10.91	121.00	140.36	Rail + Road
Gao	Abidjan	4.25	4.20	7.67	134.00	150.12	Rail + Road
Senegal							
Kidira	Dakar	4.25	4.20	3.76	34.21	46.42	Rail
Mauritania							
Rosso	Dakar	4.25	4.20	4.43	21.78	34.66	Rail
Rosso	St. Louis[c]	4.25	4.20	-	6.45	14.90	River

[a]Costs based on P. Cook report, "Sahel Transportation Analysis."
[b]Does not include import duties.
[c]Estimated literage to St. Louis from Dakar, $7.00.

Table 6. Estimated Costs in Addition to c.i.f. Receiving Port for Delivery to Selected Destinations—Bagged Fertilizer

Destination	Receiving Port	Cost, $/mt				Mode
		Stevedore and Port	Handling[a]	Internal Freight[a]	Total[b]	
Chad						
N'Djamena	Douala	7.00	6.99	83.11	97.10	Rail + Road
N'Djamena	Port Harcourt	7.00	9.13	56.65	72.78	Rail + Road
N'Djamena	Apapa (Lagos)	7.00	9.13	86.60	102.73	Rail + Road
Niger						
Niamey	Abidjan	7.00	7.35	78.89	93.24	Rail + Road
Niamey	Cotonou	7.00	8.00	59.43	74.43	Rail + Road
Maradi	Apapa (Lagos)	7.00	9.46	39.96	56.42	Rail + Road
Zinder	Apapa (Lagos)	7.00	9.46	40.47	56.93	Rail + Road
Upper Volta						
Bobo-Dioulasso	Abidjan	7.00	4.00	28.23	39.23	Rail
Bobo-Dioulasso	Dakar	7.00	5.51	122.87	135.38	Rail + Road
Ouagadougou	Abidjan	7.00	4.00	40.42	51.42	Rail
Ouagadougou	Accra	7.00	4.43	38.61	50.04	Road
Mali						
Bamako	Dakar	7.00	4.00	65.81	76.81	Rail
Bamako	Abidjan	7.00	5.51	86.00	98.51	Rail + Road
Gao	Cotonou	7.00	10.81	121.00	138.91	Rail + Road
Gao	Abidjan	7.00	7.67	134.00	148.67	Rail + Road
Senegal						
Kidira	Dakar	7.00	3.76	34.21	44.97	Rail
Mauritania						
Rosso	Dakar	7.00	4.43	21.78	33.21	Road
Rosso	St. Louis[c]	7.00	–	6.45	13.45	River

[a]Cost based on P Cook report, "Sahel Transportation Analysis."
[b]Import duties not included.
[c]Estimated literage to St. Louis from Dakar, $7.00.

Table 7. Estimated Delivered Cost of Fertilizer Shipped in Bags and Bulk with Bags and Savings for Bulk Shipment to Selected Destinations

Destination	Receiving Port	Delivered Cost, $/mt[a]					
		Urea from Rotterdam			Ammonium Sulfate from Rotterdam		
		Bagged	Bulk with Bags	Savings	Bagged	Bulk with Bags	Savings
Chad							
N'Djamena	Douala	267.53	241.27	26.26	200.58	166.08	34.50
N'Djamena	Port Harcourt	241.36	215.83	25.53	174.41	140.64	33.77
N'Djamena	Apapa (Lagos)	269.83	244.70	25.13	202.88	169.51	33.77
Niger							
Niamey	Abidjan	256.98	233.34	23.64	190.03	158.15	31.88
Niamey	Cotonou	241.53	216.40	25.13	174.58	141.21	33.37
Maradi	Apapa (Lagos)	223.52	198.39	25.13	156.57	123.20	33.37
Zinder	Apapa (Lagos)	224.03	198.90	25.13	157.03	123.71	33.37
Upper Volta							
Bobo-Dioulasso	Abidjan	202.97	179.33	23.64	136.02	104.14	31.88
Bobo-Dioulasso	Dakar	290.50	270.24	20.26	225.00	195.05	29.95
Ouagadougou	Abidjan	215.16	191.52	23.64	148.21	116.33	31.88
Ouagadougou	Accra	215.46	191.08	24.38	148.51	115.89	32.62
Mali							
Bamako	Dakar	231.93	211.67	20.26	166.43	136.48	29.95
Bamako	Abidjan	262.25	238.61	23.64	195.30	163.42	31.88
Gao	Cotonou	306.01	280.88	25.13	239.06	205.69	33.37
Gao	Abidjan	312.41	288.77	23.64	245.46	213.58	31.88
Senegal							
Kidira	Dakar	200.09	179.83	20.26	133.14	104.64	28.50
Mauritania							
Rosso	Dakar	188.33	168.07	20.26	121.38	92.88	28.50
Rosso	St. Louis	175.57	155.31	20.26	108.62	80.12	28.50

[a]Based on previous tables.

Table 8. Estimated Delivered Cost of Fertilizer Shipped in Bags and Bulk with Bags and Savings for Bulk Shipment to Selected Destinations

Destination	Receiving Port	Delivered Cost, $/mt					
		TSP from Casablanca			DAP from Rotterdam		
		Bagged	Bulk with Bags	Savings	Bagged	Bulk with Bags	Savings
Chad							
N'Djamena	Douala	260.31	234.49	25.82	288.13	264.96	23.17
N'Djamena	Port Harcourt	233.88	208.89	24.99	261.96	239.52	22.54
N'Djamena	Apapa (Lagos)	262.11	240.12	21.99	290.43	268.39	22.04
Niger							
Niamey	Abidjan	249.18	226.21	22.97	277.58	257.03	20.55
Niamey	Cotonou	233.81	209.49	24.32	262.13	240.09	22.04
Maradi	Apapa (Lagos)	215.80	191.48	24.32	244.12	222.08	22.04
Zinder	Apapa (Lagos)	216.31	191.99	24.32	244.63	222.59	22.04
Upper Volta							
Bobo-Dioulasso	Abidjan	195.17	172.20	22.97	223.57	203.02	20.55
Bobo-Dioulasso	Dakar	282.71	263.11	19.60	311.10	293.93	17.17
Ouagadougou	Abidjan	207.36	184.39	22.97	235.76	215.21	20.55
Ouagadougou	Accra	207.70	184.06	23.64	236.17	214.77	21.40
Mali							
Bamako	Dakar	224.14	204.54	19.60	252.53	235.36	17.17
Bamako	Abidjan	254.45	231.48	22.97	282.85	262.30	20.55
Gao	Cotonou	298.21	273.97	24.24	326.61	304.57	22.04
Gao	Abidjan	304.61	281.64	22.97	333.01	312.46	20.55
Senegal							
Kidira	Dakar	192.30	172.70	19.60	220.69	203.52	17.17
Mauritania							
Rosso	Dakar	180.54	160.94	19.60	208.93	191.76	17.17
Rosso	St. Louis	167.78	147.18	19.60	196.17	179.00	17.17

[a]Estimated literage from Dakar to St. Louis, $7.00.

Table 9. Estimated Freight Rates on Non-U.S. Vessels for Potassium Chloride in Bulk (FIO Basis) to Major Receiving Ports in West Africa[a]

Material	Loading Port	Unloading Port	Distance N-Miles	Steaming Time, Days (17 Knots)	Estimated Freight Charges,[b] $/mt		
					Average	Maximum	Minimum
Potash	Point Noire	Dakar	2,739	6.7	12.33	27.66	6.03
Potash	Point Noire	Abidjan	1,330	3.2	5.99	13.43	2.93
Potash	Point Noire	Lagos	1,064	2.6	4.79	10.75	2.34
Potash	Point Noire	Port Harcourt	798	1.9	3.59	8.06	1.76
Potash	Point Noire	Douala	913	2.2	4.11	9.22	2.01
Potash	Vancouver	Dakar	7,776	19.0	34.99	78.54	17.11
Potash	Vancouver	Abidjan	8,671	21.3	39.02	87.58	19.08
Potash	Vancouver	Lagos	9,132	22.4	41.09	92.23	20.09
Potash	Vancouver	Port Harcourt	9,362	22.9	42.13	94.56	20.60
Potash	Vancouver	Douala	9,477	22.9	42.65	95.72	20.85

[a]Based on Maritime Research Report, first six months, 1975.
[b]Average, $0.0045/mt mile; maximum, $0.0101/mt mile; minimum, $0.0022/mt mile.

Table 10. Estimated Freight Rates on Non-U.S. Vessels for Phosphate Rock in Bulk (FIO Basis) to Major Receiving Ports in West Africa[a]

Material	Loading Port	Unloading Port	Distance N-Miles	Steaming Time, Days (17 Knots)	Estimated Freight Charges,[b] $/mt		
					Average	Maximum	Minimum
Phosphate Rock	Aqaba	Dakar	3,648	8.9	14.96	26.63	4.38
Phosphate Rock	Aqaba	Abidjan	5,023	12.3	20.59	36.67	6.03
Phosphate Rock	Aqaba	Lagos	5,523	13.6	22.64	40.32	6.63
Phosphate Rock	Aqaba	Port Harcourt	5,698	14.0	23.36	41.60	6.84
Phosphate Rock	Aqaba	Douala	5,936	14.5	24.34	43.33	7.12
Phosphate Rock	Tampa	Dakar	3,976	9.8	16.30	29.02	4.77
Phosphate Rock	Tampa	Abidjan	4,973	12.1	20.39	36.30	5.97
Phosphate Rock	Tampa	Lagos	5,457	13.4	22.37	39.84	6.55
Phosphate Rock	Tampa	Port Harcourt	5,676	13.9	23.27	41.43	6.81
Phosphate Rock	Tampa	Douala	5,936	14.5	24.34	43.33	7.12
Phosphate Rock	Casablanca	Dakar	1,396	3.4	5.72	10.19	1.68
Phosphate Rock	Casablanca	Abidjan	2,559	6.3	10.49	18.68	3.07
Phosphate Rock	Casablanca	Lagos	3,024	7.4	12.40	22.08	3.63
Phosphate Rock	Casablanca	Port Harcourt	3,257	8.0	13.35	23.78	3.91
Phosphate Rock	Casablanca	Douala	3,452	8.4	14.15	25.20	4.14
Phosphate Rock	Dakar	Dakar	-	-	-	-	-
Phosphate Rock	Dakar	Abidjan	1,375	3.4	5.64	10.04	1.65
Phosphate Rock	Dakar	Lagos	1,875	4.6	7.69	13.69	2.25
Phosphate Rock	Dakar	Port Harcourt	2,050	5.0	8.41	14.97	2.46
Phosphate Rock	Dakar	Douala	2,288	5.6	9.38	16.70	2.75

[a]Based on Maritime Research Report, first six months, 1975.
[b]Average, $0.0041/mt mile; maximum, $0.0073/mt mile; minimum, $0.0012/mt mile.

Table 11. Estimated Freight Rates on Non-U.S. Vessels for Sulfur in Bulk (FIO Basis) to Major Receiving Ports in West Africa[a]

Material	Loading Port	Unloading Port	Distance N-Miles	Steaming Time, Days (17 Knots)	Estimated Freight Charges,[b] $/mt		
					Average	Maximum	Minimum
Sulfur	Umm Qasr	Dakar	7,175	17.8	35.16	60.99	12.91
Sulfur	Umm Qasr	Abidjan	8,344	20.4	40.88	70.92	15.02
Sulfur	Umm Qasr	Lagos	8,284	20.2	40.59	68.93	14.91
Sulfur	Umm Qasr	Port Harcourt	8,284	20.2	40.59	70.41	14.91
Sulfur	Umm Qasr	Douala	8,284	20.2	40.59	70.41	14.91
Sulfur	Kharg Island	Dakar	6,846	16.7	33.55	58.19	12.32
Sulfur	Kharg Island	Abidjan	7,665	18.8	37.55	65.15	13.80
Sulfur	Kharg Island	Lagos	7,605	18.6	37.26	64.64	13.69
Sulfur	Kharg Island	Port Harcourt	7,605	18.6	37.26	64.64	13.69
Sulfur	Kharg Island	Douala	7,605	18.6	37.26	64.64	13.69
Sulfur	Vancouver	Dakar	7,776	19.0	38.10	66.10	14.00
Sulfur	Vancouver	Abidjan	8,671	21.3	42.49	73.70	15.61
Sulfur	Vancouver	Lagos	9,132	22.4	44.75	77.62	16.44
Sulfur	Vancouver	Port Harcourt	9,362	22.9	45.87	79.58	16.85
Sulfur	Vancouver	Douala	9,477	23.2	46.44	80.55	17.06

[a]Based on Maritime Research Report, first six months, 1975.
[b]Average, $0.0049/mt mile; maximum, $0.0085/mt mile; minimum, $0.0018/mt mile.

Table 12. Estimated Delivered Prices of Potassium Chloride, Phosphate Rock, and Sulfur in Bulk to Key West African Ports

Receiving Port	Estimated Delivered Prices, $/mt[a]		
	Potassium Chloride	Phosphate Rock	Sulfur
Abidjan	74.79	58.29	100.99
Dakar	81.13	54.20	96.60
Douala	72.91	62.24	104.94
Apapa	73.59	60.27	103.25
Port Harcourt	72.39	61.17	104.37

[a]Based on tables 1, 9, 10, and 11 plus $7.00/mt for stevedoring and port fees (import duties not included). Potassium chloride from Point Noire, phosphate rock from Tampa, and Sulfur from Vancouver.