UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

18574

Distr.
LIMITED

PPD.170
14 July 1990

ORIGINAL: ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INDUSTRIAL DEVELOPMENT STRATEGIES FOR FERTILIZER INDUSTRIAL SYSTEMS IN AFRICA*

Prepared by the
Department for Programme and Project Development

---

* Mention of Company names and commercial products does not imply the endorsement of UNIDO. The boundaries shown on the maps do not imply official endorsement or acceptance by the United Nations Industrial Development Organization. This document has not been edited.

5/..

V.90 87151

Preface

This report has been prepared by UNIDO's Programme Development Support Unit (PDS).

Specialist staff from the Chemical Branch of UNIDO's Division of Industrial Operations have contributed valuable comments and assistance throughout the preparation of this study.

PDS is also grateful for valuable data supplied by FAO.

The main results of the study are summarized in the document "Industrial Development Strategies for Fertilizer Industrial Systems in Africa: Presentation of the Main Results".

CONTENTS

Tables

Figures

Glossary

A (NH_3):	Ammonia
Agricultural land.	In addition to the categories mentioned in "Arable land and land under permanent crops", this includes land under permanent meadows and pastures.
AN:	Ammonium nitrates
Arable land:	Refers to land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow or lying idle.
Arable land and land under permanent crops:	This includes land under temporary crops, temporary meadows for moving pastures, land under market and kitchen gardens, land temporarily fallow or lying idle and also under permanent crops.
AS:	Ammonium sulphates
Base diagram:	A schematic representation of an industrial system. Depicts all the components of the system from demand for final products through to primary inputs. Illustrates the linkages between each component as well as the area of action of government policies. The base diagram permits a view of the integrated character of an industrial system.
Bulk fertilizer:	Refers to unpacked fertilizer.
Bulk-blended fertilizer:	Two or more granular fertilizers of similar size mixed together to form a compound fertilizer.
CAN:	Calcium ammonium nitrate
Cluster analysis:	A statistical technique for grouping objects according to readings on more than one variable
Commercial fertilizer:	Refers to a material containing at least one of the primary nutrients in a form assimilable or "available" to plants in known amounts.

Complex fertilizers:	Refers to the compound fertilizer formed by mixing ingredients that react chemically.
Compound fertilizer:	Fertilizer containing two or more nutrients.
Country group:	A number of countries from a sample which based on a pre-defined set of characteristics (in this case FERTIS components) are more similar than the other objects in the sample.
CPEs:	Centrally planned economies
DAP:	Di-ammonium phosphate
Developing Africa:	Here includes all the countries of the African continent with the exception of South Africa and Namibia. At the time of the preparation of this report Namibia was not an independent state.
Development pattern:	The sum of readings on the level of development of all components making up an industrial system.
DSP:	Double super phosphate
Fertility of soils:	Refers to the ability of soils to supply the plants with the essential nutrients needed to complete their life cycle.
Fertilizer:	Any material, organic or inorganic, natural or synthetic, that furnishes plants with one or more of the chemical elements necessary for normal growth. In this document the term "fertilizer" will be used in the sense of commercial fertilizer.
Fertilizer nutrient:	One of the three primary plant nutrients (N, P and K).
Fertilizer production:	Refers to production based on ammonia, phosphoric acid or rock phosphate.
FERTIS:	Fertilizer industrial system
GR:	Ground phosphate rock
Grade:	The grade of a fertilizer is the nutrient content expressed in weight percentages of N, P_2O_5, and K_2O in that order.
Granular fertilizer:	Refers to fertilizer in the form of particles, usually within the range of 1- 4 mm in diameter.

Indicative programme:	The second stage of the programme approach. The programme is integrated in nature and comprises appropriate investments, technical assistance and policy prescriptions. The programme is "indicative" of the sectoral pattern of development in other countries of the same typology group identified during the first stage of the programme approach, namely the preparation of sectoral typologies (see "The Application of a Programme Approach to Technical Assistance Project Identification and Formulation", UNIDO/APP, October 1988).
Industrial system:	The sum of productive capacities, supportive infrastructure and flows of goods and services resulting in the production of a given industrial output. Comprises one entire sector or several interlinked sectors or subsectors. The industrial system is composed of a set of production components, an institutional and policy framework. The components of a system are highly interdependent, in that any change in one component tends to modify the whole system.
KCL:	Potassium chloride or muriate of potash.
K_2O:	Potash
Macronutrients:	Refers to nutrients required in relatively large amounts such as nitrogen, phosphorus, potassium, calcium, magnesium, carbon, hydrogen and oxygen. Of these, carbon, hydrogen and oxygen are available from air and water.
MAP:	Mono ammonium phosphate
Micronutrients:	Refers to elements required in small quantities. These are also known as trace elements.
Mixed fertilizer:	Refers to the compound fertilizer formed by mechanical mixing without chemical reaction.
MOP:	Muriate of potash
N:	Nitrogen
NA:	Nitric acid

NOP:	Nitrate of potash
NP:	Nitrogen and phosphate
NPK:	Nitrogen, phosphate and potash
P_2O_5:	Refers to the phosphate nutrient. It is an oxide of phosphorous.
PA:	Phosphoric acid
Plant nutrient:	Any of the elements essential to plant growth.
Primary nutrients:	Refers to nitrogen, phosphorus and potassium.
Programme approach:	A methodology aiming to promote the integrated development of industrial systems. Comprises three interrelated stages which should usually be undertaken consecutively. The concept underlying all three stages is that of an industrial system. The development of an industrial system requires simultaneous actions across all components of the system to eliminate constraints affecting the operation of the system as a whole.
SA:	Sulphuric acid
Secondary nutrients:	Refers to calcium, magnesium and sulphur.
Sectoral typologies:	Refers to the application of the first stage of the programme approach. Involves identification of groups of countries with homogeneous development patterns in a given sector from among a large number of countries.
Simple disaggregation:	Refers to the identification of the components and the interlinkages of a given industrial system.
SOP:	Sulphate of potash
SSP:	Simple superphosphate
Straight fertilizer:	Fertilizer containing only one nutrient, e.g. urea or superphosphate.
System:	See "Industrial system".
Trace elements:	See "Micronutrients"
TSP:	Triple superphosphate
U:	Urea

EXECUTIVE SUMMARY

The present study provides an assessment of and strategy design for the development of the fertilizer industrial system in developing Africa. The study was prepared as the first stage in the application of the Programme Approach to programming the 1990/1991 biennium for the Industrial Development Decade for Africa (IDDA). Equivalent sectoral typology work has been carried out in other African agro-industries, namely agricultural machinery, pesticides and agro-food processing industries.

The Programme Approach entails the disaggregation of an industrial system into its component parts, permitting a quantitative assessment of each component, the relationship between components and the linkages existing between components and the rest of the economy. Twelve components were identified as making up the fertilizer industrial system. Variables were then selected to provide a quantitative description of the level of development of each component. Multivariate statistical methods were applied to these variables with the aim of identifying homogeneous patterns of development in the fertilizers industry.

The main output of the report was the identification of ten distinct patterns of development in the fertilizers industry and the design of pattern specific development strategies. Policy prescriptions as well as technical assistance and investment activities required to implement pattern-specific development strategies were also detailed. In addition to the formulation of development programmes, the classificatory technique used here can facilitate the design of means for promoting economic co-operation between the countries studied. Furthermore, the study will assist in indicating countries suitable for the repetition of strategies successfully implemented in other countries having the same development pattern.

The study has a number of potential clients. Firstly, it can be used as a tool in the industrial planning exercise to be undertaken by African governments programming priority sectors in the context of the second Industrial Development Decade for Africa (IDDA II). Government offices responsible for planning fertilizer industry development and overviewing the daily operations of the industry can rectly use the study's output for programming the system and setting priorities for action in an integrated manner. Developing countries can likewise use the study as a means of learning from the development experience of countries facing a similar range of problems. The study will also be useful to international technical assistance agencies and aid-giving financial organizations in designing integrated programmes for groups of countries rather than for individual countries. Government and business alike may also find a practical benefit in the methodological approach applied in the study.

1. INTRODUCTION

1.1 Background and overview

The present study analyses one of the most important industrial input systems for the development of African agriculture. The analysis of Africa's fertilizer industry is here undertaken using the UNIDO programme approach. This approach has been developed with the goal of increasing the impact of technical assistance and investment projects. The programme approach comprises three interrelated steps; sectoral typologies, indicative programmes and quantitative integrated sectoral programmes. The first of these steps, the sectoral typology, is used in this study.

The objective of a sectoral typology is to group countries according to similarities in patterns of development of a given industrial system. An industrial system is conceptualized as the sum of goods and services flows resulting in a given industrial product. An industrial system may comprise one or several sectors. For example, in the case of the fertilizers industrial system (FERTIS) it is clear that chemical, mining and agricultural sectors are involved, either from the supply or demand side.

Much classificatory work related to developing countries is of a univariate and frequently macro-economic nature. Countries are often grouped according to single measures of national income, rate of growth of exports, rates of literacy and infant mortality, regional location and even language. Such categories are of limited utility in the identification and formulation of technical assistance and investment projects.

However, the sectoral typologies employed under the programme approach focus on an industrial system and are of a multivariate character, simultaneously assessing the performance of each component within the industrial system. The use of multivariate statistical tools in comparing the constituent elements of an industrial system across a number of countries provides classifications which facilitate the identification and formulation of technical assistance and investment needs. The uses and advantages of such classifications are outlined below:

- To provide a basis for designing pattern-specific development strategies.

- To provide developing countries with a means of assessing and drawing on the development experience of other countries.

- To facilitate the design of programmes of technical assistance and investment projects.

- To facilitate the design of means for promoting economic co-operation between developing countries.

- To indicate which countries would be suitable for the repetition of strategies successfully implemented in a country having the same development pattern.

The choice of the fertilizers industrial system as the subject of this study was made on account of the priority placed on agro-related industries and input subsystems by African countries in the context of the Industrial Development Decade for Africa (IDDA) 1/, United Nations Programme of Action for African Economic Recovery and Development (UNPAAERD) 2/ and the African Priority Programme of Economic Recovery (APPER) 3/.

The major outputs of the study are:

- An assessment of the fertilizer industrial system in forty-three African countries and the identification of ten development patterns from amongst these forty-three countries (although 50 African countries were considered, inadequate coverage of the data only permitted analysis on 43 countries). The country groupings identified reflect similarities of an industrial nature rather than of a geographical, political or purely macro-economic character. The similarities identified in fertilizer industry development reflect a range of industrial indicators rather than any single measure of fertilizer industry development.

- The basis for development strategies specific to each of the ten identified patterns of fertilizer industry development.

- A description of actions required to realize these strategies in terms of investments, technical assistance, policies and options for the promotion of industrial co-operation among the countries studied.

- Demonstration of a methodology whereby changing patterns of development in Africa's fertilizer industrial system can be consistently evaluated. This will provide a methodological tool for the ongoing formulation of appropriate and integrated packages of technical assistance, investments and policy prescriptions.

The most beneficial output of this study, which differentiates the study from conventional approaches, is the set of development strategies and actions corresponding to each development pattern. Furthermore, by analyzing the fertilizer industrial system as an integrated whole it is hoped that the resulting development strategies and actions will themselves be of an integrated character and hence that the likelihood of achieving significant impact will be enhanced. A further beneficial output is the empirical assessment at the regional level of the process of fertilizer industry development.

The study has a number of potential clients. Firstly, it can be used as a tool in the industrial planning exercise to be undertaken by African governments programming priority sectors in the context of the second Industrial Development Decade for Africa (IDDA II). Government offices responsible for planning fertilizer industry development and overviewing the daily operations of the industry can directly use the study's output for

---

1/ See UNIDO Programme Budget 1990/1991, document GC period 3/10, paragraph 27.

2/ See the General Assembly Resolution S - 13/2, July 1st 1986.

3/ See Africa Priority Programme of Economic Recovery 1986-1990, A/40/666 Annex 1.

programming the system and setting priorities for action in an integrated manner. Developing countries can likewise use the study as a means of learning from the development experience of countries facing a similar range of problems. The study will also be useful to international technical assistance agencies, aid-giving and financial organizations in designing integrated programmes for groups of countries rather than for individual countries. Government and business alike may also find a practical benefit in the methodological approach applied in the study.

1.2 Structure of the report

This introductory chapter is followed by a chapter presenting an overview of the African fertilizer industrial system. Chapter 2 places the African fertilizer industrial system in the global context, comparing its position and recent performance with that of other developing and developed regions. Chapter 2 describes production, trade and consumption of fertilizers in Africa as well as salient features of the main African producers. Those factors affecting agriculture and the consumption of fertilizers are examined in detail. Potential development of the fertilizers industrial system in Africa is assessed through an examination of raw materials availability, general and industrial infrastructure, manpower, energy and water supply. Environmental aspects of fertilizer industry development are considered towards the end of the chapter. Constraints to further development in this industry which are particular to the African case are commented on throughout chapter 2.

Chapter 3 provides a detailed description of the operations of the fertilizers industrial system. While of a technical nature, the text is accessible to the non-specialist reader. A detailed description is made of the twelve interlinked components which make up the fertilizer industrial system. The variables used to quantitatively describe each component during the application of multivariate statistical techniques are briefly commented upon. Two further sets of variables of particular use in strategy formulation, namely constraint and enhancement variables, are also described. The constraint variables are connected with important bottlenecks to the development of the fertilizer industrial system while the enhancement variables represent factors favourable to the development of the system. Limitations imposed on the study by uneven data coverage are also noted.

Chapter 4 presents the results of the classificatory exercise. The ten country groups identified are described in detail with emphasis being placed on the factors which give each country group a distinct development pattern.

Chapter 5 presents development strategies specific to each of the country groups identified. Technical assistance, investments and policy prescriptions best suited to the amelioration of each group's specific constraints are described in this chapter.

It should be noted that data for 1986 has been used throughout the report. This was the last year for which data was of sufficiently wide availability for African countries.

2. OVERVIEW OF THE FERTILIZER INDUSTRIAL SYSTEM IN AFRICA

2.1 Introduction

There is growing concern over how to feed an expanding world population. This problem is particularly urgent for low-income developing countries where a large share of new food demand is created. The Food and Agricultural Organization (FAO) states that the world has the potential to feed a population of 6.2 billion in the year 2000 moderately better than it fed 4.4 billion in 1984. However, in order to realise this potential, developing countries will have to double their food production in order to keep pace with population growth.

If this goal cannot be achieved, the number of seriously undernourished people in the world could be as high as 600 million by the year 2000, the Far East and Africa being the regions worst hit. Conditions generally in the world are favourable for a sustained increase in food production and advances in food production technology make it possible for mankind to eradicate hunger within the next ten to twenty years. Sufficient fertilizer supplies, along with other yield increasing agricultural technologies, are available to support this goal. The African population of over 570 million in 1986 is projected to increase to around 870 million by the year 2000. The continent must intensify agricultural operations to produce additional food. In many African countries agricultural exports are the principal source of foreign exchange earnings. The ability of the agricultural sector to supply domestic demand for food and raw materials and produce a surplus for export is of vital importance for African nations. This can be done by increasing yields on cultivated land, expanding cultivated land where possible and increasing cropping intensity. In addition to food production, agriculture can produce materials for energy-generation such as methane biogas, alcohol and biomass to replace non-renewable sources such as petroleum. Increasing both the acreage and yield of existing land will require that large quantities of fertilizers become available to the farmer in the right kinds and at the proper time.

The fertilizer industry is a complex system consuming large amounts of raw materials, energy, capital and manpower. Furthermore, the system involves the storage, transport and distribution of large amounts of manufactured final products and can only be developed successfully through complex actions related simultaneously to mining, refining, energy, transport and the engineering subsectors. Proper logistics are of key importance in FERTIS development even if the country is primarily a fertilizer importer. Distributional infrastructure and capabilities must reach consumers and may begin with the infrastructure of a sea-port such as vessels, terminals, and unloading facilities, through to a transportation network and transportation fleet and ending with storage facilities in the remotest areas if needs be.

This chapter positions African countries within the world fertilizers context by giving an overview of the production, consumption and trade of fertilizers in the continent.

2.2 Production of fertilizers in Africa

Table 2.1 presents data on world and regional production of NPK fertilizers in 1986. The table clearly illustrates the limited extent of fertilizers production in Africa which accounts for a mere 2.4 % of world production. The position of developing Africa is weaker still, contributing only 1.9 % of world fertilizers production. The absence of potassium related fertilizer production in Africa is also noteworthy.

Table 2.1 Production of NPK fertilizers in the world in 1986 (thousands of metric tonnes)

	N	P_2O_5	K_2O	NPK	Share %
Western Europe	11282	4717	4897	20896	14,60
Eastern Europe	22306	11597	13713	47615	33,40
Africa Total	1664	1832	0	3496	2,40
Developing Africa	1300	1470	0	2760	1,90
North America	13642	8513	8251	30406	21,30
Central America	1674	263	0	1937	1,40
South America	1358	1654	11	3022	2,10
Middle East	1761	720	1926	4406	3,10
Asia CPEs	12231	2521	25	14776	10,40
South and East Asia	11290	3860	0	15149	10,60
Oceania	253	788	0	1041	0,70
WORLD TOTAL	77460	36460	28820	142740	100

Source: FAO, Yearbook 1987

2.2.1 Production processes used

There are three distinct routes in the manufacture of nitrogen fertilizer:

-ammonia (A) with carbon dioxide to urea (U)

-ammonia to nitric acid (NA) ammonium nitrate (AN)/calcium ammonium nitrate (CAN)

-ammonia (A) with sulphuric acid (SA) to ammonium sulphate (AS).

All three routes are used in Africa. The routes to urea and ammonium nitrate are of almost equal importance. There is, however, a slight advantage with AN/CAN products as these can be manufactured more flexibly both from imported ammonia and from ammonia produced through water electrolysis since there is no need to use carbon dioxide to produce urea.

Of the three straight potash fertilizers i.e. muriate of potash (MOP), sulphate of potash (SOP) and nitrate of potash (NOP), none is produced in Africa. The most widely used is potassium chloride (KCl), known as muriate of potash (MOP).

As far as sulphuric acid is concerned, the process of sulphur (brimstone) burning with air predominates in Africa. However, sulphuric acid is also produced from pyrites and through utilization of sulphur-bearing smelter off-gasses, although on a much lower scale.

Ammonia produced in fertilizer plants and complexes has many industrial applications. Ammonium nitrate is employed as an industrial explosive in coal mines and limestone quarries producing both coal necessary for the generation of steam used in fertilizer complexes and limestone which is itself the source of agricultural lime used for improving soil fertility.

Urea is used for the production of plastics such as melamine and urea-formaldehyde resins. Ammonium sulphate, which in industrialised countries is mainly a by-product of the caprolactam process, is manufactured in Africa through synthesis of ammonia and sulphuric acid. Though the importance of ammonium sulphate is less than that of ammonium nitrate or urea, it can be used for sulphur deficient African soils.

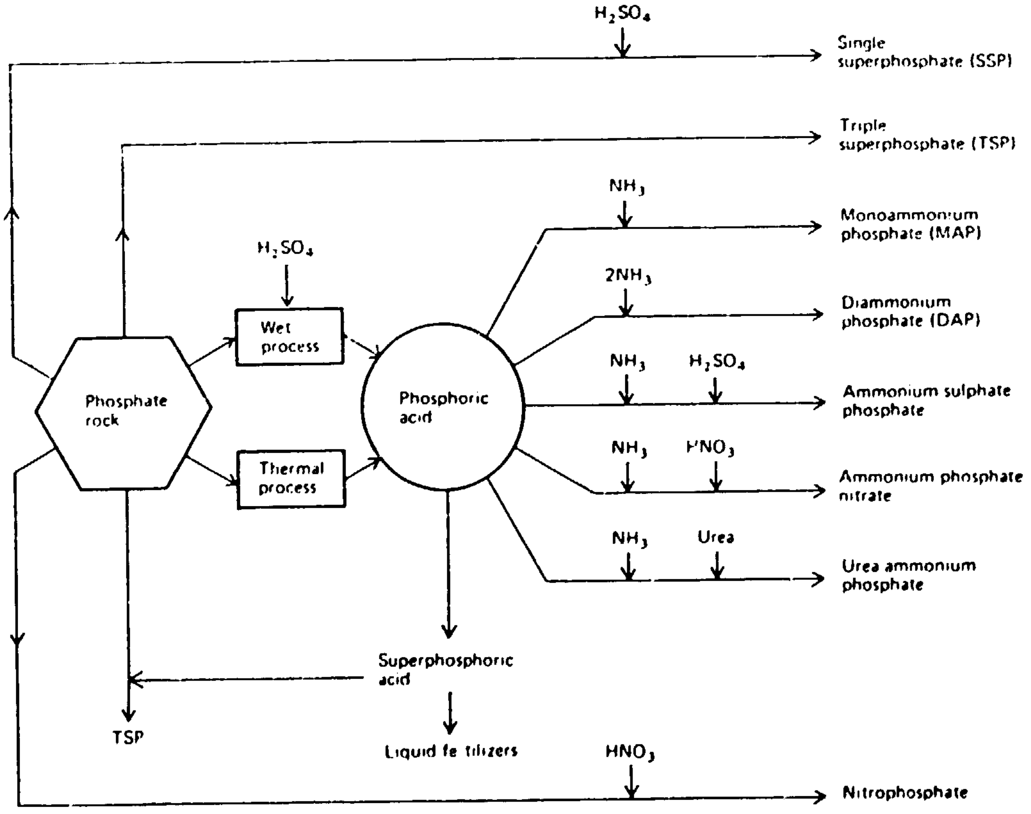
The balance of nitrogen fertilizers manufactured in Africa comes from the production of complex NP and NPK fertilizers, mostly through the reaction of ammonia with phosphoric acid to yield di-ammonium phosphate (DAP) or mono-ammonium phosphate (MAP).

Superphosphates, single (SSP), double (DSP) and triple (TSP) are straight phosphate fertilizers widely produced in Africa, DSP being of lesser importance in terms of production.

Phosphoric acid is used in the manufacture of many industrial chemicals and products. For example, sodium tripolyphosphate and other phosphates are used in soap, washing powders and detergent industries.

There are many opportunities to produce complex fertilizers based on phosphate rock and phosphoric acid, as is illustrated in figure 2.1 below. Wet phosphoric acid technology, based on a reaction of phosphate rock with sulphuric acid is most commonly used process in Africa.

Figure 2.1 Processing options for the production of complex fertilizers based on phosphate rock



Source: UNIDO - Development and Transfer of Technology Series No. 8, Process Technologies for Phosphate Fertilizers, New York, 1978.

2.2.2 Primary nutrients - synthesis

There are twelve producers of NPK fertilizers in Africa manufacturing altogether some 2.7 million mt of NP fertilizers. In alphabetical order these are: Algeria, Côte d'Ivoire, Egypt, Libya, Mauritius, Morocco, Nigeria, Senegal, Tanzania, Tunisia, Zambia and Zimbabwe. Table 2.2 illustrates production, consumption and trade in fertilizers in the twelve producing countries. Salient features of the fertilizers industrial system in each of the twelve countries are commented on below.

Algeria produces both ammonia and phosphoric acid. Production of fertilizers in 1986 amounted to 166.000 mt of NP, with 112.000 mt being of nitrogen fertilizer. Total fertilizer production covered 61% of local consumption. Imports of nitrogen exceeded exports. However, Algeria is self-sufficient in nitrogen fertilizers. Production of phosphate amounted to 50% of consumption and all potash requirements were imported. The additional ammonia capacity in Annaba is likely to be directed towards the export market as Algeria already exports ammonia. The new plant has a capacity of 272,000 mt of nitrogen.

Côte d'Ivoire does not produce ammonia or phosphoric acid. Production of nitrogen fertilizers is based on imported ammonia and sulphur. Single superphosphate (SSP), and compound granulated NPK are also produced. Fertilizer production amounted to over 12% of local consumption in 1986. Exports of fertilizers were reported for 1986, making the fertilizer balance in this country unclear.

Egypt produces nitrogen fertilizers on a large scale. Nitrogen fertilizer accounted for over 80% of its total fertilizers production in 1986, the balance being phosphate fertilizers. Potash is imported. Fertilizer production covered over 90% of local consumption. There is some export of phosphate and import of nitrogen fertilizers. Egypt is also an important producer of ammonia, with phosphoric acid being produced in small amounts. 747,000 mt of ammonia-derived nitrogen capacity is planned to come on stream during the early 1990s. Much of this excess capacity will be directed towards ammonium nitrate manufacture. There are two ammonium nitrate projects at Abu Quir and Suez having a total capacity of 464,000 mt of nitrogen and due to come on stream in the early 1990s.

Libya is a large-scale producer of ammonia and nitrogen fertilizers (urea). Production of nitrogen fertilizers far exceeds local consumption. The surplus of nitrogen is exported. Small quantities of phosphate and potash are imported and there is no production of phosphate or potash fertilizers. Another important nitrogen complex at Sirte has been suspended. The complex has a total planned ammonia capacity of 750,000 mt of nitrogen contained in two plants, with down-stream units for urea production, two NPK plants, a sulphuric acid plant and an ammonium sulphate plant.

Mauritius produced about 10,000 mt of nitrogen fertilizers in 1986 (AN) based on imported ammonia. Being self-sufficient in nitrogen, Mauritius imports straight phosphate and potash fertilizers for its downstream NPK compound granulation plant.

Table 2.2

Fertilizers Production, Imports, Exports and Consumption of the twelve African producing coutries in 1986
(In metric tonnes)

	PRODUCTION			IMPORTS				EXPORTS			CONSUMPTION				PRODUCTION NPK/
	Nitrogen	Phosphate	TOTAL	Nitrogen	Phosphate	Potash	TOTAL	Nitrogen	Phosphate	TOTAL	Nitrogen	Phosphate	Potash	TOTAL	CONSUMPTION NPK (in percentage)
Algeria	112490	53800	166290	18790	88780	56650	164220	12060		12060	112680	105800	53180	271660	61
Cote D'Ivoire	1000	2700	3700	10800	8000	17700	36500	3800	3800	7600	8000	7000	15000	30000	12
Egypt	601850	128100	729950	53600		37200	90800		6500	6500	655450	121600	30100	807150	90
Libya	239940		239940	7710	13800	800	22310	223000		223000	24810	13800	800	39410	609
Mauritius	10079		10079	4571	8273	19047	31891	2105		2105	9889	3687	11730	25306	40
Morocco	59060	466500	525560	110700		62300	173000	15290	335610	350900	153340	118550	51000	322890	163
Nigeria		5000	5000	146000	87000	17600	250600	3800		3800	173000	92000	30000	295000	2
Senegal	5600	10000	15600	4900		2000	6900		5800	5800	7500	7500	6000	21000	74
Tanzania	5740	4659	10399	18546	4298	1385	24229				25333	11854	3231	40418	26
Tunisia	146000	631000	777000	1994		8158	10152	101030	574463	675493	47110	57800	1000	105910	734
Zambia	14286		14286	41810	12680	5380	59870				53816	16492	6668	76976	19
Zimbabwe	73925	47110	121035	12299		31040	43339	320	840	1160	81885	42775	33205	157865	77

SOURCE: FAO, Yearbook 1987.

Morocco is a large producer of phosphoric acid and phosphate fertilizers. Nitrogen fertilizers (MAP/DAP) are produced on the basis of imported ammonia. Production of phosphate fertilizers was four times higher than local consumption. The surplus is exported. In 1986, some nitrogen and all potash fertilizers were imported.

In 1986 Nigeria was reported as a small producer of phosphate fertilizers (5,000 mt of P_2O_5 in single superphosphate), and as a huge importer of nitrogen, phosphate and potash. Over 220,000 mt of NPK was imported in 1986. With its new nitrogen complex at Onne (ammonia plant capacity of 272,000 mt of nitrogen, with downstream urea and NPK plants) put into operation in 1987/88, Nigeria can supply its demand for NPK reported as 295,000 mt in 1986. Nigeria is still dependent, however, on imports of phosphoric acid and potash. There are already plans for an additional 228,000 mt capacity urea plant, again located at Onne, expected to come on stream in the early 1990s.

As with Morocco, Senegal produces phosphoric acid, basing its production of nitrogen fertilizers on imported ammonia and potash. Total production of NP (DAP and TSP) was around 16,000 mt, almost equalling local consumption of NPK.

Tanzania produced only 10,000 mt of NPK fertilizers in 1986, supplying 25% of local consumption. Production is based on imported ammonia, sulphur and potash. Phosphate rock is delivered from local mines. An ammonium sulphate and a small phosphoric acid unit are coupled with a downstream NPK compound granulation plant. An ammonia/urea complex at Kilwa Masoko was planned at the beginning of the 1980s with a capacity of 330,000 mt of nitrogen-derived ammonia and 250,000 mt of nitrogen-derived urea. The complex has as yet not been put into operation.

Tunisia based its NPK production on own phosphate rock and phosphoric acid. Ammonia, sulphur and potash are totally imported. Total NPK production in 1986 was equal to 860,000 mt, eight times higher than consumption, with the excess being exported. Tunisia is the biggest producer and exporter of NPK fertilizers of the twelve African producer countries.

Zambia bases its production on own ammonia derived from coal. It operates the only coal gasification plant in the analyzed countries. With production of nitrogen fertilizers (ammonium nitrate and ammonium sulphate) of around 14,000 mt of nitrogen in 1986, Zambia supplied only 25% of domestic nitrogen consumption. Both potash and phosphate fertilizers, and the remaining 75% of nitrogen fertilizer, were imported. Production of sulphuric acid is based on local pyrites.

The Zambian coal based ammonia plant is currently being extended (to 80,000 mt of nitrogen) together with the downstream units at Kafue. These units include nitric acid, ammonium nitrate, ammonium sulphate and NPK fertilizer plants.

Zimbabwe based its NPK production on own ammonia produced by electrolysis of water. Phosphoric acid production is based on own phosphate and sulphuric acid produced from own pyrites. All potash requirements were imported. With a production of 120,000 mt of NP fertilizers in 1986 and imports of potash, Zimbabwe totally covered its consumption of NPK fertilizers. Small amounts of nitrogen were imported and nitrogen and phosphate was exported.

Further plans for fertilizer production in African countries include small ammonia/urea complexes in Sudan and Madagascar, a Mozambican ammonia/urea complex and di-ammonium phosphate (DAP) and NPK plants presently under construction in Morocco and Tunisia.

World ammonium nitrate and urea fertilizer plant capacities show that urea capacities are growing rapidly. In 1976 world Ammonium nitrate capacities were estimated at 15 million mt of nitrogen and world capacities of urea at 21 million mt. of nitrogen. Projections for 1990 show that world ammonium nitrate capacities may grow at most to 20 million mt of nitrogen, while those of urea to as much as 45 million mt of nitrogen. Ammonium nitrate continues to be directed to domestic consumption rather than trade, and static or falling capacity is expected in all regions, except Africa and Western Europe. Total African ammonium nitrate capacity is forecast to rise by some 30% in the period 1986-1990, to around 1.25 milllion mt of nitrogen.

Certain agronomic advantages are increasingly claimed for urea as against ammonium nitrate for tropical, sub-tropical and warm temperate regions. For instance, advantages are claimed in the cultivation of rice under irrigation, as the plant nutrient supply of the urea fertilizer is quickly available to crops.

Estimated and projected world urea capacity in the years 1986-1990-1995 was around 40-45 and 50 million mt of nitrogen. Africa's share is not high, and urea capacities are estimated correspondingly at 1.3, 1.4 and 1.4 million mt of nitrogen in this period.

Estimated and projected global ammonia capacity in the years 1986-1990-1995 was 118, 127 and 136 million mt of nitrogen respectively, with the corresponding figures for Africa being 3.4, 3.9 and 4.6 million mt of nitrogen.

The nitrogen capacities in Africa for 1990 are estimated as follows: Ammonia (3.9 million mt of nitrogen) divided between ammonium nitrate (1.25 million mt of nitrogen), urea (1.4 million mt of nitrogen) plus 1.25 million mt of nitrogen shared between ammonium sulphate and MAP/DAP complex fertilizers.

The difference between Africa's consumption of fertilizers in the year 2000[4/] and Africa's production of fertilizers in 1986 is equal to 3.5 million mt of NPK fertilizers. This amount is distributed between the three nutrients as follows: Nitrogenous fertilizers (2.2 million mt of nitrogen), Phosphatic fertilizers (0.6 million mt of P_2O_5), Potassic fertilizers (0.7 million mt of K_2O).

The gap between projected NPK fertilizers demand and production of fertilizers in 1986 is particularly great in the Sub-Saharan countries. Only 7% of African NPK production in 1986 was located in Sub-Saharan Africa. The remaining 93% of NPK production was located in the five North-African countries; Tunisia, Egypt, Morocco, Libya and Algeria. Projected demand for NPK in the year 2000 shows even wider fluctuations, ranging from 1,400 mt for Uganda to 1,530,000 mt for Egypt.

4/ See Table 2.8

2.3 African trade in fertilizers

Table 2.3 provides figures on world and regional exports of fertilizers in 1986. Table 2.3 shows the very limited contribution of the African continent, just over 3%, to world fertilizer exports. Of note are the low figures for Central and South America, Oceania and the centrally planned economies of Asia. North America clearly has a predominating status in world fertilizer exports. In exports of phosphate fertilizers, however, it can be seen that Africa performs relatively well, and is surpassed only by Western Europe and North America.

Table 2.3 World exports of NPK fertilizers by region in 1986
(thousands of metric tonnes)

	N	P_2O_5	K_2O	NPK	Share %
Western Europe	4512	1967	3286	9765	22,60
Eastern Europe	4819	729	5993	11541	26,70
Africa Total	413	929	15	1358	3,10
North America	3242	3468	7464	14174	32,70
Central America	291	16	8	316	,70
South America	152	0	1	153	,40
Middle East	1456	607	1781	3844	8,90
Asia CPEs	7	34	0	41	,10
South and East Asia	1325	610	86	2021	4,70
Oceania	46	0	0	46	,10

Source: FAO Fertilizers Yearbook 1987

Table 2.4 provides figures on world and regional imports of fertilizers. Table 2.4 illustrates the limited role played by the African continent in world imports of fertilizers, at 3.6%. African imports of phosphate fertilizers as a percentage of world phosphate imports is a little higher however at 5.4%. Also noteworthy is the importance of South East Asia in fertilizer imports, accounting for 15.5% of the world total.

Table 2.4 World imports of NPK fertilizers by region in 1986
(thousands of metric tonnes)

	N	P_2O_5	K_2O	NPK	Share %
Western Europe	4991	2784	4004	11778	27,90
Eastern Europe	608	994	3161	4763	11,30

Table 2.4 continued

	N	P_2O_5	K_2O	NPK	Share %
Africa Total	653	412	465	1530	3.60
Developing Africa	653	412	327	1392	3.30
North America	2841	301	4525	7667	18,20
Central America	588	312	461	1359	3,20
South America	822	574	1805	3199	7,60
Middle East	694	593	65	1353	3,20
Asia CPEs	2067	654	699	3440	8,10
South and East Asia	2557	1144	2807	6508	15,50
Oceania	164	188	183	535	1,20
WORLD TOTAL	16004	7955	18174	42133	100

Source: FAO Fertilizer Yearbook 1987

2.4 Agriculture and consumption of fertilizers in Africa

Table 2.5 presents data on world and regional consumption of fertilizers. Africa's consumption of NPK fertilizers is seen to represent only 2.6% of world consumption. Of particular note is the large share of world consumption attributable to eastern Europe.

Table 2.5 World consumption of NPK fertilizers in 1986 (thousands of metric tonnes)

	N	P_2O_5	K_2O	NPK	Share %
Western Europe	11664	5336	5231	22271	16,70
Eastern Europe	16584	11507	10076	38131	28,70
Africa total	1899	1218	416	3534	2,60
Developing Africa	1538	881	297	2717	2
North America	10407	4297	4792	19495	14,70
Central America	1962	586	425	2973	2,20
South America	1891	2224	1591	5706	4,30
Middle East	1076	704	80	1859	1,40
Asia CPEs	14223	3164	654	18041	13,60
South and East Asia	12182	4752	2528	19463	14,60
Oceania	400	942	217	1559	1,20
WORLD TOTAL	72273	34749	26009	133033	100

Source: FAO Fertilizers Yearbook 1987

Table 2.6 presents data for Africa and the world on consumption of fertilizers per capita and per hectare of arable land.

Table 2.6 World and African consumption of NPK fertilizers per hectare of arable land (A) and per capita (B)

	1975		1980		1985	
	A	B	A	B	A	B
World	63.2	22.2	80.1	26.2	87.1	26.6
Africa	13.4	5.7	18.4	6.9	20.1	6.7
Developing Africa	9.9	4.3	13.8	5.1	16.6	5.5

Source: FAO Yearbooks

While world consumption of fertilizer per hectare has expanded in the last ten years, world consumption in kg of NPK per capita has been steady. Africa has followed the same trend in the last decade but the rate of increase has been less than the world rate.

2.4.1 Trends and projections in demand to the year 2000

FAO and UNIDO projections of the demand for NPK fertilizers in Africa by the year 2000 are presented in table 2.7. FAO projections were complemented by UNIDO forecasts whenever data was lacking.

Scenario "A" prepared by FAO in 1980 is based on an increase in food self-sufficiency and greater availability of food for export. To achieve these goals an estimated annual growth rate of 8.5% in NPK fertilizer consumption is assumed necessary.

Scenario "B" prepared by FAO in 1988 is an extrapolation of past trends, resulting in lower annual growth rates for agricultural inputs and, consequently, lower rates of growth in NPK fertilizer consumption than in scenario "A".

Scenario "C" prepared by UNIDO in 1983 is less optimistic than scenario "A". Scenario "C" is similar to "B" in the total consumption of NPK but differs from "B" in the ratio of N:P:K. For the purpose of this study, scenario "B" is used. This is the latest FAO projection, based on an N:P:K ratio of 1.00:0.57:0.20 . This ratio is closest to the present N:P:K consumption ratio of 1.00:0.47:0.21.

Based on projected NPK demand in the year 2000 and production figures for 1986, the total NPK gap in 2000 was calculated for each country and is shown in table 2.8.

Growth in crop production may be ascribed to changes in three factors: arable land, cropping intensity and yields. Historically, expansion of arable area has been the main source of growth. Since 1950, however, higher yields

Table 2.7 Demand for NPK fertilizers by the year 2000

NO.	COUNTRY	DEMAND 2000 ACCORDING TO FAO SCENARIO "A" - 1980				DEMAND 2000 ACCORDING TO LATEST FAO ESTIMATIONS SCENARIO "B" - 1988				DEMAND 2000 ACCORDING TO UNIDO SCENARIO "C" - 1983			
		N	P	K	NPK	N	P	K	NPK	N	P	K	NPK
1.	ALGERIA	450	552.4	186	1188.4	248.7	286.4	99.2	634.3	266	270	130	666.0
2.	ANGOLA	16.3	14.2	13.1	43.6	5.8	5.6	0.6	12.0	25.0	11.0	9.0	45.0
3.	BENIN	6.2	4.7	6	16.9	8.1	4.1	1.5	13.7	4.7	3.8	2.7	11.2
4.	BOTSWANA	2	2	1.2	5.2	2	2	1.2	5.2	2	2	1.2	5.2
5.	BURKINA FASO	3.2	2.5	0.8	6.5	10.3	9.8	7.1	27.2	2.6	2.7	1.7	7.0
6.	BURUNDI	2.9	2.9	1.0	6.8	1.8	1.2	1.3	4.4	2.3	2.3	0.9	5.5
7.	CAMEROON	38.3	31.2	47.[illegible]	117.3	51.4	15.4	32.3	99.1	39.0	21.0	38.0	98.0
8.	CAPE VERDE												
9.	CENTRAL AFR. REP.	4.0	4.4	2.3	10.7	1.5	0.1	0.2	1.8	2.8	2.3	1.4	6.5
10.	CHAD	18.8	13.5	5.6	37.9	5.2	3.5	3.9	12.6	8.8	6.8	4.5	20.1
11.	COMOROS ISLANDS												
12.	CONGO	14.7	15.7	8	38.4	2.0	0.0	2.5	4.5	7.0	6.2	6.0	19.2
13.	CÔTE D'IVOIRE	115.4	70	157.2	342.6	20.2	14.4	44.4	79.0	80.0	49.0	89.0	218.0
14.	DJIBOUTI												
15.	EGYPT	566.4	455	214.9	1236.5	1202	297	32	1530.0	1120	320	80	1520.0
16.	EQUAT. GUINEA												
17.	ETHIOPIA	80.5	93.3	18.1	191.9	38.7	59	0.3	98.0	64.0	71.0	14.5	149.5
18.	GABON	0.5	0.3	0.5	1.3	1.1	1.0	2.3	4.5	0.5	0.3	0.4	1.2
19.	GAMBIA	1.3	1.1	0.5	2.9	3.4	4.0	0.6	8.0	3.0	2.8	0.5	6.3
20.	GHANA	48.1	38.6	27.7	114.4	31.1	14	12.8	57.9	34.0	23.0	19.0	76.0
21.	GUINEA	4.1	2.9	2.5	9.5	0.7	0.3	0.4	1.5	3.3	2.3	2.0	7.6
22.	GUINEA-BISSEAU												
23.	KENYA	172	129.1	35.0	336.1	94.6	108.5	14.1	217.2	120.0	90.0	32.0	242.0
24.	LESOTHO	6	12	2	20.0	6	12	2	20.0	6	12	2	20.0
25.	LIBERIA	3.3	2.3	8.5	14.1	2.1	1.8	0.8	4.7	3.3	2.3	2.3	7.9
26.	LIBYA	45.8	52.8	17.9	116.5	(69.0	93	12.0	174.0)	69.0	93	12.0	174.0
27.	MADAGASCAR	22.1	15.2	7.9	45.2	19.7	7.9	14.8	42.4	15.0	11.0	7.9	33.9
28.	MALAWI	40.9	35.3	14.0	89.6	56.8	25.8	10.7	93.4	40.3	25.(	14.0	79.3
29.	MALI	18.5	15.4	6.6	40.5	20.3	7.9	6.8	34.9	15.0	10.2	6.6	31.9
30.	MAURITANIA	5.7	3.8	1.7	11.2	2.0	0.3	0	2.3	4.0	2.2	1.4	7.6
31.	MAURITIUS	25.7	17.4	11.4	54.5	(25.7	12.0	18.0	55.7)	25.7	12.0	18.0	55.7
32.	MOROCCO	320	418.3	109	847.3	264.7	257.6	103.4	625.7	260	290	135	685.0
33.	MOZAMBIQUE	10.8	14.4	11.8	37.0	21.7	16.9	11.0	49.5	35.0	21.0	9.5	65.5
34.	NIGER	1.8	1.6	0.5	3.9	4.5	1.4	0.8	6.7	2.5	2.3	0.5	5.3
35.	NIGERIA	101.9	81.3	40.9	224.1	451.1	304.8	90.3	846.2	210	140	41.0	391.0
36.	RWANDA	0.8	1.2	0.2	2.2	1.9	0.9	0.5	3.3	0.7	0.7	0.2	1.6
37.	SAO TOME AND PRINC.												
38.	SENEGAL	87.1	78.7	38.7	204.5	25.5	32.9	19.4	77.9	60.0	54.0	31.0	145.0
39.	SEYCHELLES												
40.	SIERRA LEONE	26.1	17.7	5.3	49.1	0.6	0.5	0.7	1.8	8.4	4.6	3.7	16.7
41.	SOMALIA	13.8	10.1	4.5	28.4	4.2	0.9	0.8	5.9	11.0	8.0	3.6	2[illegible].6
42.	SUDAN	239.7	204.2	79.2	523.1	(180.0	50.0	20.0	250.0)	180.0	50.0	20.0	250.0
43.	SWAZILAND					10.7	6.7	3.7	21.1				
44.	TANZANIA	110.3	78.8	45.6	234.7	(88.0	39.0	26.0	153.0)	88.0	39.0	26.0	153.0
45.	TOGO	4.3	3.4	2.7	10.4	4.4	4.6	2.7	11.7	3.5	2.7	2.0	8.2
46.	TUNISIA	186	220	77.1	483.1	80.2	112.6	11.1	203.9	130	154	42	326.0
47.	UGANDA	10.3	8	3.6	21.9	1.1	0.3	0.0	1.4	7.0	3.7	3.0	13.7
48.	ZAIRE	5.8	5.6	3.4	14.8	8.5	7.1	4.3	19.9	6.0	4.5	3.2	13.7
49.	ZAMBIA	139.3	119.5	60.9	319.7	130.2	41.6	19.1	190.9	128	61.0	20.0	209.0
50.	ZIMBABWE	229.9	164.3	40.7	434.8	271.9	131.2	68.8	471.9	184	115.0	64.0	363.0

Source: UNIDO 1983, Sectoral Studies Series, IS.416, "Mini-Fertilizer Plant Projects" (UNIDO and FAO sources), pages 171 through 185. FAO, Rome 1988, African country profiles on agriculture. UNIDO - Final Report DP/RAF/86/013 -- "Study on the Manufacture of Industrial Chemicals in the Member States of SADCC", Warsaw 1988.

Table 2.8 The Gap Between Fertilizers Demand in the Year 2000 and Production in 1986 (in 000' mt per year of pure nutrients)

Country	NPK Demand 2000	NPK Production 1986	NPK GAP 2000
Algeria	634.3	166.2	468.1
Angola	12.0	0	12.0
Benin	13.7	0	13.7
Botswana	5.2	0	5.2
Burkina Faso	27.2	0	27.2
Burundi	4.4	0	4.4
Cameroon	99.1	0	99.1
Cape Verde			
CA Republic	1.8	0	1.8
Chad	12.6	0	12.6
Comoros			
Congo	4.5	0	4.5
Côte d'Ivoire	79.0	3.7	75.3
Djibouti			
Egypt	1530.0	729.9	800.1
Equatorial Guinea			
Ethiopia	98.0	0	98.0
Gabon	4.5	0	4.5
Gambia	8.0	0	8.0
Ghana	57.9	0	57.9
Guinea	1.5	0	1.5
Guinea-Bissau			
Kenya	217.2	0	217.2
Lesotho	20.0	0	20.0
Liberia	4.7	0	4.7
Libya	174.0	239.9	(65.9)
Madagascar	42.4	0	42.4
Malawi	93.4	0	93.4
Mali	34.9	0	34.9
Mauritania	2.3	0	2.3
Mauritius	55.7	10.1	45.6
Morocco	625.7	525.5	100.2
Mozambique	49.5	0	49.5
Niger	6.7	0	6.7
Nigeria	846.2	5.0	841.2
Rwanda	3.3	0	3.3
Sao Tome and Principe			
Senegal	77.9	15.6	62.3
Seychelles			
Sierra Leone	1.8	0	1.8
Somalia	5.9	0	5.9
Sudan	250.0	0	250.0
Swaziland	21.1	0	21.1
Tanzania	153.0	10.3	142.7

Table 2.8 continued

Country	NPK Demand 2000	NPK Production 1986	NPK GAP 2000
Togo	11.7	0	11.7
Tunisia	203.9	862.4	(658.5)
Uganda	1.4	0	1.4
Zaire	19.9	0	19.9
Zambia	190.9	14.3	176.6
Zimbabwe	471.9	121.0	350.9
TOTAL COUNTRIES	6179	2704	3475

NOTE: An NPK Surplus is expected in Libya and Tunisia.

Source: Elaborated from UNIDO and FAO databases, using Scenario "B", Table 2.7

have increasingly become the source of output growth in a number of developing countries. According to the FAO study "World Agriculture Toward 2000" increases in average yields will be the main source of crop production growth in developing countries over the next 15 years. In North Africa, there is practically no potential for an expansion of arable land and close to 80% of crop production increases will have to be achieved through yield increase, with the balance through growth in cropping intensity.

In Sub-Saharan Africa it is estimated that 26% of the crop production increase will be achieved through increases in arable land. 57% and 17% of increased crop production will stem from yield increases and higher cropping intensity respectively. African potential land reserves are concentrated in a few countries, such as Zaire. Most of the reserves have soils of marginal quality. Some soils are suited to perennial tree crops, others have very unreliable rainfall, and almost all are dependent on the introduction of existing technologies or the development of new ones before they can be cultivated on a sustainable basis.

Relative land scarcity, determined both by the magnitude and the quality of land reserves, will play a future role in fertilizer use and irrigation development.

It has been estimated by FAO that by the year 2000, about two-thirds of the increase in arable land in the world will be achieved through the expansion of irrigation in developing countries.[5/]. In North Africa rain-fed agricultural land is utilized almost fully. Therefore, rain-fed and desert lands must be irrigated. With the higher cropping intensity associated with irrigated areas, this will actually be the sole source of expansion of harvested land in this region. It is the lack of water rather than land which

---

5/ See Agriculture Towards 2000, FAO, Rome 1981.

is a constraint on agricultural production over millions of hectares of potentially suitable arable land in Africa. It is only when this water constraint is overcome that other constraints such as low nutrient levels and pests become important. Higher rates of fertilizer use, and consequently, higher yields, prevail in irrigated agriculture. In Africa, only Egypt has more than 30 per cent of arable land under irrigation. Morocco, Madagascar, Mauritius, Swaziland and Sudan have only 10-30 per cent of arable land under irrigation. In Algeria, Tunisia, Libya and all the remaining Sub-Saharan countries less than 10 per cent of arable land is irrigated. In Sub-Saharan Africa, expansion of irrigated land will account for a minor part of increases in cultivated area because of reserves of rain-fed land, coupled with higher costs of irrigation development and a shortage of technical manpower.

In North Africa around 80 per cent of total fertilizer consumption is used for irrigated agriculture, particularly cash crops. For rain-fed crops, however, the bulk of fertilizer is used for cereals. In all, rain-fed or irrigated cereals account for 30 per cent of fertilizer consumption, with most of this being used on large-scale modern farms. In North Africa, fertilizer use accounted for 15-20 per cent of the increase in cereal production during the last 20 years.

In Sub-Saharan Africa, fertilizers were introduced mainly to intensify production of export crops, especially cotton and groundnuts. Some countries have used fertilizers for cereals, particularly maize in Kenya, Zimbabwe, Zambia, Malawi and Tanzania, and for rice in West Africa. Fertilizers tend to be used primarily by state and modern farms. In Zimbabwe and Kenya, increases in fertilizer use have also occurred with small farmers. Application of food crop fertilizer in Sub-Saharan Africa is still very low at around 5 kg/ha. Fertilizer consumption for export and industrial crops is around 30 kg/ha of arable land. Fertilizers account for about 40-60 per cent of the increases in food crop yields observed in Sub-Saharan Africa. However, the overall impact of fertilizer use is low due to very low levels of application. Food crop fertilizers have often been misused, either due to inappropriate nutrient ratios or incorrect application. There is also a poor fertilizer response under certain conditions.6/ Fertilizer use in 43 African countries in 1986 is illustrated in figure 2.2.

The bulk of increased food production in Africa would have to come from the intensification of rain-fed agriculture through the wider use of improved seeds, fertilizers, pesticides and mechanization. Where rainfall is unreliable, new technologies and new food varieties would be needed. These developments would require a substantial increase of fertilizer use in Sub-Saharan Africa. Fertilizer imports in Sub-Saharan Africa would have to grow at about 7 per cent a year, but shortages of foreign exchange are likely to make such imports difficult if not impossible.7/ Fertilizer aid should therefore increase substantially. The potential benefits of such increases in fertilizer use are easily demonstrated. Many small-scale maize growers in

---

6/ IFA Paris, 1988 - "The Outlook for Fertilizers in Sub-Saharan Africa", page 20.

7/ FIAC - FAO, Promoting Competition in Fertilizer Marketing in Africa, Rome 1987.

Malawi and Zimbabwe use improved varieties and high levels of fertilizer very profitably, achieving an average maize yield of about 5 mt per hectare. There are, however, more than 100 million hectares of land in the sub-humid and semi-arid parts of Africa which produce maize yields of less than 1 mt per hectare. Fertilizer use in Côte d'Ivoire has permitted one of the world's highest yields in both cocoa and oil-palm production. Fertilizer aid could gradually replace structural and some emergency food aid in many countries. For example, 200,000 mt of fertilizer (product) aid in Ethiopia in 1985-86 could have replaced 700,000 mt of food - equivalent to the food aid pledged for 1936 - if it had been applied in the higher rainfall areas and had producer prices been favourable. Per capita dietary energy supply (DES) in kcals/day, reported by FAO for Africa for the year 1984, gives concrete indications as to priorities for the future food/fertilizer aid strategy and complex development actions in agriculture.8/

As can be seen in figure 2.3 urgent action should be directed to such countries as Ethiopia, Sudan, Chad and Mozambique. The first two countries will have substantial demand for fertilizers as well as a large NPK gap in the year 2000 to be filled through import substitution.

2.4.2 Other factors affecting the use of fertilizers

(a) Credit

An important problem for the farmer is access to credit. This is a very important component of the input delivery package which has played a key role in the promotion of cash crops. The real risk of crop failure presents a strong disincentive to extend the credit system to the food producer. A very broad credit system has to be implemented if governments wish to increase fertilizer use among food producers.

In some countries the limitation of official credit and the inability to meet financial requirements for traditional food crops have provided considerable scope for unofficial credit and money lending. The promotion of this traditional credit system through village unions is a promising option.

(b) Research

Agricultural research is a very important factor that influences farmers in the adoption of fertilizer technology. Information on crop/fertilizer requirements is not widely available in many African countries. Farmers tend to use more fertilizer where research has established the optimal rates of application between different crops, soils and regions. The existence of well organized extension services is very important to promote the use of

8/ "African agriculture: The next 25 years", including " Atlas of African agriculture", FAO, Rome 1986.

fertilizers because they communicate agricultural research findings and recommendations to farmers. Extension services in Africa tend to be centrally controlled or directed by government and are usually understaffed with a poorly paid personnel.9/

(c) Fertilizer Prices for Farmers

A key component of an agricultural policy aimed at inducing further consumption of fertilizers involves the adequate remuneration of farmers. The farmer will consume more fertilizer if the cost of introducing one unit of fertilizer is less than the gain from increased yields. Governments have frequently addressed this situation through the implementation of fertilizer subsidies. This is the case for most African countries with the exception of Sudan and Zimbabwe. Nigeria for example has recently experienced a boom in agricultural production based on one of the world's highest levels of fertilizer subsidies. In view of government budget deficits and the increase in consumption of fertilizers by farmers, some governments have reduced subsidies, as is the case of Tanzania. However, this may entail a future drop in fertilizer use.

Table 2.9 presents a comparison of farm level urea prices in Africa, Asia and Latin America. This table reveals that the average price of urea in Africa is higher than in the other continents. In some African countries the cost is lower due mainly to subsidies. For instance in Zambia, a landlocked country, the cost of urea is even lower than in India or Malaysia both of which produce urea. The same table presents the "real cost" of fertilizer in terms of a kilogram of crop (maize, rice and wheat) required to buy 1 kg of nitrogen through urea. This comparison indicates that the "real cost" was not significantly higher in Africa than in the other countries. It should be noted however that the crops selected in the table are not dominant in Africa. Stronger conclusions would be obtained using crops such as sorghum and millet. African countries also use more compound and complex fertilizers than single urea. With these caveats in mind we may still note that Madasgacar, Zambia and Kenya have the highest "real cost" values within Africa and Asia with the exception of the Philippines.

(d) Storage

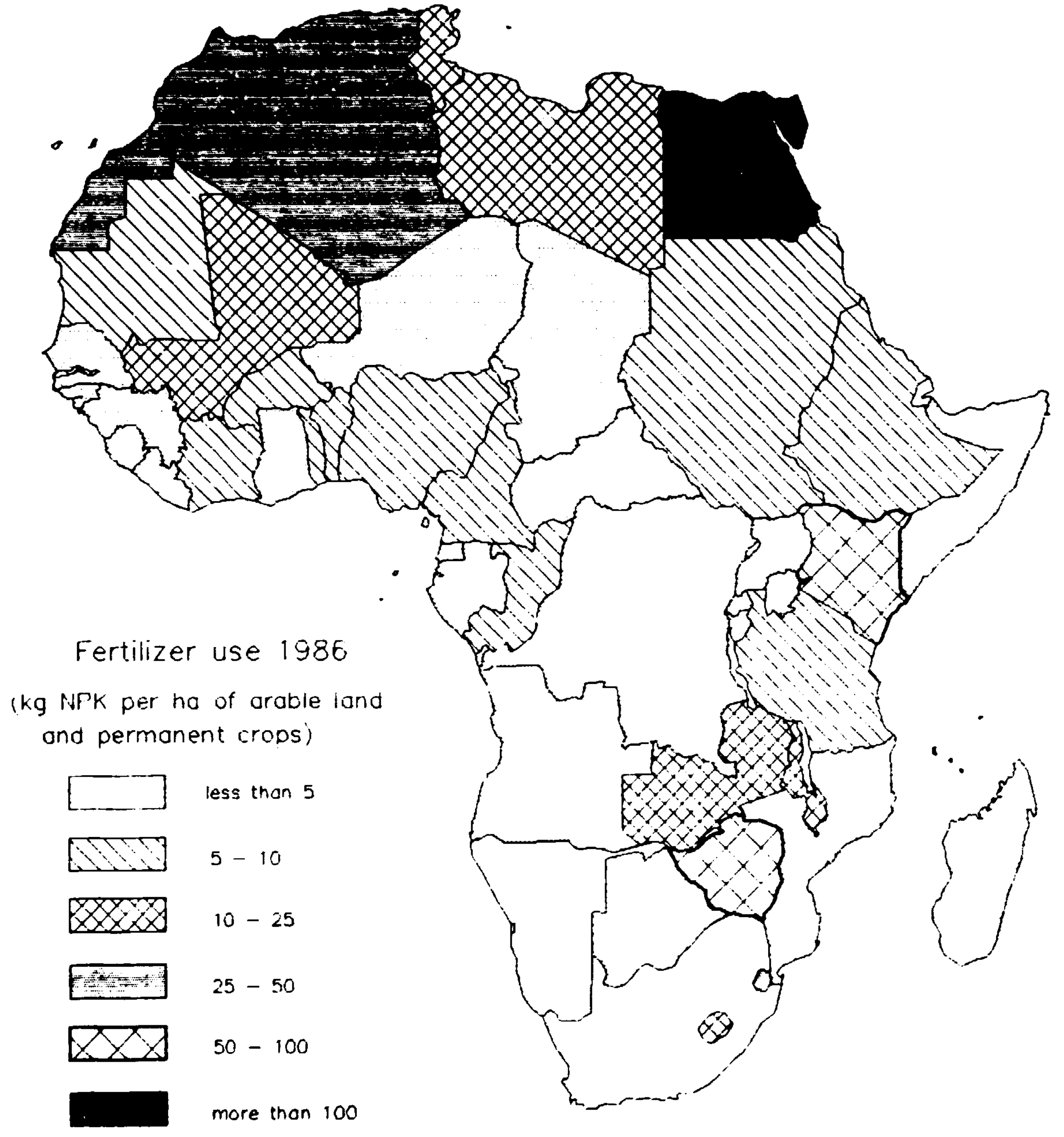
In view of the problems related to transporting fertilizers, and the fact that most countries in Africa have one cropping season per year, storage capacity for fertilizer is an indispensable service. In many African countries government is the owner of storage capacity, although exceptions exist such as Zimbabwe where the commercial sector plays an important role.

Co-operatives in Africa have not reached a level of infrastructural development sufficient to solve the problem of storage, mainly because the required investments are very considerable.

9/ UNIDO - "Regional Consultation on the Phosphatic Fertilizers", ID/WI, 475/6 (SPEC.), Issue paper 1 "The necessity of an integrated approach to fertilizer production and use in Africa", 1988.

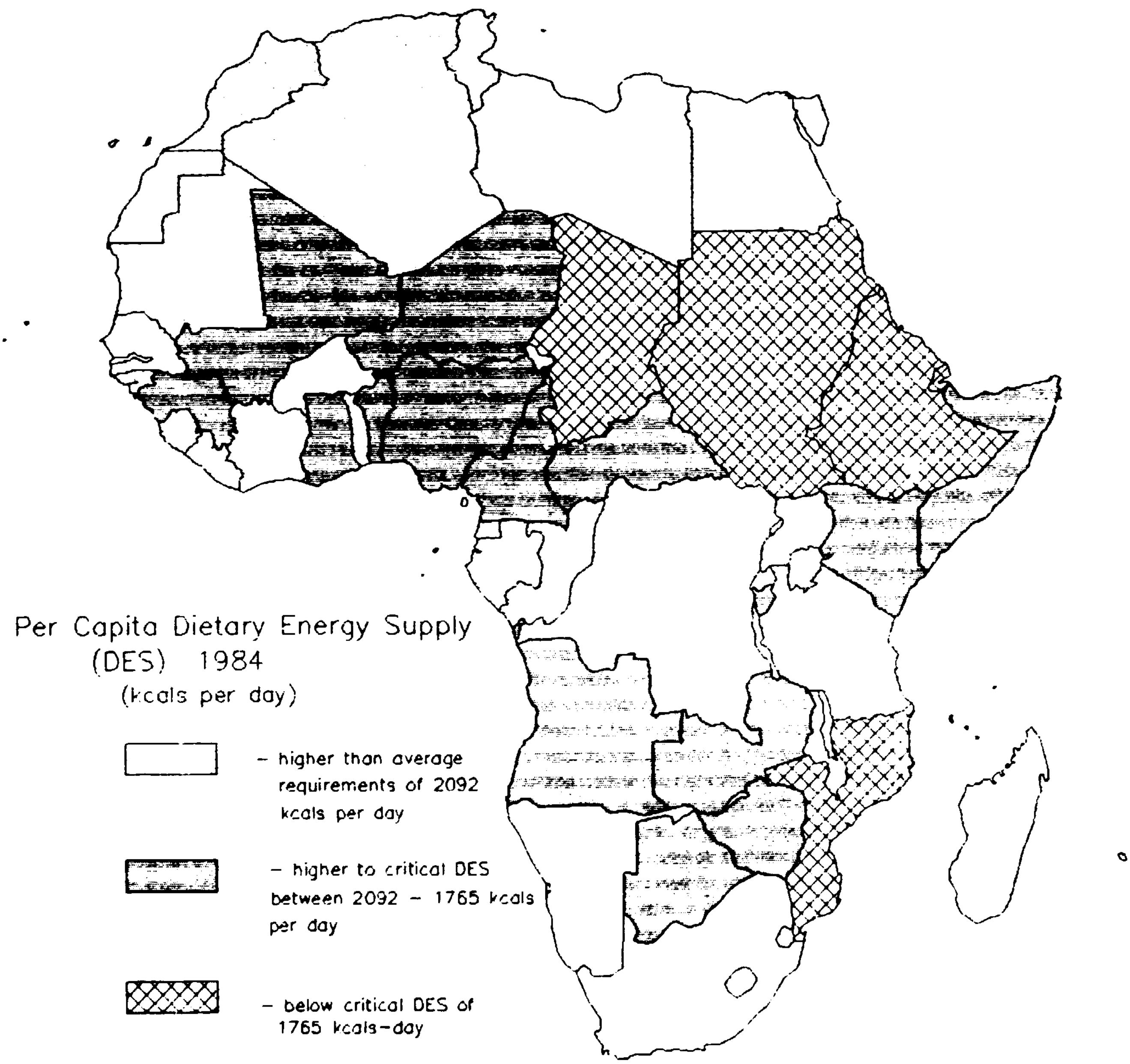
Figure 2.2

FERTILIZER USE IN AFRICA (1986)



SOURCE: FAO, 1989

Figure 2.3 **PER CAPITA DIETARY ENERGY SUPPLY 1984**



Source: UNIDO based on FAO "Atlas of African Agriculture", Rome 1986.

Table 2.9 Fertilizer and Crop Prices in selected countries of Africa, Asia and Latin America, 1985/86

	Urea	Maize	Rice	Wheat	Kilograms of crop output required to buy 1 kg of N through urea		
					Maize	Rice	Wheat
		(US $/ton)			(US $/ton)		
Africa							
Burkina Faso	128	153	259	-	1.80	1.07	-
Cameroon	98	177	440	-	1.20	0.48	-
Kenya	231	116	158	164	4.33	3.18	3.06
Madagascar	282	63	134	282	9.73	4.57	2.17
Zambia	135	81	120	-	3.62	2.45	-
Zimbabwe	247	110	173	-	2.25	3.10	-
Average	186.5						
Asia							
Bangladesh	185	-	173	165	-	2.32	2.44
Burma	42	96	61	224	0.95	1.50	0.41
India	177	124	234	180	3.10	1.64	2.13
Indonesia	95	99	154	-	2.09	1.34	-
Malaysia	164	-	278	-	-	1.28	-
Pakistan	152	139	161	186	2.37	2.05	1.78
Philippines	251	150	173	-	3.64	3.15	-
Average	152.3						
Latin America							
Argentina	189	72	157	81	5.71	2.62	5.07
Brazil	250	90	188	-	6.04	2.89	
Colombia	248	320	335	249	2.81	2.94	2.17
Mexico	84	124	116	105	1.47	1.57	1.74
Venezuela	40	186	158	-	0.46	0.55	-
Average	162.2						
World[a]	136						

a. for f.o.b. NW Europe

Source: International Fertilizers Development Center, Internal Report on Price Survey, 1988.

(e) Marketing and distribution costs

It is clear that African countries have to pay high prices for imported materials, but farmers of these countries must also pay high marketing costs because of inadequate infrastructure facilities. Table 2.10, presents different marketing costs in Africa and Asia based on an FAO survey from 1985-1986.10/ All the African countries surveyed, with the exception of Somalia, have higher marketing costs than the Asian countries. It is also shown that the most important components in African marketing and distribution costs are transport and financial charges. Zimbabwe appears to have the lowest marketing costs in Africa. This is partly explained by the fact that Zimbabwe produces its own supplies and has a well developed private and competitive distribution system. It is calculated that 70% of total marketing costs correspond to "margins and others".

Fertilizer marketing has most commonly been carried out by a state monopoly. This system is applied in 31 of the countries from Sub-Saharan Africa and in most of the North African countries.11/ In only a few countries, such as Zimbabwe, Kenya, Swaziland and Mauritius, does there exist a competitive system of distribution although this system usually involves a high degree of government control of prices and margins. A combined system of competitive channels and government distribution is found in Cameroon, Côte d' Ivoire, Central African Republic, Malawi and Liberia. Morocco is an exception, employing a mix of government and private structures.

As a consequence, attempts to improve distribution of fertilizers in Africa have generally focused on improving the efficiency of the parastatal and state agencies. More attention should be paid to the retail level which is a weaker point of the distribution chain in many African countries.

2.5 Potential for development of the African fertilizer industry

Enhancements and constraints to development of the African fertilizer industry are discussed in this section.

10/ See FAO/FIAC: "Fertilizer Marketing Costs and Margins in Developing Countries, 1985-1986"

11/ FAO/FIAC - Promoting competition in fertilizer marketing in Africa, Rome 1987.

Table 2.10 Fertilizer marketing costs in Africa and Asia, 1985-86
(US$ per ton)

	Transport costs	Handling and storage costs	Physical losses	Interest charges	Margins and other costs	TOTAL
AFRICA						
Madagascar	56	15	6	9	43	124
Tanzania	124	16	2	37	67	246
Zambia	47	15	4	5	21	92
Zimbabwe[a/]	20	4	2	2	50	78
Somalia	17	13	14	-	13	57
Sudan	40	17	5	-	103	165
Rwanda	41	61	19	84	63	268
Zaire	44	18	22	-	23	107
Burkina Faso	41	6	-	-	30	77
Gambia	11	10	7	6	83	117
Ghana	42	19	3	18	25	107
ASIA						
India[a/]	19	5	2	2	25	53
Indonisia	29	8	-	12	15	64
Malaysia[a/]	10	13	1	13	9	46
Philippines	7	4	3	16	42	72
Rep. of Korea	12	8	-	22	10	52
Sri Lanka	6	2	1	8	28	45
Thailand[a/]	7	11	2	1	39	60

a/ Distributed through private sector marketing channels.

Source: FAO and FADINAP

2.5.1 Availability of raw materials

The purpose of this section is to note the main raw materials required for fertilizer production and present information regarding potential resources, adequacy and location of known reserves, present extraction levels, possible future extraction and constraints limiting future exploitation of raw material reserves in Africa.

The manufacture of fertilizers worldwide uses the following proportions of world production of raw materials:

-approximately 3% of natural gas and about 0.5% of oil products and coal (for nitrogen fertilizers).

-approximately 85% phosphate rock and 40% of sulphur (for phosphate fertilizers).

-approximately 95% of potash ores (for potash fertilizers).12/

(a) Nitrogen related raw materials

As well as natural gas, coal and oil products some less important but renewable sources of nitrogen related raw materials exist. These are:

(i) water (with hydroelectric power used for electrolysis of water to produce hydrogen) and air (a source of nitrogen which combined with hydrogen produces ammonia).

(ii) biomass (wood wastes, sugar cane wastes, straw, euphorbia, etc.) can be gasified to yield synthesis gas for ammonia production. This is a renewable source of fixed carbon, which means that as with natural gas, oil and coal, this feedstock can be processed simultaneously with ammonia and carbon dioxide leading to urea production.

There are also other intermediary products, such as oven coke or refinery gas, that can be used for ammonia production in specific locations. Ammonia production through water electrolysis is also fully proven industrially both with smaller capacities and in minifertilizer plants, since in this process economies of scale are not of prime importance. Biomass gasification technologies are still not fully proven industrially. In spite of many trials and pilot plants tested in many countries this process cannot compete with natural gas, oil and coal-based processes.

Thus, for nitrogen fertilizers, starting with ammonia production, all raw materials are available for a fertilizer industry in Africa. This is a strong enhancement for nitrogen fertilizer industry development in most regions. As natural gas is the dominant and most competitive feedstock for effective

---

12/ The British Sulphur Corporation Ltd., "Nitrogen" No. 156 through 180, 1985-1989; "Phosphorus & Potassium" No. 145 through 162, 1986-1989; "Sulphur" No. 197 through 203, 1988-1989;

ammonia production. it is useful to compare reserves in Africa with those in the world, as well as to illustrate Africa's reserves of oil and coal. This comparison is shown in table 2.11.

(b) Phosphate related raw materials

World phosphate reserves and resources are dominated by Africa, as shown in table 2.11. Africa possesses 47% of world reserves of phosphate rock, equivalent to 30% P_2O_5 concentrate. Phosphate rock deposits are reported in Niger, Gabon, Congo, Burundi, Nigeria, Benin, Cameroon, Gambia, Madagascar, Chad and the Central African Republic.

In the long run the vast reserves of Morocco will become increasingly important in supplying world demand. In the short term Egypt's growing output of phosphate rock is also promising and production of phosphate concentrate from Tunisia, Togo, Senegal and Algeria is equally important.

There have been many findings of natural gas and crude oil deposits recently in other African countries e.g. in Cameroon, Côte d'Ivoire, Sudan, Tanzania, Mozambique, Madagascar, Ghana, Ethiopia, Senegal and Rwanda. The widespread occurrence of natural gas coupled with the relative ease of transporting it by pipeline offers considerable flexibility and opportunity for the establishment of new ammonia plants. By contrast, coal based ammonia manufacture must be located at or near the source of coal supplies.

World phosphate rock production in 1986 amounted to 144 million mt of which Africa produced 67 million mt, with Morocco producing 21 million mt Tunisia 4.5 million mt, Togo 2.3 million mt, Senegal 2.0 million mt, Egypt 1.3 million mt and Algeria 1.2 million mt.[13/] High analysis phosphate rock concentrates from Togo, Senegal, Western Sahara/Morocco are attracting the attention of importers because they offer the opportunity of expanding the nominal capacity of many phosphoric plants. It is noteworthy that Morocco, Tunisia and Senegal have significantly expanded their downstream phosphoric acid capacities and now contribute around 60% of world trade in phosphoric acid.

With regard to sulphur, the second raw material for the phosphate fertilizer industry, Africa is poorly endowed. This is especially so in the case of brimstone. In 1986 world sulphur production was reported as 57 million mt of sulphur equivalent of which developing Africa produced only 0.2 million mt. In 1986 Africa contributed a mere .03 % of world brimstone production. Thus, by contrast with the size of phosphate deposits, phosphate rock and phosphoric acid production, sulphur deposits and the scale of sulphur production represent constraints to the development of the fertilizer industry in Africa. Sulphur recovery from natural gas and at oil refineries, as well as from copper-nickel smelting facilities should be given the closest attention. The use of nitric or hydrochloric acid, instead of sulphuric acid, for dissolving phosphate rock should be examined during strategy formulation.

13/ FAO, "Fertilizer Yearbook", 1987.

Table 2.11 Availability in Africa and the world of raw materials for the production of fertilizers

	Nitrogen related			Phosphate related
	Natural gas (billions of cubic meters)	Oil (millions mt)	Coal (billions mt)	Phosphate Rock (millions mt)[a]
World Total	65881	87938	9230	144212
Africa	5923	8299	21	67189
Algeria	3564	932		1000
Angola	42	166		120
Burkina Faso				4
Congo	1	39		
Egypt	79	267		2800
Gabon	71	291		
Liberia				2
Libya	731	3494		
Mali				20
Mauritania				5
Morocco	1	0		40000
Nigeria	1246	2672		
Senegal				3390
Tanzania				10
Togo				300
Tunisia	187	370		1300
Uganda				200
Zaire	1	68		83
Zimbabwe				20
South Africa				435

a/ One unit of phosphate rock is equivalent to 30% P_2O_5 concentrate.

Source: UNIDO, Fertilizer Manual, Development and Transfer of Technology Series, No.13, 1980.

Figure 2.4 presents the location of major phosphate rock and sulphur production facilities in the world, together with phosphate concentrate and sulphur production data for 1984. It is evident that the United States and the Soviet Union have a predominant position in production of both sulphur and phosphate rock. No African country appears in the top ten producers of sulphur. However, the position of Africa is considerably stronger in the case of phosphate concentrate production. Four countries from developing Africa are included in the world's top eleven producers. Most notably, Morocco is seen to be the world's third largest producer of phosphate concentrate.

(c) Potash related raw materials

World potash reserves are estimated at about 113 billion mt of K2O equivalent in potash ores and brines. The only African country included in world potash statistics is the Congo. Other potash deposits are reported however in Ethiopia, Botswana, Tunisia and possibly in Libya, Algeria, Morocco, Nigeria, Uganda and Kenya. In the latter group deposits are considered either too small, too poor or too badly located to make exploitation worthwhile. These deposits are not mined at present. The techno-economic viability of their exploration should be given special consideration, especially in Ethiopia, Botswana and Tunisia.

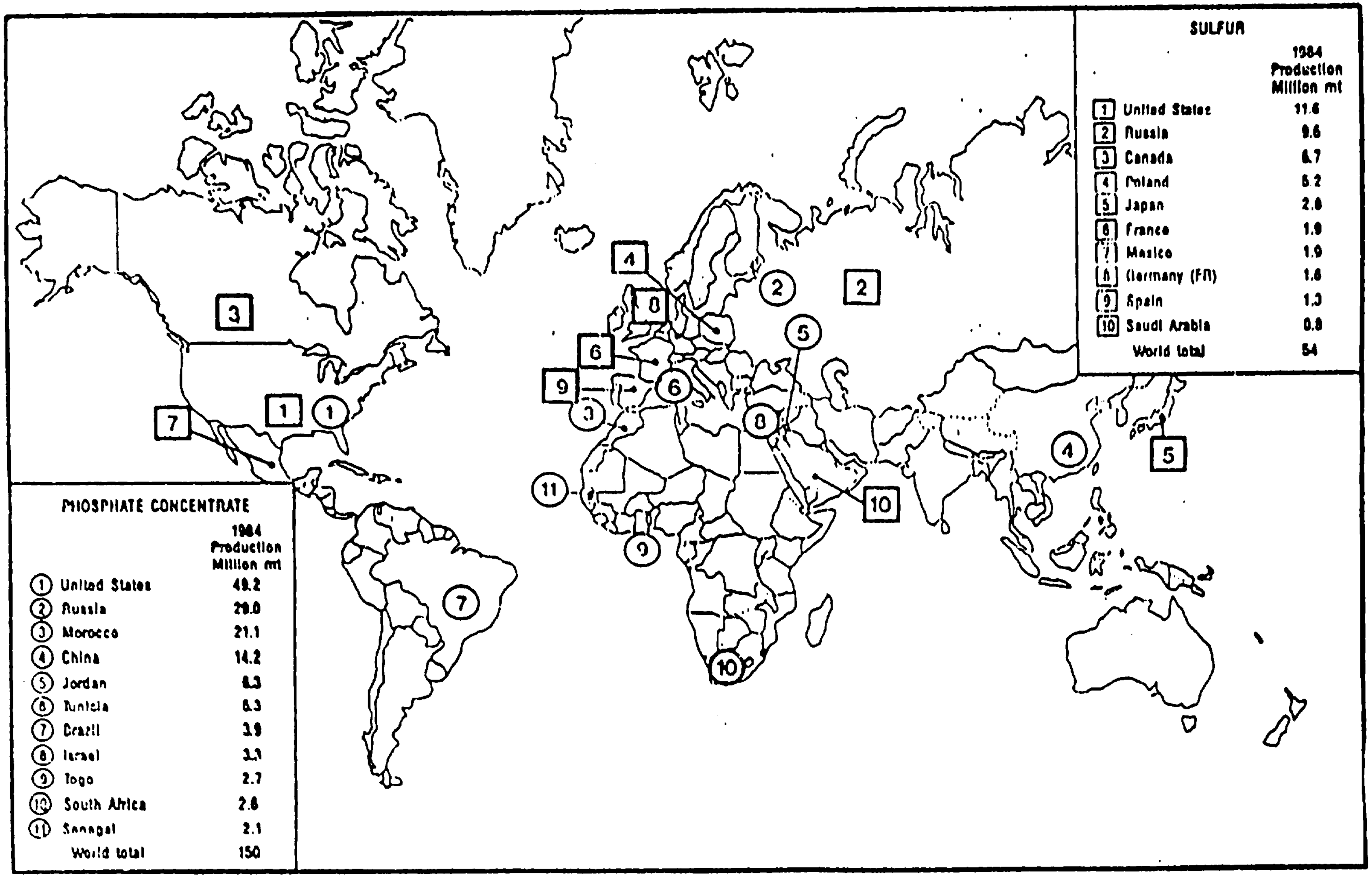
No African country presently produces potash and Africa is totally dependent on imports of muriate, sulphate and nitrate of potash. Together with the sulphur shortage this is a great constraint on fertilizer industry development. The location of major potash production facilities in the world and potash production data for 1984 is shown in figure 2.5. Important reserves for the production of fertilizers in Africa south of the Sahara such as natural gas, phosphates and potash are illustrated in figure 2.6 (a detailed account of the raw material endowments of African countries is also given in the description of the identified development patterns, chapter 4).

2.5.2 General Infrastructure

Transportation infrastructure, including port facilities, ships, railways and railway rolling stock, roads and navigable rivers, is an essential condition for fertilizer and fertilizer raw materials delivery to agricultural and industrial locations. With projected demand for NPK fertilizers in the year 2000 equal to around 6 million mt of pure nutrients it should be borne in mind that as much as 12 million mt of fertilizer product per year will have to be handled in Africa.

The transportation of some 35 million mt. per year of phosphate rock and phosphoric acid poses a still greater challenge for some African countries. In most of the African countries transport facilities are government owned. Transport is generally expensive in these countries due to the high cost of vehicles, spare parts and fuel and the high rate of depreciation caused by roads in bad conditions. A very important exception is Zimbabwe where a high proportion of road transport is provided by the private sector and particularly by the commercial farmer. The commercial areas in Zimbabwe are well serviced by the existing rail and road transport systems. In the other areas transport infrastructure is not well developed but distribution is facilitated by co-operative societies. Distributional problems are often

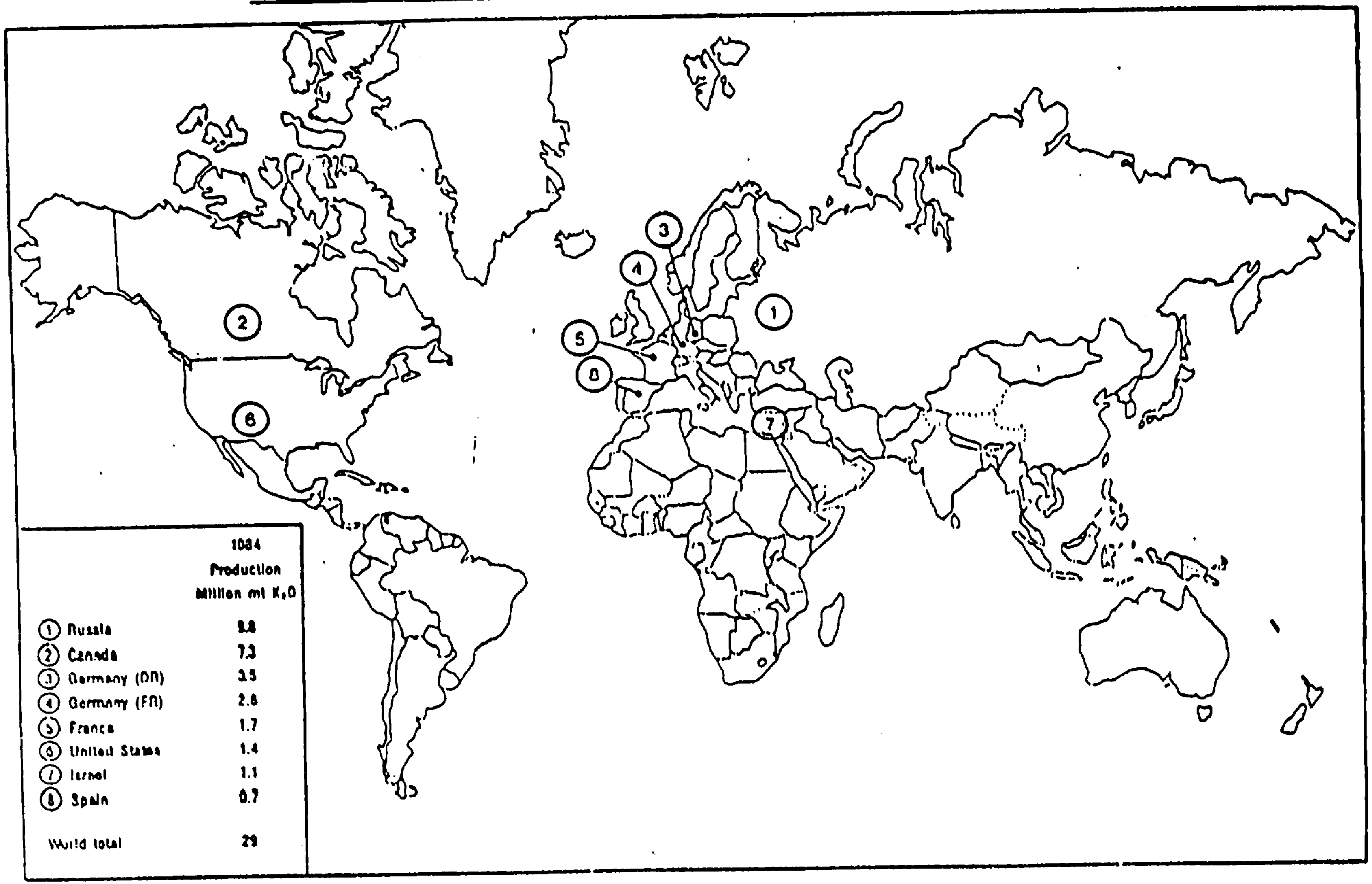
Major Phosphate Rock and Sulphur Production Facilities in the World



Source: IFA Paris, "Fertilizer Use and Crop Production", Senegal 1987, page 134.

Figure 2.4

Major Potash Production Facilities in the World

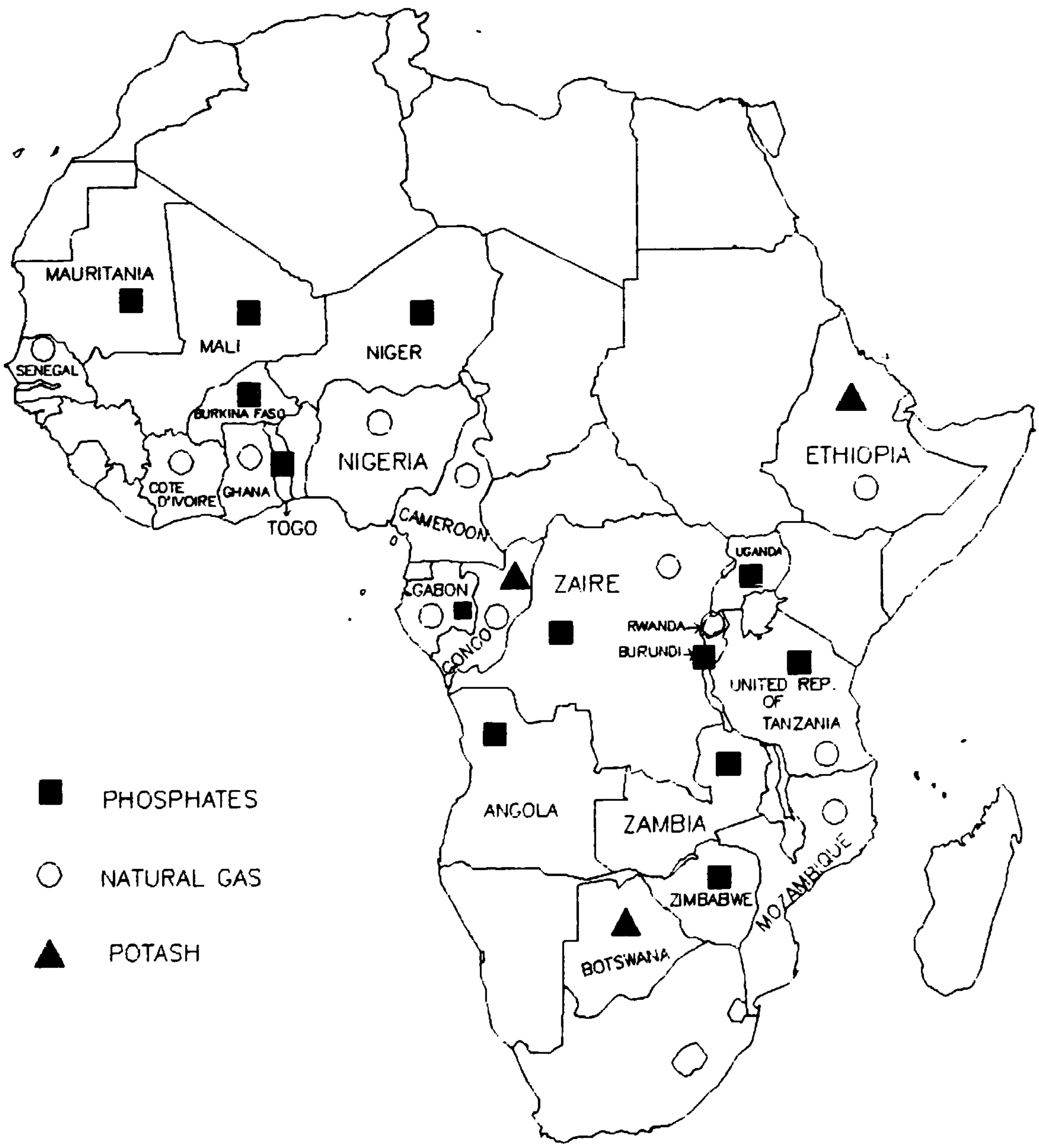


Source: IFA Paris, "Fertilizer Use and Crop Production", Senegal 1987, page 135.

Figure 2.5

Figure 2.6

IMPORTANT RAW MATERIAL RESERVES FOR THE PRODUCTION OF FERTILIZERS IN AFRICA SOUTH OF THE SAHARA



SOURCE: IFA PARIS, "The Outlook for Fertilizer in Sub-Saharan Africa", Paris 1988, page 68.

exacerbated in landlocked countries due to the lack of control over port facilities. The often isolated condition of the fertilizer consumer militates against policies to promote fertilizer use. Only 5 kilometers of road are available for every 100 square kilometers of area in Africa while in Asia the relation is 45 kilometers of road for each 100 square kilometers.

In recent years, transport problems have been exacerbated by inadequate foreign exchange to import machinery and spare parts required for the construction of new roads. High costs of transporting fertilizer are charged directly to the product and consequently, placing pressure on the demand for fertilizer.

2.5.3 Inputs and services

Many important inputs and services are required for the fertilizer industry to function properly. The most important inputs and services are discussed here.

(a) Manpower

There are two options related to reducing the gap between production of fertilizers in 1986 and projected demand for fertilizers in the year 2000.[14/] They are, either to cover NPK demand by imports of fertilizers, or to increase investment in the fertilizer industry in Africa. In the second option, the demand for at least partly qualified manpower to operate new fertilizer complexes and facilities would be very significant. The following manpower requirements are estimated for different productive facilities:

- A new nitrogen fertilizer complex requires a workforce of 600 of which at least 30% need to be educated in secondary technical schools and 10% at technical university level. At least 50% of the staff should be trained in fertilizer training centres and at similar nitrogen fertilizer facilities.

- A world-scale phosphate fertilizer complex requires a workforce of 1000 persons of which at least 20% need to be educated in secondary technical schools and 5% in institutes providing training in technical management.

- A new potash extraction/production plant requires a workforce of 400 persons with qualifications similar to those in the phosphate fertilizer industry.

In order to close the gap between fertilizer consumption in the year 2000 and production in 1986 through the establishment of new fertilizer complexes, some 8,000 persons would be needed to operate new fertilizer facilities. This includes some 600 chemical, mechanical and electrical engineers with at least some industrial practice in similar fertilizer facilities. Insufficient qualified manpower is clearly a constraint to fertilizer industry development in Africa.

14/ See table 2.8.

(b) Industrial infrastructure

The level of development of the chemical industry in Africa is extremely diverse. In a number of Sub-Saharan countries there is no chemical industry while existing chemical industries are weakly developed. In some other countries, particularly in North Africa, the chemical industry is quite well developed.

The chemical industry is a highly diversified sector with processing chains and interlinkages comprising thousands of chemical products. A major part of the chemical industry's output serves as intermediate inputs into chemical processes, agriculture and other subsectors of the economy. In Africa, agricultural chemicals appear to be the most important of these outputs, and it is the fertilizer (and/or mining) industry that in many cases was the nucleus of the development of the chemical industry subsector in Africa, and not vice versa.

The fertilizer industry cannot develop rapidly without a parallel development of the agricultural sector. Equally, the fertilizer industry cannot function properly without at least a moderate development of the chemical industry. Each of the fertilizer industrial sub-sectors, be it the nitrogen, phosphate/sulphur or potash industry, are characterized by specific requirements. For instance several different types of specific sophisticated catalysts are required for ammonia, nitric acid and sulphuric acid production. Similarly, special anticorrosive agents, antifoam additives and different clays, fillers and fertilizer anticaking additives are also needed. All of them can either be delivered by the national chemical industry or must be imported.

Secondary nutrients (e.g. calcium, magnesium) and micronutrients (e.g. boron, zinc), slow release fertilizers and other agents must be delivered from the inorganic and organic chemical industries. Ammonium sulphate is obtained as a byproduct in the caprolactam production process. Some fertilizer processes require raw materials which may be obtained from salt or sodium carbonates. Various secondary sources of hydrocarbons may be used for ammonia feedstock, such as oven coke gas, liquefied petroleum gas, refinery tail gas or byproduct hydrogen from electrolytic chlorine production. Polyethylene or polyethylene bags for fertilizer packing are delivered from the petrochemical and plastics chemical industries.

The chain of uses of industrial inorganic acids, hydrochloric, nitric and, by far the most important, sulphuric acid, is so diversified that it is sometimes difficult to make a clear distinction between the fertilizer and other chemical industries, especially in large, diversified fertilizer/inorganic or fertilizer/petrochemical complexes. Fertilizer intermediaries and products also serve in many other subsectors of the chemical industry such as ammonia (refrigeration, dyestuffs), urea (melamine, urea-formaldehyde resins), ammonium nitrate (explosives) and phosphoric acid (washing powders).

(c) Energy and water supply

The fertilizer industry is a large consumer of energy. Therefore, energy self-sufficiency and energy supply reliability is a sine qua non for efficient functioning of the industry. The availability of primary energy sources such as coal, fuel oil, and natural gas to produce steam and deliver process energy as well as electricity is essential. Similarly, the availability of cooling water, process water and industrial gases (compressed air, nitrogen) is vital. In practice, most of the process inputs (steam, cooling water, process water, compressed air) must be generated, at least partly, within the fertilizer complex, or at a nearby location. Electricity is usually partly generated within the fertilizer complex but may also be sent from longer distances.

The ammonia process uses mostly primary energy (natural gas), and in modern plants both steam and electricity use is roughly balanced. A modern urea plant uses approximately one ton of steam, 125 kilowatts per hour of electricity and 70 cubic meters of cooling water per ton of product.

A phosphoric acid plant uses approximately 1.5-1.8 tons of steam, 150 kilowatts per hour of electricity and 150 cubic meters of cooling water per ton of P_2O_5 produced. These examples show how strongly the fertilizer industry depends on a reliable energy supply. It is impossible to properly operate fertilizer plants and facilities, without the energy sector having been developed and stabilized first. High on-stream coefficients, emergency situations and deterioration of fertilizer equipment are inevitable when fertilizer plants have inefficient energy supplies.

Amongst engineering and allied metal working industries it is the peripheral engineering industry that is most closely connected with the fertilizer industry. Examples of the interlinkage between the peripheral engineering industries producing capital goods and services and the fertilizer industry include the following:

- conventional and special-purpose machine tools and metal working equipment for the manufacture of specific parts and components;

- various welded parts from the fabrication shop;

- nickel-chrome, phosphate, anodized and other metal-coated parts and components from the metal-coating shop;

- reconditioning facilities for worn-out machinery and equipment from the heavy repair and maintenance shop.

Without a domestic engineering industry the fertilizer industry is dependent on imports of even small spare parts.

Many African countries are endowed with huge hydroelectricity potential. The Congo-river's hydroelectricity potential is estimated at about 25% of total world potential. Other sources of hydroelectricity include the Kariba Dam on the boundaries of Zambia and Zimbabwe, the Kafue Dam in Egypt, the Akasombo Dam in Ghana, and the Kainji Dam in Nigeria. Total hydro-electric power in Africa is estimated at 350,000 megawatts.

Water is a frequently underestimated input when planning fertilizer industry development. A large scale ammonia-urea complex uses around 200 cubic meters of water per hour. Such large quantities of water are not always readily available, particularly in arid regions of Africa. Water delivered to an ammonia process is also a raw material in the strict sense of the word as it is the source of more than half of the hydrogen needed to produce ammonia from the electrolysis of water. This water must be of very high quality, decarbonized and demineralized. Impure cooling water may also be problematic, particularly when sea water is used. A high concentration of the chloride ion is responsible for chloride corrosion of stainless steel in fertilizer plants.

(d) Packaging

It is also obvious that a fertilizer industry cannot be established or function without a parallel packaging industry, or appropriate packaging facilities established within the fertilizer complex. In most African countries fertilizers cannot be transported in bulk, especially to the more remote agricultural areas. Therefore, either paper bags, natural fibre bags, or preferably polyethylene bags must be delivered to, or manufactured directly in, the fertilizer industrial complex. Double bags with a woven polypropylene, jute or sisal outer bag and a polyethylene or other moisture-proof inner bag may be required for transport within countries where manual handling is involved.

Packing will be important in the case of a large increase in African production of fertilizers. Should the gap between production of fertilizers in 1986 and consumption of fertilizers in the year 2000 be closed by an increase of domestic production then Africa will require approximately 150 million (50 kg) polyethylene bags per year. This requirement is equivalent to the production of 3 large-scale polyethylene bag facilities. Packaging costs are frequently the second or third largest element in total manufacturing cost, behind the cost of raw materials and energy.

2.6 Environmental protection

Increasingly stringent regulations in pollution control will need new technologies and equipment to protect the natural environment. This applies to all African countries and in particular to those near the Mediterranean. The closure of some fertilizer plants in North Africa due to excessive pollution is symptomatic of this trend.

Gaseous effluents such as ammonia, nitric oxides, sulphur oxides, fluorine off-gases, mists, fumes and dusts from fertilizer plants are of concern in this context. Liquid effluents from nitrogen and phosphate fertilizer industries, in particular those effluents containing phosphate and fluosilicic acid are the most dangerous for the natural environment. Improved drainage and sewage systems must be planned, especially for slow-moving shallow waters, where vegetational pollution is a serious problem. Phosphogypsum from the wet phosphoric acid process is by far the most harmful solid waste in this respect. It is produced as a by-product at the rate of approximately 6 tons per ton of phosphoric acid. New and costly pollution combating technologies will have to be introduced. In old fertilizer complexes and in complexes with a very high concentration of fertilizer manufacture at one location, these additional measures may render fertilizer production uneconomic.

2.7 Research and development

A wide ranging effort is needed in most African countries to establish a reasonable degree of technological independence in the chemical and fertilizer industries. Because of the significant economies of scale that characterize research and development and process engineering in the fertilizer industry, these functions can be successfully undertaken only in close association with chemical research at universities, as well as work at process engineering institutions and engineering enterprises. Such work should be undertaken with the participation of technical staff and management from the fertilizer industry. Some African countries such as Algeria, Egypt, Libya, Mauritius, Morocco, Nigeria, Senegal, Tanzania, Tunisia, Zambia and Zimbabwe have already made substantial progress in this direction. Egypt and Tunisia in North Africa have developed complex capabilities in services in the fertilizer industry, including research, training facilities, engineering capabilities, fertilizer equipment, spare parts manufacture, maintenance and equipment assembly capabilities.

3. THE FERTILIZER INDUSTRIAL SYSTEM AND VARIABLES USED TO DESCRIBE ITS DEVELOPMENT

3.1 Assessing the development of the Fertilizer Industrial System in Africa

Fertilizers are one of the most important inputs to agricultural production. Fertilizers can be considered as agricultural chemicals, at least as far as their end-use is concerned. However, the linkage of the fertilizer industrial system to mining and engineering industries, as well as the sophistication of processes, unit operations and equipment used, makes it necessary to classify the fertilizer industrial system in the industrial chemicals group (ISIC group 351).

Figure 3.1 illustrates the interrelation of chemical process industries with basic needs provision and food production. It is clear that the satisfaction of a number of basic needs, such as nutrition, healthcare, and shelter is related to the availability of certain products from the chemical process industries, be these products of domestic or foreign origen. The fertilizer industry also has backward linkages with other industries such as petroleum refining, petrochemical and mining industries.

The fertilizer industry is a complex system where:

- Alternative processes and raw materials are employed for manufacture of the same product. For example, ammonia may be derived through natural gas reforming, coal gasification or electrolysis of water.

- Sophisticated technology involving multi-stage processing is required. A case in point is urea production using highly corrosive media and chemical reactions carried out in heterogeneous phases at elevated pressures and temperatures.

- Production facilities are highly subject to scale economies. Such is the case in production of ammonia, nitric, sulphuric and phosphoric acid.

- Energy requirements are high. This is evident in the production of ammonia through water electrolysis and phosphoric acid through wet and thermal processes.

- A large proportion of highly qualified personnel is needed. This requirement is evident in the production of sulphuric acid based on sulphur-bearing smelting off-gases and likewise in production of NPK complex fertilizers.

- The heterogeneity of products and viability of production is dependent on an integrated approach with economic outlets for co- and by-products. Such is the case with production of sulphuric acid which co-produces steam used in phosphoric acid and TSP production.

- Possible significant effects may be registered on the ecosystem, requiring incorporation of effluent treatment and safety measures. Such problems are seen in the production of SSP, TSP and phosphoric acid with fluorine off-gases to be utilized to fluorine chemical compounds used in aluminum metallurgy, problems of phosphogypsum storage and disposal and with flammable and explosive hydrogen, and toxic ammonia and nitric oxides in ammonia and nitric acid processes.

- A close linkage exists with other areas of industry and other sectors of the economy. Sulphuric acid and ammonia for instance, have literally hundreds of uses in the developed economy.

Development programmes and projects usually lack the necessary focus that would permit them to consider the intersectoral linkages mentioned above.

A development strategy for FERTIS in Africa cannot be designed on the basis of individual projects and actions. The likelihood of a strategy being effective will be increased if undertaken in a comprehensive and multiproject fashion, that is, through a programme. The programme approach provides a tool to assist in this objective. The programme approach emphasises the extended concept of an industrial system, taking into account the interdependence between macro-economic and micro-economic aspects in strategy formulation and including the policies necessary to support development strategies. This approach facilitates the ordering of large amounts of information relating to an industrial system in a way which is useful for formulating integrated development programmes for a given industrial system. Thus, instead of concentrating on individual fertilizer projects, information is here gathered in such a way as to facilitate detailed assessment of all the components of the fertilizer industrial system, upstream or downstream, affecting the operation of that system.

3.2 The Fertilizer Industrial System (FERTIS)

FERTIS can be defined as a system where all the industrial and agricultural resources, inputs, services and policies related to the fertilizer industry and the consumption of fertilizers in agriculture interact in an integrated and interdependent manner. The components of the FERTIS are interdependent, and a change in one will tend to modify the system as a whole.

An important feature of the FERTIS system is that development of the system has to satisfy both the most effective industrial options (raw materials, process routes, plant capacity selection etc.) and at the same time the agricultural targets that emphasize the crop response for fertilizer application.

A description of the system is given in figure 3.2. Figure 3.2 is a base diagramme of FERTIS in Africa displaying 12 components of the system as well as the linkages between these components. The fertilizer industrial system in Africa analysed here includes the most important components and variables connected with nitrogen, phosphorous and potassium fertilizers and also touches, where applicable, on issues connected with sulphur and sulphuric acid.

3.2.1 The twelve FERTIS components

The following twelve components of the African FERTIS were identified:

(I.) Natural resources
(II.) Processing to intermediary products
(III.) Processing to straight and compound NPK fertilizers
(IV.) Other operations

Figure 3.1 Interlinkage of chemical process industries with basic needs

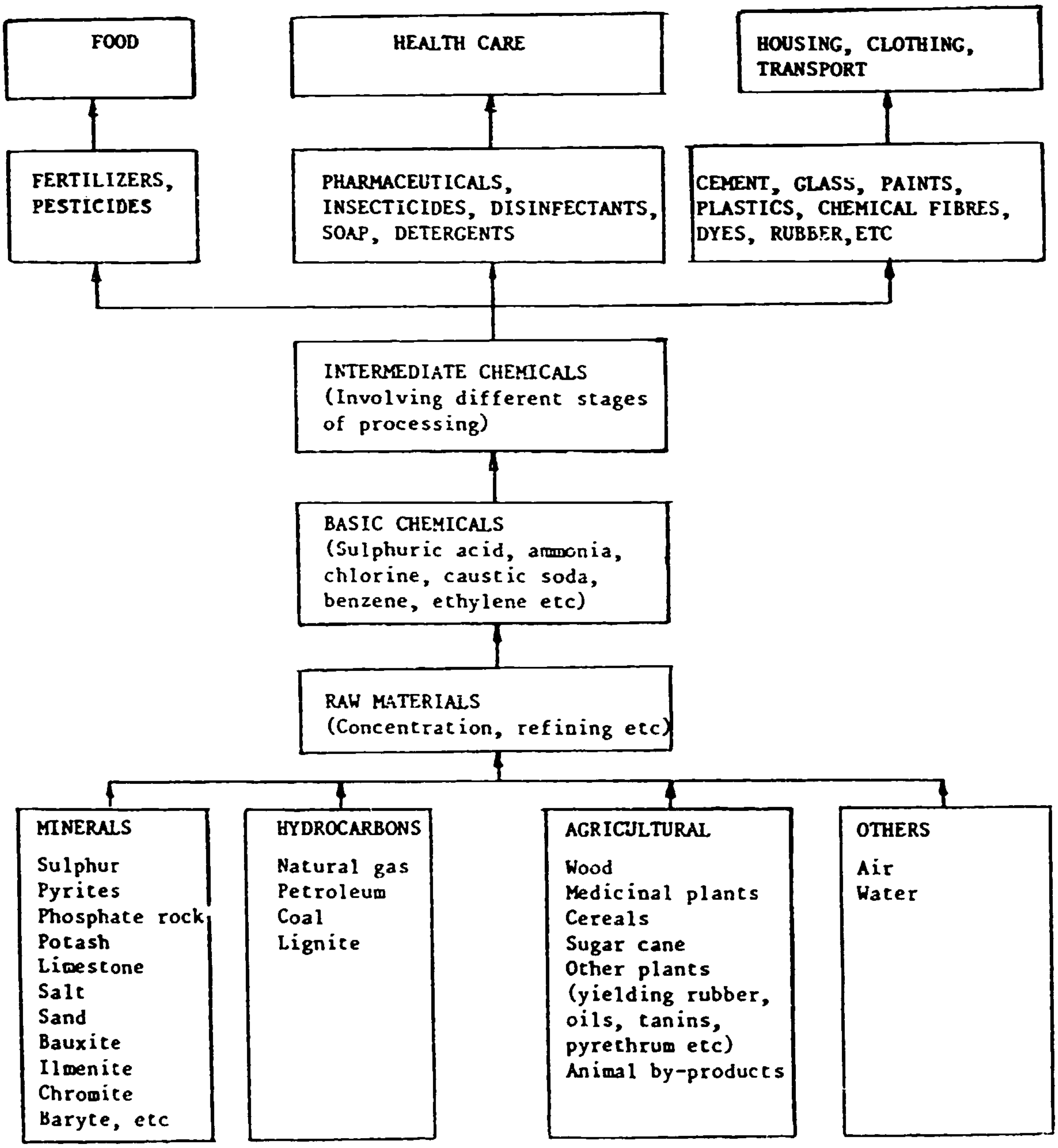
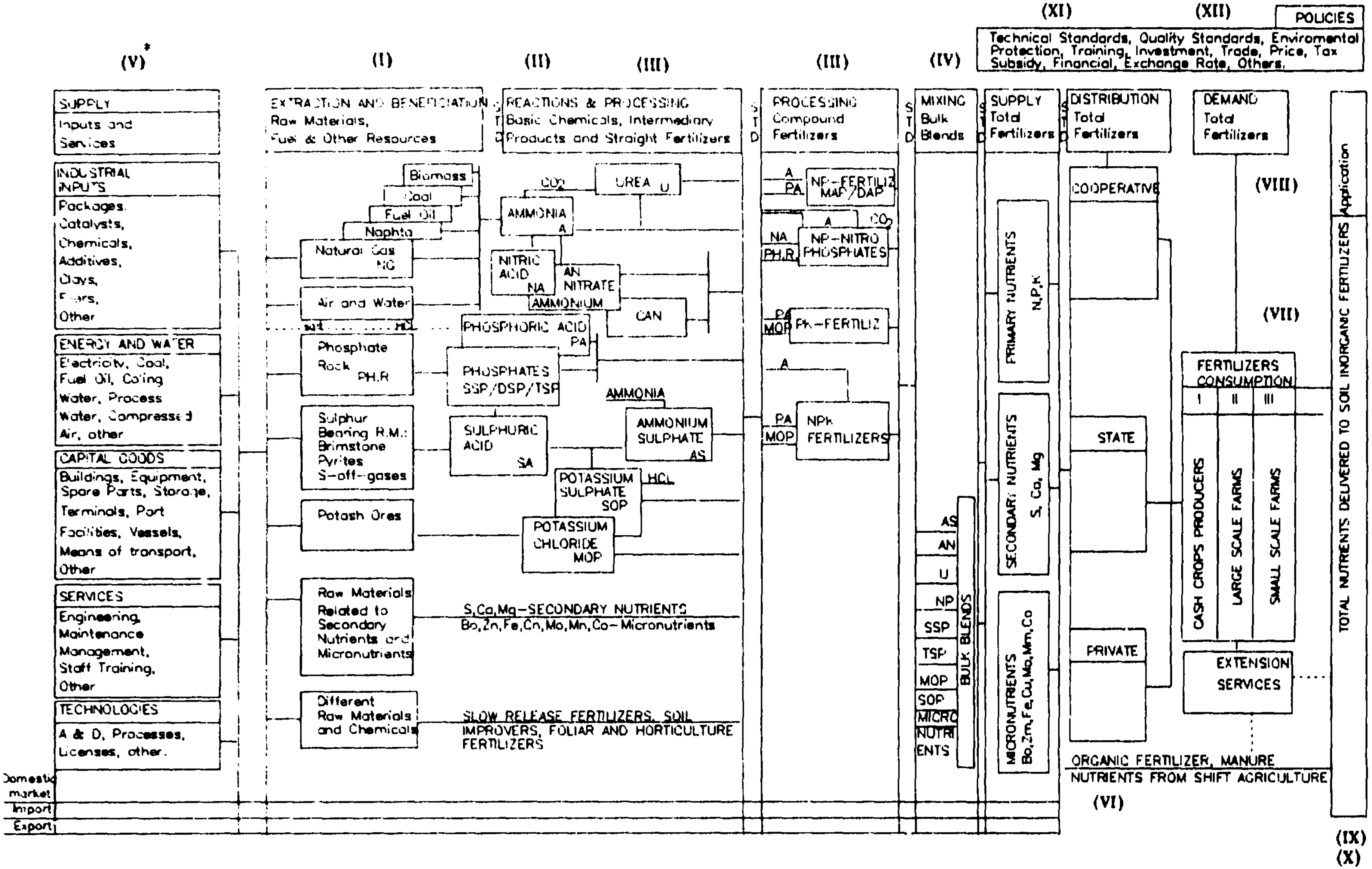


Figure 3.2 "FERTIS" - FERTILIZER INDUSTRIAL SYSTEM IN AFRICA



Note : S.T.D = STORAGE, TRANSPORT AND DISTRIBUTION

* The roman numerals between brackets correspond to the FERTIS components.These are described in Chapter 3

(V.) Industrial inputs and services
(VI.) Storage/transport and distribution
(VII.) Consumption of NPK fertilizers
(VIII.) Demand for fertilizers by the year 2000
(IX.) Fertilizer application in agriculture
(X.) Fertilizer impact on agricultural production
(XI.) Government policies related to FERTIS
(XII.) Government strategy and priority in FERTIS

A comprehensive analysis of fertilizer industrial systems essentially involves the evaluation of each of the above mentioned components and their interlinkages. The twelve components are briefly described below:

(i) Natural resources - This component describes the existence and extraction/recovery potential of FERTIS related raw materials. The raw materials considered are related to nitrogen (natural gas, oil, coal), phosphate (phosphate rock) and potash (potash ores).

(ii) Processing to intermediary products - This component is connected with the capacity, capacity utilization, manufacture and trade of the main intermediary products related to FERTIS such as ammonia, sulphuric acid, phosphoric acid and muriate of potash. These plants are generally more sophisticated than downstream fertilizer units. As these intermediary products are internationally traded, the option exists of establishing fertilizer production facilities based on importation of these intermediaries.

(iii) Processing to NPK fertilizers - This component describes production, capacity utilization and trade of the most important straight and complex fertilizers, i.e. final products that can be applied directly to the soil. Downstream fertilizer plants may be located at the same site as plants manufacturing intermediaries. In many cases, such as with the production of nitric acid, ammonium nitrate, calcium ammonium nitrate etc., locations are either unconnected or only partly connected with the plants that manufacture intermediaries.

This component best expresses the possibilities of fertilizer production based either on a country's own raw materials, on imported raw materials, or on imported intermediaries.

(iv) Other operations - This component describes another group of facilities connected with other operations such as mixing of fertilizers (bulk-blending), granulation of fertilizers and phosphate rock grinding. Phosphate rock partial acidulation facilities have been included in this component. These operations are very important for the African countries as an alternative path for development of the fertilizers system.

(v) Industrial inputs and services This component is one of the most important for the classification of African countries. It describes the whole "industrial environment" that supports the fertilizer industry. The component includes energy availability, energy self-sufficiency, maintenance capabilities, availability of trained manpower, compatibility of typical plant capacities with the demand for fertilizers in each country and the contribution of the fertilizer industry to GDP.

(vi) Storage, transport and distribution - This component is strongly related to and partly converges with component five. However, because of the importance of logistics in FERTIS development patterns, and particularly the importance of the distribution of fertilizers, this component also encompasses the size of the analysed country and the availability of distribution/marketing channels.

(vii) Consumption of NPK fertilizers - This component illustrates NPK consumption quantity and nutrients ratios. Imports and domestic production are compared with consumption of fertilizers.

(viii) Demand for NPK fertilizers by the year 2000 - Component eight analyses the future situation in FERTIS development by 2000. The gap between demand 2000 minus production 1986 expresses the difference between the potential of the domestic fertilizer industry and expected demand for NPK fertilizers by 2000 as estimated by FAO. For countries not producing fertilizers, the demand will be equal to this gap and should be covered by imports. For large fertilizer producers, the demand 2000 will be lower than production in 1986.

(ix) Fertilizer application in agriculture - This component illustrates agricultural potential and its relation to the amount of fertilizer used. It includes natural constraints and enhancements relating to agricultural, arable and irrigated land potential, natural vegetation conditions and cropping intensity, fertility of soils, patterns of crop production, as well as seed types used, application of pesticides and mechanization of agriculture.

(x) Fertilizer impact on agricultural production - In this component several important functions are combined, illustrating the effectiveness of fertilizer use (the ratio of crop yield to fertilizer consumption), nutritional level of the population, net balance of cereals in the year 2000 as well as the self-sufficiency ratio in cereals for the year 2000.

(xi) Government policies related to FERTIS - Government policy towards FERTIS is expressed in this component by pricing policy and the resulting incentive to use fertilizers by farmers (crop/fertilizer price ratio).

(xii) Government strategy and priority in FERTIS - This component illustrates general government strategy toward the fertilizer subsector, analyzing possible options in FERTIS development ranging from importation of food, through imports of fertilizers, import substitution of fertilizers, self-sufficiency in fertilizer production and fertilizer export promotion. Exports of fertilizer raw materials and intermediaries are also considered in this component. The investment climate is assessed, as is the possibility of increasing productive capacity through industrial rehabilitation, modernization and implementation of new projects in the fertilizer industry.

3.3 Variables used to quantitatively describe each component

After selection and definition of the FERTIS components a set of variables were defined with the purpose of quantifying the performance of each component in each country. More than 150 variables were examined, from which 30 variables were finally selected in order to simplify the following analysis. The variables are described below.

COMPONENT		VARIABLES	DESCRIPTION
I.	Natural resources	Raw materials related to FERTIS	Existence and potential exploitation of nitrogen, phosphorous, sulphur and potassium related raw materials, size and access to deposit, raw material quality and current exploitation.
II.	Processing to intermediaries	Total ammonia capacity Total phosphoric acid capacity Sulphuric acid capacity Imports of Sulphur	Existence and potential of industrial facilities for manufacture of intermediary products used for synthesis of straight and compound fertilizers. These variables illustrate the potential sophistication of the FERTIS.
III.	Processing to NPK fertilizers	Production of NPK fertilizers Import of NPK fertilizers Export of NPK fertilizers	Variables illustrating development of domestic fertilizer industry, degree of dependence on fertilizer imports, and extent of fertilizer exports. The combination of these variables provides information on the fertilizer consumption pattern for each of the nutrients nitrogen, phosphorous and potassium.
IV.	Other operations	Bulk-blending, NPK granulation compounding, ground phosphate rock plants	An assessment of the stage of FERTIS development when fertilizers are not being synthesized, but blended and compounded on the basis of imported products, or when domestic phosphate rock is ground and used as phosphate ferti[illegible]
V.	Industrial inputs and services	Total energy self-sufficiency	A <u>sine</u> <u>qua</u> <u>non</u> condition for smooth and reliable plant operation. Necessary

		Energy consumption per capita	for continuous raw material and fuel supply and to avoid interruption of production or imports of fertilizers.
VI.	Storage, transport, distribution	Infrastructure and transport network Total country area	Assessment of the flexibility and reliability of the distribution chain in delivering fertilizers to consumers (private or paratastal channels and distributors). Total country area provides an indirect measure of the distribution problems faced.
VII.	Consumption of NPK fertilizers	Consumption of NPK fertilizers Nitrogen/ phosphorous/ potassium ratio	Indicates size of the domestic market for fertilizers and scale of possible capacity increases. NPK consumption pattern in agriculture indicates the directio of FERTIS development required to overcome any nutrient deficiencies.
VIII.	Demand for fertilizers by 2000	Demand for NPK by 2000 Ratio between consumption 1986 and demand 2000 Foreign exchange needed to fill the gap between future demand and production in 1986 through fertilizer imports	These variables aim to assess the difference between production and demand for fertilizers, measure consumption growth to the year 2000, and indicate the ability of the country to close the gap between future fertilizer requirements and production through imports.
IX.	Fertilizer application in agriculture	Share of arable land with permanent crops Consumption of fertilizers per hectare of arable land and permanent cropland	The variables are closely linked to conditions in agriculture and affect fertilizer consumption levels.

		Arable land with permanent crops in the year 2000 Population supporting capacity of the land. Persons per hectare of arable land and permanent cropland in the year 2000	
X.	Fertilizer impact on agricultural production	Effectiveness of fertilizer use Balance of cereals per capita in the year 2000 Population in the year 2000 GDP in the year 2000	The effectiveness of fertilizer use is indicated by a ratio of fertilizer application to cereal yields. The measure of national income is a proxy indicator of the ability of the country to supply inputs to agriculture.
XI.	Government policies related to FERTIS	Incentive to use fertilizers	This variable measures the ratio of fertilizer to crop prices.
XII.	Government strategy and priority in FERTIS	Government strategy in FERTIS Exports of raw materials related to FERTIS	These variables examine qualitatively the government strategy and orientation on: import. of food and/or fertilizers, and achievement of food self-sufficiency, all of which will affect the development of the national fertilizer industry. Exports of raw materials likewise provides a measure of the degree of processing of raw materials and the extent of export substitution.

Note: According to FAO estimates, increased yields will make a much greater contribution to increases in agricultural production than will growth of arable land and changes in cropping intensity. Therefore, both effectiveness of fertilizer use, and the incentive for farmers to use fertilizers are included among the 30 variables.

A description of the variables used in terms of the units in which each variable is expressed is given below:

COMPONENT	VARIABLE TO MEASURE FERTIS COMPONENT
I. Natural Resources	Strength, diversification and completeness of raw material "environment" and its base according to a scaled variable.
II. Processing to: intermediaries	(a) Capacity utilization in ammonia and phosphoric acid plants (b) Ammonia total capacity in thousand mt per year of N (c) Phosphoric acid total capacity in thousand mt per year of P_2O_5 (d) Import of sulphur in thousand mt per year (1986)
III. Processing to NPK fertilizers	(a) Production level of NPK fertilizers in thousand mt per year of NPK (1986) (b) Import of NPK in thousand mt per year (1986) (c) Export of NPK in thousand mt per year (1986)
IV. Other operations	Existence of bulk-blending, compound granulation and phosphate rock grinding plants.
V. Industrial inputs and services	(a) Total energy self-sufficiency in % (1986) (b) Total energy consumption per capita in terms of kg of oil equivalent (1986)
VI. Storage, transport, distribution	(a) Total area of the country (scale 1-3) (b) General infrastructure and transport network (scale 0 -3)
VII. Consumption of NPK fertilizers	(a) Consumption of NPK in 000 MTPY (1986) (b) N:P:K ratio in fertilizer consumption (1986)
VIII. Demand for fertilizer by 2000	(a) Foreign exchange needed to fill the gap between NPK demand in 2000 and production in 1986 Foreign trade net balance (+/- million US$) (b) Consumption of NPK 1986 as a percentage of demand in the year 2000

IX.	Fertilizer application in agriculture	(a) Consumption of NPK in terms of kg per ha of arable land and permanent crops (1986). (b) Arable land with permanent crops in the year 200 in millions ha. (c) Share of arable land and permanent crops in agricultural area (%). 1986. (d) Population supporting capacity of the land in the year 2000 in persons per ha.
X.	Fertilizer impact on agricultural production	(a) Effectiveness of fertilizer use: Yield of cereals in kg per ha of arable land and permanent crops versus consumption of NPK kg per ha of arable land and permanent cropland. (kg of cereals/kg of applied NPK). (b) Population in the year 2000 (million inhabitants). (c) GDP in the year 2000 (million US$). (d) Balance of cereals. kg/capita 2000.
XI.	Government policies related to FERTIS.	Incentive to use fertilizers by farmer; expressed as the ratio between the price of a unit of crops and the price of a unit of NPK fertilizer.
XII.	Government strategy and priority in FERTIS	(a) Export of nitrogen related raw materials (scale 0-5) (b) Export of phosphorous related raw materials (scale 0 - 5) (c) Gradation of countries according to the following scale: Import of fertilizers = 0 Import substitution = 1; Self-sufficiency = 2; Export promotion in fertilizers = 3

The 30 variables were chosen in order to answer questions concerning scenarios to the year 2000, both in FERTIS development and in food self-sufficiency ratios.

3.3.1 FERTIS constraint variables

Some of the above mentioned variables could be considered constraint variables, that is, variables connected with the most important bottlenecks hindering FERTIS development. The 17 variables describing constraints on the development of each component are presented below:

COMPONENT NUMBER	CONSTRAINT NUMBER	CONSTRAINT DESCRIPTION
I.	1.	The Nitrogen/phosphorous/sulphur/potassium raw material "environment" differs from country to country, and for the majority of African countries includes one of the raw materials at most. The poorer the raw material base, the more constraining will be the effect on future FERTIS development. Potash and Sulphur raw materials most constrain FERTIS development in Africa, precluding a balanced and diversified development of fertilizer production based wholly on indigenous raw materials.
II.	2.	The rate of capacity utilization is one of the most important constraints on the development of the fertilizer industry in Africa. This constraining variable describes the inability of several countries to utilize nominal capacities of fertilizer plants and complexes, thus diminishing the possibility of maintaining low manufacturing costs, diminishing competitiveness and profitability. This constraint may have many causes such as poor maintenance, obsolete processes and plant, unqualified staff, inappropriate industrial policies, etc.
II.	3.	Imports of ammonia and, especially, of sulphur have been selected as constraints in the development of FERTIS in many African countries. The dependency of African countries on imported phosphoric acid is of lesser importance, this being exported from North Africa to other continents rather than to sub-saharan countries. The dependency of Africa on imported muriate of potash is greatest. This will, however, be considered under constraints related to component 3 as muriate of potash is considered a final potash fertilizer.
III.	4.	Importation of fertilizer has been selected as a constraint, with potash imports being the most important. The rate of capacity utilization is also a constraining factor, in a fashion similar to component 2.

IV.	5.	Imports of straight and compound fertilizers to be blended or granulated is the strongest constraint in this component. This constraint also applies to component 3. Inadequate logistical support is a general constraint to FERTIS development and has been included in components 5 and 6.
V.	6.	Low rates of self-sufficiency in electrical energy can be a strong constraint on fertilizer industry development and efficient operation of existing plants. Shortages of electricity and unforeseen breaks in electricity supply cause emergencies in the fertilizer industry as well as deterioration of installed equipment.
V.	7.	The diversified nature of the fertilizers industry and the minimum capacities of typical fertilizer units makes it very difficult for any country with a small fertilizer market to be self-sufficient in major products. Economies of scale and high investment costs are in this sense major constraints. However, the variety of industrially proven technologies and the scale of capacities offered are so varied that for some African countries, even with a moderate fertilizer demand (domestic or from neighboring countries), this strong constraint might be lessened. The lower the demand for fertilizers the more constraining will be this variable.
V.	8.	The impact of FERTIS on the natural environment is a constraint for some large North African fertilizer producers, forcing them to close some obsolete plants polluting the atmosphere and the Mediterranean sea. This constraint may also be important in other countries.
VI.	9.	The total area of the country illustrates a constraint related to transport, storage and distribution. The larger the country, the more difficult may be the distribution of final products to consumers who are sometimes located in remote areas at a great distance from either sea-ports (imported fertilizers) or from fertilizer plants (domestic production).

VII.	10.	Imports of NPK as a percentage of NPK consumption indicates the foreign exchange burden involved in purchasing fertilizers. The higher the share of imported fertilizers, the greater the constraining effect on the economy.
VIII.		No constraint variable was identified.
IX	11.	The share of arable land and permanent crops in the agricultural area describes a land potential or, in other words, a scope for more extensive agriculture. This is an enhancement for agricultural production but may act as a constraint on demand for fertilizers.
IX.	12.	Insufficient or absent extension services is an important constraint hindering FERTIS development.
IX.	13.	A low share of mechanized area in arable land illustrates a constraint to modern fertilizer application techniques.
X.	14.	Population supporting capacity of the land is a constraining factor for fertilizer usage. The lower the population density per hectare of arable land, the higher will be the availability of land per capita and hence a constraint may be imposed on demand for fertilizers.
X.	15.	A low demand for cereals which respond positively to fertilizer application may be a constraining factor in some countries. This variable may also be an enhancement where demand for cereals is high.
XI.	16.	The incentive to use fertilizers may be a key constraint where the cereals/fertilizers price index is low, as the farmer's gain from fertilizers use will be relatively low and demand for fertilizers may fall.
XII.	17.	Both a high average rate of inflation and total external debt will be major constraints for many African countries. Indispensable infrastructural support may be particularly badly affected.

3.3.2 FERTIS enhancement variables

The enhancement variables indicate factors which may be particularly favourable to the overall development of FERTIS. The 12 enhancement variables are presented below:

COMPONENT NUMBER	ENHANCEMENT NUMBER	ENHANCEMENT DESCRIPTION
I.	1.	The raw material environment may be very rich in some countries, including all four major nutrients. Of particular value is a raw materials potential in potash and sulphur as a shortage of these raw materials exists throughout Africa. This enhancement indicates the possibility of developing a diversified fertilizer industry in some countries, meeting all the requirements of agriculture.
II.	2.	Exports of liquid ammonia and phosphoric acid indicate a potential for future development in downstream fertilizer units. Through exports of ammonia and phosphoric acid some countries are in a position to improve their foreign trade balance and increase investment in FERTIS.
III.	3.	High exports of fertilizers and a high share of exports in production indicate a potential to meet future domestic demand for fertilizers, an ability to generate foreign exchange, and a potential for bartering and/or purchasing other fertilizers not manufactured in the country.
IV.		No enhancement variable has been identified for component 4. However, the enhancement in component 5 is to some extent representative for this component.
V.	4.	Ammonia, phosphoric acid, fertilizer and raw material terminals in sea-ports equipped with appropriate loading/unloading facilities are a strong enhancement to development of the fertilizer industry in sea-side located countries. This enhancement also applies to the development of bulk-blending and granulation compounding operations based on imported products.

V.	5.	Direct access to a sea-port is an important enhancement for sea-side located countries, as they will have a great cost advantage over land-locked countries when fertilizers, intermediary products or raw materials are delivered from international markets. They may also enjoy more favorable conditions for timely shipment, unloading and dispatching of investment equipment, spare parts or even modularized units to the site of a fertilizer complex. Access to a port is also a strong enhancement for countries with an export-oriented fertilizer industry.
VI.	6.	By contrast with the constraint variable for this component, a small country area may be a strong enhancement to FERTIS development as far as storage, transport and distribution of fertilizers is concerned.
VII.	7.	Production as a percentage of consumption illustrates the potential for further FERTIS development, although the realisation of a potential may require the elimination of constraints. A production higher than consumption is an indicator of export potential in fertilizers.
VIII.	8.	A high demand for agricultural inputs per hectare of arable and permanent cropland will be an enhancement to FERTIS and will create a pressure for the development of FERTIS, either through investments in the domestic fertilizer industry, or through increased imports of fertilizers.
IX.	9.	The amount of pesticides used can be considered an enhancement to FERTIS, as additional agricultural production derived from fertilizer use may be protected against crop diseases and pests.
X.	10.	The contribution of agriculture to GDP can be considered an enhancement to FERTIS. Countries with a high contribution of agriculture to GDP may place particular priority on agricultural production and exports and consequently on the supply of inputs to agricultural production.

XI.	11.	By contrast with the constraint variable, a high cereals/fertilizers price index will be a strong enhancement to FERTIS development, providing an incentive to farmers to use greater amounts of fertilizers.
XII.	12.	Exports of raw materials related to FERTIS indicates further potential for processing those raw materials used in existing or new fertilizer facilities to more valuable fertilizers and directing these to the domestic or foreign market.

3.4 Countries included in the classification

50 African countries were originally to be considered in the typology exercise. However, during the preparation of the study it appeared that the coverage of data, gathered either through questionnaires sent to Africa or from other sources, was not sufficient to enable a classification of all countries. The data coverage was particularly thin for the following countries; Cape Verde, Comoros Islands, Djibouti, Equatorial Guinea, Guinea Bissau, Sao Tome and Principe and Seychelles. Hence it was not possible to include these countries in the typology work. Data for Morocco encompasses Western Sahara. On completion of the analytical work Namibia was not yet an independent nation.

The final list of countries is given below. Countries not included in the classification are indicated with an asterisk.

1. Algeria
2. Angola
3. Benin
4. Botswana
5. Burkina Faso
6. Burundi
7. Cameroon
8. Cape Verde*
9. Central African Republic
10. Chad
11. Comoros Islands *
12. Congo
13. Côte d'Ivoire
14. Djibouti *
15. Egypt
16. Equatorial Guinea*
17. Ethiopia
18. Gabon
19. Gambia
20. Ghana
21. Guinea
22. Guinea Bissau*
23. Kenya
24. Lesotho
25. Liberia
26. Libya
27. Madagascar
28. Malawi
29. Mali
30. Mauritania
31. Mauritius
32. Morocco
33. Mozambique
34. Niger
35. Nigeria
36. Rwanda
37. Sao Tome and Principe*
38. Senegal
39. Seychelles*
40. Sierra Leone
41. Somalia
42. Sudan
43. Swaziland
44. Tanzania
45. Togo
46. Tunisia
47. Uganda
48. Zaire
49. Zambia
50. Zimbabwe

3.5 Methodology Used to Group Countries

This section briefly describes the techniques used to identify groups of countries having distinct patterns of FERTIS development.

As stated previously, data was collected for variables describing the twelve components of the fertilizer industrial system. These variables were to be used as inputs to the statistical analysis. The statistical procedures would identify homogeneous development patterns. The statistical method used was cluster analysis. Cluster analysis is a technique useful in identifying similarities and dissimilarities between objects when these objects are measured by a number of variables. In this case, the objects to be grouped were the FERTIS of each country.

A host of clustering techniques exist, some using more complex algorithms than others. Each technique has specific clustering characteristics. Two methods were employed here, the Wards Minimum Variance Method and the Average Linkage Method. These two methods are perhaps the most commonly used techniques in the cluster analysis literature. The Wards Method was here found to give the most consistently satisfying results. Unlike a regression equation, the outputs of the clustering process are not subject to tests of statistical significance. For this reason the two techniques were applied to the same data and their outputs compared. This cross-check would act as a means of assessing whether results could be considered artifacts particular to either technique. A useful overview of the different clustering methods, their limitations and the philosophy behind numerical taxonomy is given in Everitt, B.S. (1980) (Cluster Analysis, Second Edition, London: Heineman Educational Books Ltd.

Data was gathered from numerous sources, including UNIDO publications and reports, FAO fertilizer and agriculture yearbooks, the World Bank, publications of the fertilizer industry, in-house interviews with UNIDO specialists, and questionnaires formulated by PDSU and sent to African development banks, ministries of industry and fertilizer industry associations. The variables contained information in different forms. Information was most often given in continuous form, occasionally in discontinuous form and in a few instances in dichotomous form. Some 150 variables were originally collected. Interpretation of such a volume of information would clearly have been problematic, as would the drawing of conclusions on investment, technical assistance or policy requirements. The problem of interpretation from a large number of variables is initially compounded by the fact that variables have equal weight in the clustering process, and hence less important information easily obscures critical data (weighting variables is possible but may be confusing at least until after an initial interpretation of results). For these reasons it was necessary to reduce the number of variables used while simultaneously minimizing the amount of information lost.

Reducing the number of variables was carried out in a variety of ways, drawing simultaneously on a number of statistical tools and on the knowledge of the expert. Firstly, the expert sifted out variables which from a technical standpoint might be of a less critical nature. Secondly, variables could be discarded selectively by identifying those variables containing similar information, that is, those variables having a high degree of statistical correlation. Principal components analysis was likewise used to identify variables most important in the formation of given clusters. This permitted the omission of variables contributing least to the formation of country-groups.

This process of finding a tractable number of variables was supplemented by a continuous data review. Each clustering output was interpreted by the expert and PDSU staff, and where results appeared anomalous a check was made to ensure that the data was correct. Suspect data was modified and the clustering process re-run. Where data did not appear to be at fault an interpretation of the results was made with a view to explaining why countries had grouped in an apparently anomalous way. This iterative process of cluster interpretation, data revision and re-use was employed throughout, and served both as a didactic experience in itself as well as a means of refining the final outputs.

It has been noted above that "constraint" and "enhancement" variables were identified from among the thirty variables used to group countries. No specific statistical use was made of the constraint and enhancement variables, although their identification was an important aid in the description of country-groups and in the formulation of development strategies.

4. TYPOLOGY RESULTS

As described in chapter 3, thirty variables were finally selected to measure the FERTIS components (see section 3.3.2.4). Data was used for the period 1986-2000. The steps of the clustering process with 30 variables are illustrated in figure 4.1. Reading this figure is an instructive way of visualizing both the clustering process and the degrees of similarity between the FERTIS systems of different countries.

One can conceptualize the clustering process as a series of steps between two extreme states, the first in which there are the same number of groups as there are countries, and the last in which all countries form a single group. In the first state similarities between countries are not recognized. Through a process of giving gradual recognition to similarities between countries the final state is arrived at where the recognition of some degree of similarity between all countries results in a single country grouping. One can consider this process as a sort of progressive tolerence to the similarities between objects measured by a number of variables. As such, following the stages of the clustering process shown in figure 4.1 affords an insight into immediate and distant similarities between countries.

Despite being an industrial system connected to some degree with almost every African country, the classification of African countries according to their FERTIS development tends to resist other than simple disaggregations. This is a result of comparing a few very large producers of fertilizers in North Africa with all other producers and consumers of fertilizers in Sub-Saharan Africa. Even in the initial partitions the large producers, Egypt, Libya, Algeria, Tunisia and Morocco immediately separate from all other countries except Nigeria. Through all the stages to the partition with only two country groups it is clear that the large North African producers and Nigeria have strongly distinctive characteristics. Lesotho, perhaps surprisingly, is seen to separate early from other countries. This is due to its exceptional N:P:K ratio. However, as the clustering proceeds and other variables are considered Lesotho joins group II as a country with little consumption of fertilizers but proper policies in application. As might be expected, Ethiopia and Sudan group together early. Both countries then join the fertilizer import substituting countries, a group which is quite stable throughout the clustering process. It is notable that groups I, II and III contain almost the same countries throughout the various clustering stages, a fact which underlines the integrity of these groupings. The final choice of country groups was considered most appropriate at the second partition.

It should be reiterated that the typology is dynamic, reflecting expected FERTIS development by the year 2000.

4.1 Classification of African countries

A map illustrating the 10 clusters (groups) derived from the classification of 43 African countries is shown in figure 4.2. Table 4.1 lists the countries belonging to each cluster. Each cluster is also given a characteristic name which refers to a salient feature of that cluster.

Table 4.1 Country groups belonging to each identified development pattern

GROUP	COUNTRY NAME	GROUP NAME
I.	1. Mozambique	Fertilizer Import Substituting Countries
	2. Mali	
	3. Sudan	
	4. Ethiopia	
	5. Burkina Faso	
	6. Tanzania	
	7. Niger	
	8. Zambia	
II.	1. Liberia	Little Consumption with Proper Policies in Fertilizer Application.
	2. Guinea	
	3. Sierra Leone	
	4. Ghana	
	5. Benin	
	6, Burundi	
	7. Gambia	
	8. Rwanda	
	9. Somalia	
	10. Uganda	
	11. Central African Republic	
III.	1. Zaire	FERTIS Development in Line with African Mean Values
	2. Swaziland	
	3. Madagascar	
	4. Malawi	
	5. Cameroon	
	6. Côte d'Ivoire	
	7. Chad	
	8. Kenya	
	9. Mauritania	
IV.	1. Gabon	Strong in Energy and Potash/Nitrogen Related Natural Resources
	2. Congo	
	3. Angola	
	4. Botswana	
V.	1. Tunisia	Export Oriented in Phosphate Fertilizers
	2. Morocco	
VI.	1. Algeria	Export Oriented in Nitrogen Related Raw Materials
	2. Libya	
VII.	1. Nigeria	Strong Demand for NPK Fertilizers
VIII.	1. Egypt	High Fertilization Rates with self-sufficiency in FERTIS
IX.	1. Lesotho	Exceptional in N:P:K Consumption Ratio

X.	1. Mauritius 2. Zimbabwe 3. Togo 4. Senegal	Principal Sub-Saharan Fertilizer Producers

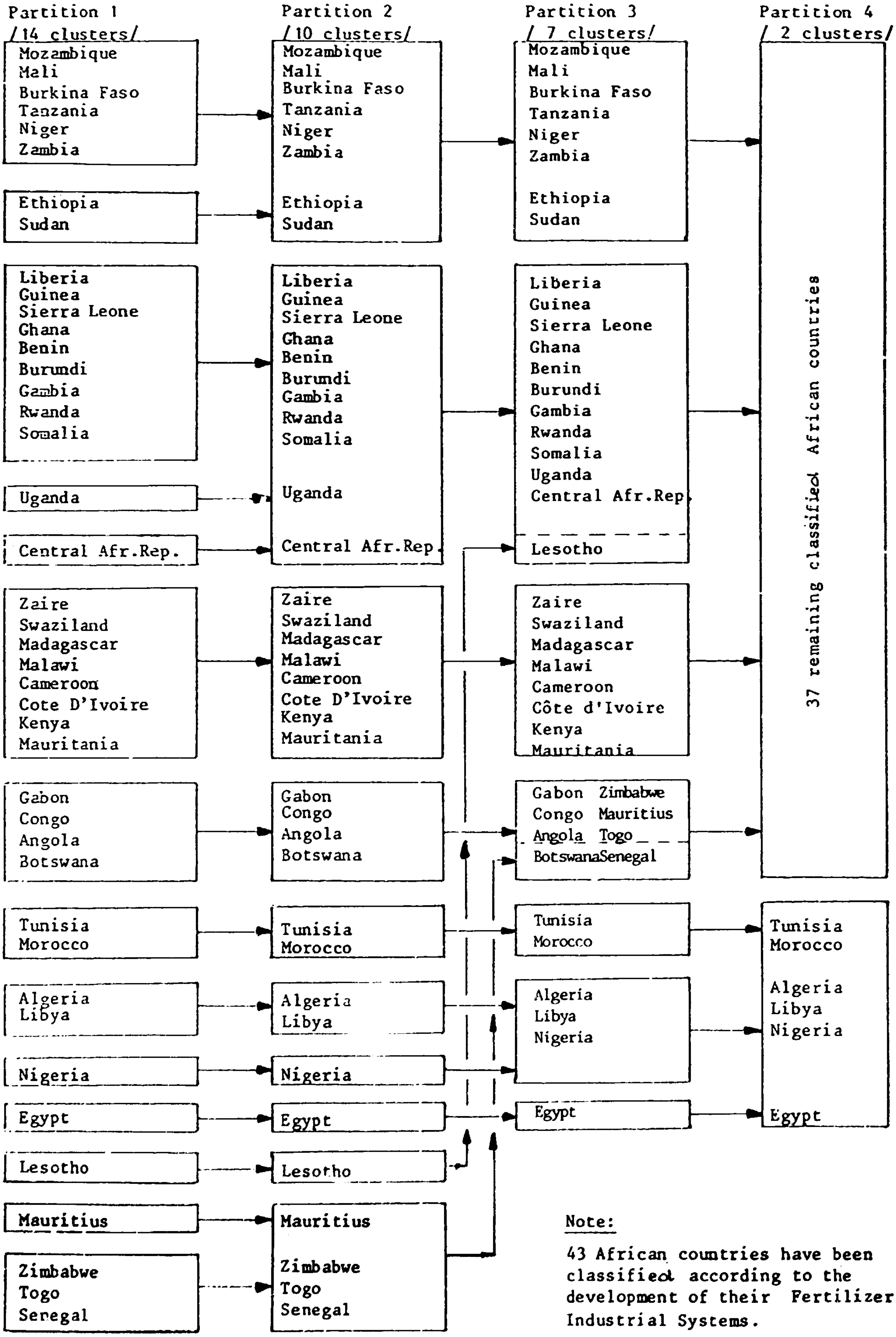
---

4.2 Characteristics of the development patterns

Below is a short description of the 10 country-groups. All twelve FERTIS components are addressed in the description of country group 1. In subsequent country groups, only those components are described the readings on which serve to differentiate that country group from the others. Profiles illustrating the pattern of development of each country group across the FERTIS components are presented in figure 4.3. A point plotted near the vertical line indicates that for the countries of that group the variable reading is, on average, equal to the average reading on the same variable for all forty three countries.

Figure 4.1

STEPS IN THE CLUSTER ANALYSIS USING 30 FERTIS VARIABLES

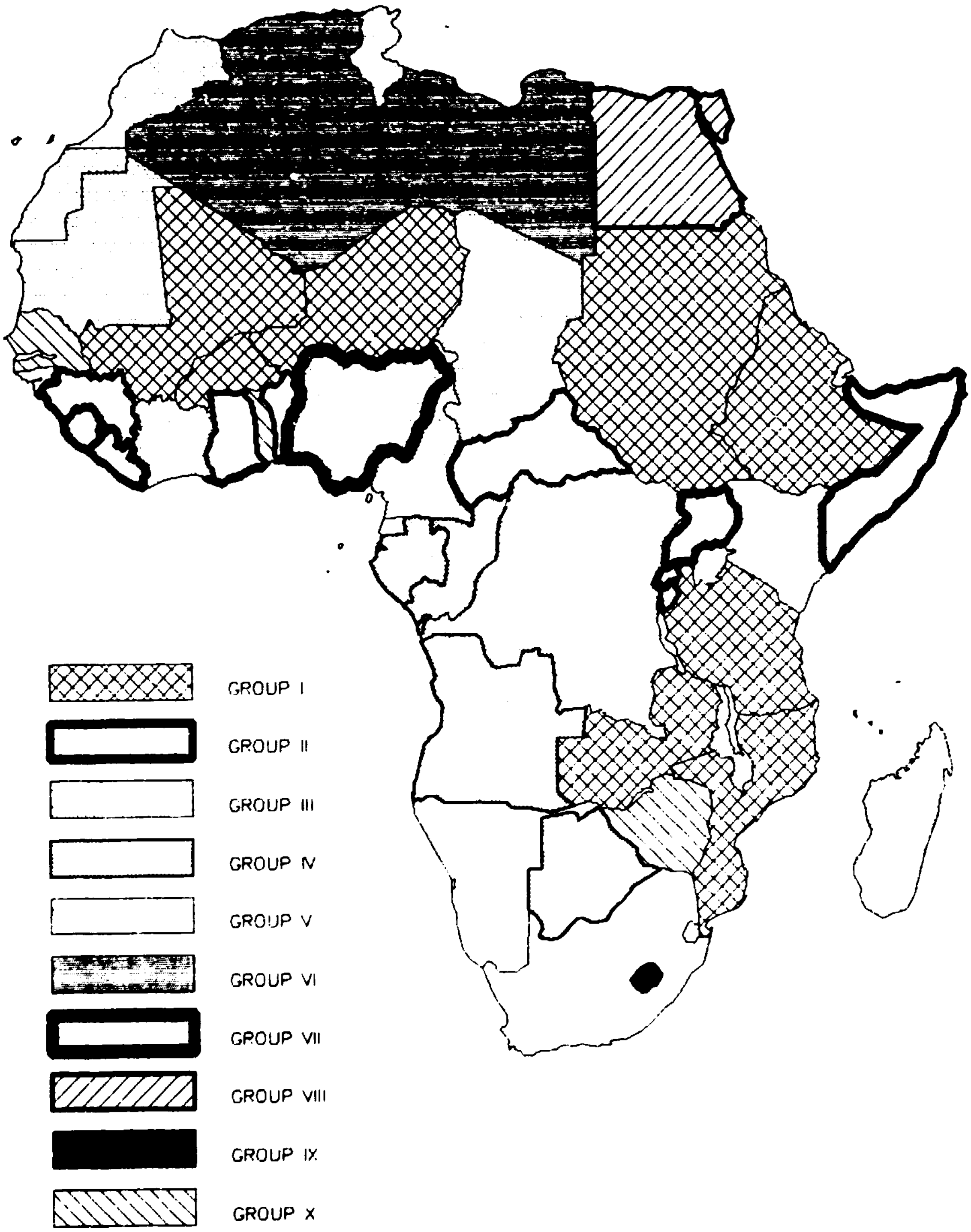


Note:

43 African countries have been classified according to the development of their Fertilizer Industrial Systems.

Figure 4.2

TEN COUNTRY GROUPS IDENTIFIED IN THE TYPOLOGY
OF THE FERTILIZER INDUSTRY IN AFRICA



SOURCE: UNIDO, 1989

Figure 4.3

FERTILIZER INDUSTRIAL SYSTEM IN AFRICA
PATTERNS OF DEVELOPMENT OF COUNTRY GROUPS

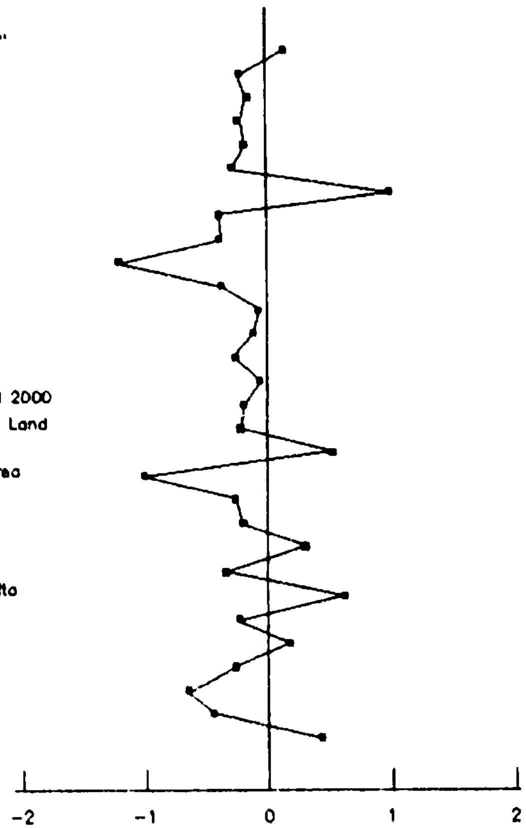
COMPONENTS

- I. NATURAL RESOURCES
- II. PROCESSING TO INTERMEDIARY PRODUCTS
- III. PROCESSING TO NPK FERT.
- IV. OTHER OPERATIONS
- V. INDUSTRIAL INPUTS AND SERVICES
- VI. STORAGE, TRANSPORT AND DISTRIBUTION
- VII. CONSUMPTION OF NPK FERTILIZERS
- VIII. DEMAND FOR FERTILIZERS YEAR 2000
- IX. FERTILIZER APPLICATION IN AGRICULTURE
- X. FERTILIZER IMPACT ON AGRICULTURAL PRODUCTION
- XI. GOVERNMENTAL POLICIES
- XII. GOVERNMENTAL STRATEGY AND PRIORITY IN FERTIS

VARIABLES

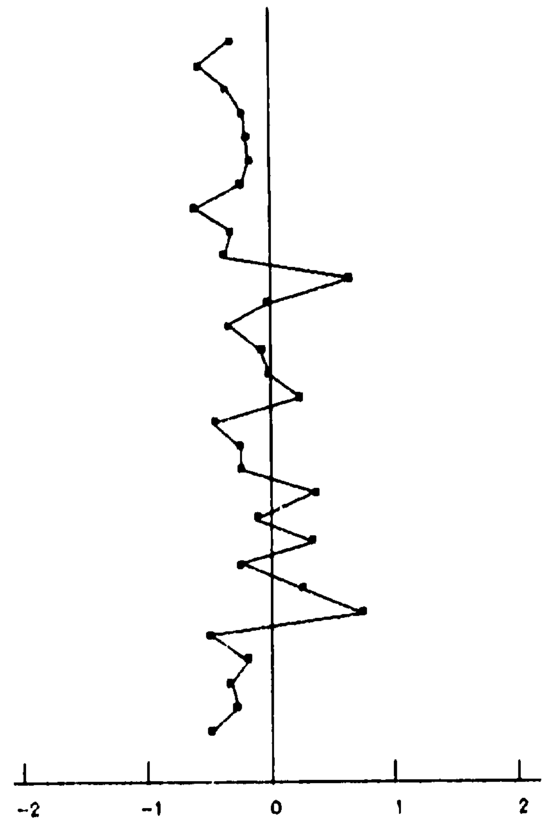
1. Strenght of raw material "environment"
2. Capacity utilization in A and PA plants
3. Ammonia total capacity
4. Phosphoric Acid total capacity
5. Import of Sulphur
6. Production of NPK fertilizers
7. Existence of BB, CG, PRG Plants
8. Total Energy self-sufficiency
9. Energy consumption per capita
10. Total Area of the country
11. Infrastructure and Transport Network
12. Consumption of NPK
13. P:N ratio in fertilizer consumption
14. K:N ratio in fertilizer consumption
15. Forex needed to fill the NPK gap
16. Consumption of NPK as % of Demand 2000
17. Consumption of NPK per ha of Arable Land
18. Arable Land with Permanent Crops
19. Share of Arable Land in Agriculture Area
20. Population suporting capacity of land
21. Effectiveness of fertilizer use
22. Population 2000
23. GDP 2000
24. Net balance of Cereals 2000 per capita
25. Incentive to use fertilizers
26. Import of NPK fertilizers
27. Export of NPK fertilizers
28. Export of N related raw materials
29. Export of P related raw materials
30. Governmental Strategy in FERTIS

GROUP I.



FERTILIZER IMPORT SUBSTITUTING COUNTRIES

GROUP II.



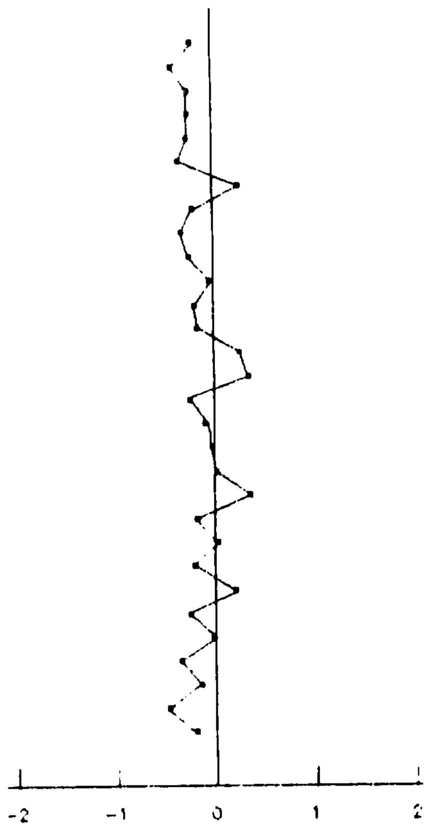
LITTLE CONSUMPTION WITH PROPER POLICIES IN FERTILIZER APPLICATION

Figure 4.3 (cont.)

FERTILIZER INDUSTRIAL SYSTEM IN AFRICA
PATTERNS OF DEVELOPMENT OF COUNTRY GROUPS

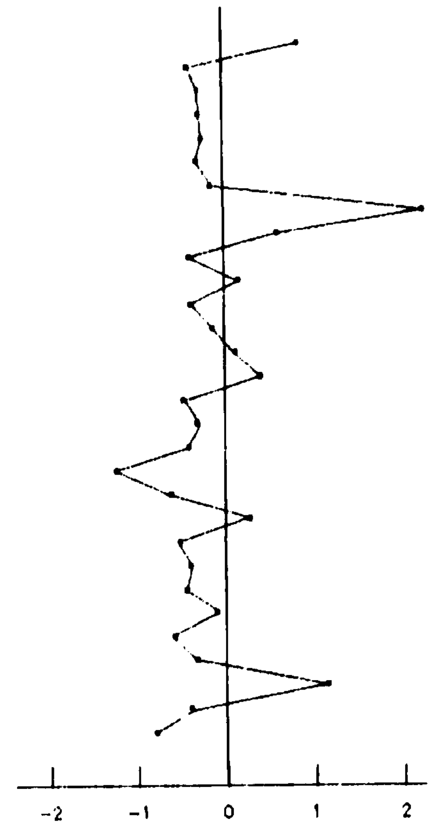
COMPONENTS		VARIABLES
NATURAL RESOURCES	1	Strenght of raw material "environment"
II. PROCESSING TO INTERMEDIARY PRODUCTS	2	Capacity utilization in A and PA plants
	3	Ammonia total capacity
	4	Phosphoric Acid total capacity
	5	Import of Sulphur
III. PROCESSING TO NPK FERT	6	Production of NPK fertilizers
IV. OTHER OPERATIONS	7	Existence of BB, CG, PRG Plants
V. INDUSTRIAL INPUTS AND SERVICES	8	Total Energy self-sufficiency
	9	Energy consumption per capita
VI. STORAGE, TRANSPORT AND DISTRIBUTION	10	Total Area of the country
	11	Infrastructure and Transport Network
VII. CONSUMPTION OF NPK FERTILIZERS	12	Consumption of NPK
	13	P:N ratio in fertilizer consumption
	14	K:N ratio in fertilizer consumption
VIII. DEMAND FOR FERTILIZERS YEAR 2000	15	Forex needed to fill the NPK gap
	16	Consumption of NPK as % of Demand 2000
IX. FERTILIZER APPLICATION IN AGRICULTURE	17	Consumption of NPK per ha of Arable Land
	18	Arable Land with Permanent Crops
	19	Share of Arable Land in Agriculture Area
	20	Population supporting capacity of land
X. FERTILIZER IMPACT ON AGRICULTURAL PRODUCTION	21	Effectiveness of fertilizer use
	22	Population 2000
	23	GDP 2000
	24	Net balance of Cereals 2000 per capita
XI. GOVERNMENTAL POLICIES	25	Incentive to use fertilizers
XII. GOVERNMENTAL STRATEGY AND PRIORITY IN FERTIS	26	Import of NPK fertilizers
	27	Export of NPK fertilizers
	28	Export of N related raw materials
	29	Export of P related raw materials
	30	Governmental Strategy in FERTIS

GROUP III.



FERTIS DEVELOPMENT IN LINE WITH AFRICAN MEAN VALUES

GROUP IV.



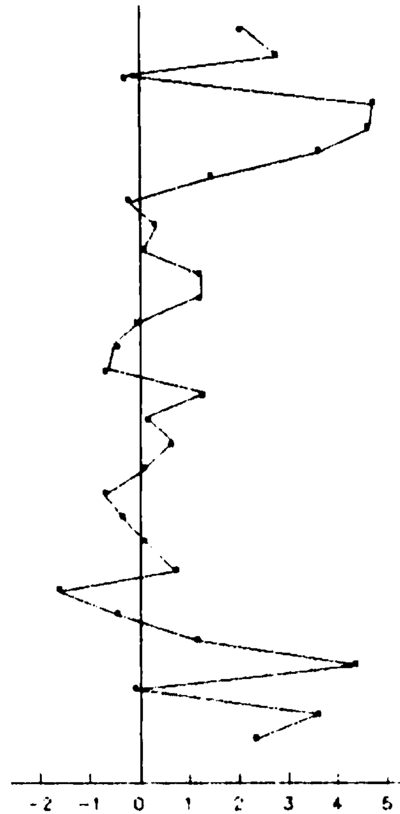
STRONG IN ENERGY AND POTASH/NITROGEN RELATED NATURAL RESOURCES

Figure 4.3 (cont.)

FERTILIZER INDUSTRIAL SYSTEM IN AFRICA
PATTERNS OF DEVELOPMENT OF COUNTRY GROUPS

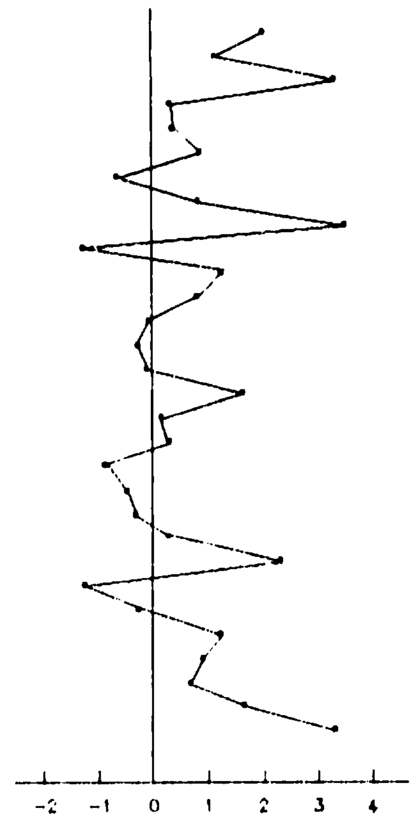
COMPONENTS	VARIABLES
I NATURAL RESOURCES	1. Strenght of raw material "environment"
II PROCESSING TO INTERMEDIARY PRODUCTS	2 Capacity utilization in A and PA plants
	3 Ammonia total capacity
	4. Phosphoric Acid total capacity
	5. Import of Sulphur
III PROCESSING TO NPK FERT.	6. Production of NPK fertilizers
IV OTHER OPERATIONS	7 Existence of BB, CG, PRG Plants
V INDUSTRIAL INPUTS AND SERVICES	8. Total Energy self-sufficiency
	9. Energy consumption per capita
VI STORAGE, TRANSPORT AND DISTRIBUTION	10 Total Area of the country
	11. Infrastructure and Transport Network
VII CONSUMPTION OF NPK FERTILIZERS	12. Consumption of NPK
	13. P:N ratio in fertilizer consumption
	14. K:N ratio in fertilizer consumption
VIII DEMAND FOR FERTILIZERS YEAR 2000	15. Forex needed to fill the NPK gap
	16 Consumption of NPK as % of Demand 2000
IX. FERTILIZER APPLICATION IN AGRICULTURE	17 Consumption of NPK per ha of Arable Land
	18 Arable Land with Permanent Crops
	19. Share of Arable Land in Agriculture Area
	20. Population suporting capacity of land
X. FERTILIZER IMPACT ON AGRICULTURAL PRODUCTION	21. Effectiveness of fertilizer use
	22 Population 2000
	23. GDP 2000
	24. Net balance of Cereals 2000 per capita
XI GOVERNMENTAL POLICIES	25 Incentive to use fertilizers
XII GOVERNMENTAL STRATEGY AND PRIORITY IN FERTIS	26. Import of NPK fertilizers
	27. Export of NPK fertilizers
	28 Export of N related raw materials
	29 Export of P related raw materials
	30 Governmental Strategy in FERTIS

GROUP V.



EXPORT ORIENTED IN PHOSPHATE FERTILIZERS

GROUP VI.



EXPORT ORIENTED IN NITROGEN RELATED RAW MATERIALS

Figure 4.3 (cont.)

FERTILIZER INDUSTRIAL SYSTEM IN AFRICA
PATTERNS OF DEVELOPMENT OF COUNTRY GROUPS

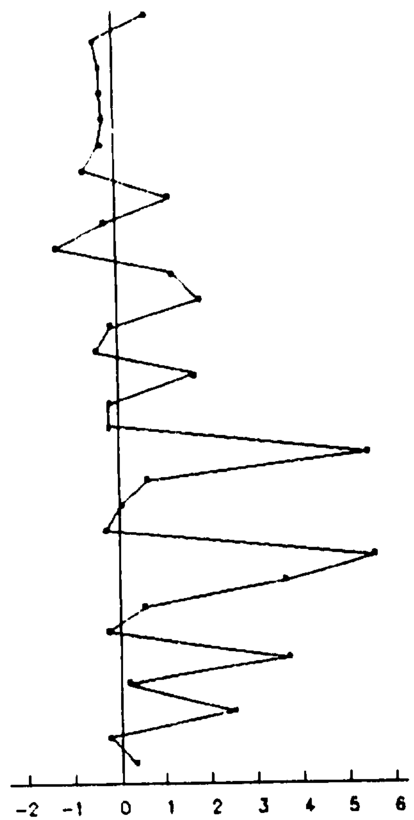
COMPONENTS

I NATURAL RESOURCES
II. PROCESSING TO INTERMEDIARY PRODUCTS
III PROCESSING TO NPK FERT.
IV OTHER OPERATIONS
V INDUSTRIAL INPUTS AND SERVICES
VI STORAGE, TRANSPORT AND DISTRIBUTION
VII. CONSUMPTION OF NPK FERTILIZERS
VIII. DEMAND FOR FERTILIZERS YEAR 2000
X. FERTILIZER APPLICATION IN AGRICULTURE
X FERTILIZER IMPACT ON AGRICULTURAL PRODUCTION
X GOVERNMENTAL POLICIES
XII. GOVERNMENTAL STRATEGY AND PRIORITY IN FERTIS

VARIABLES

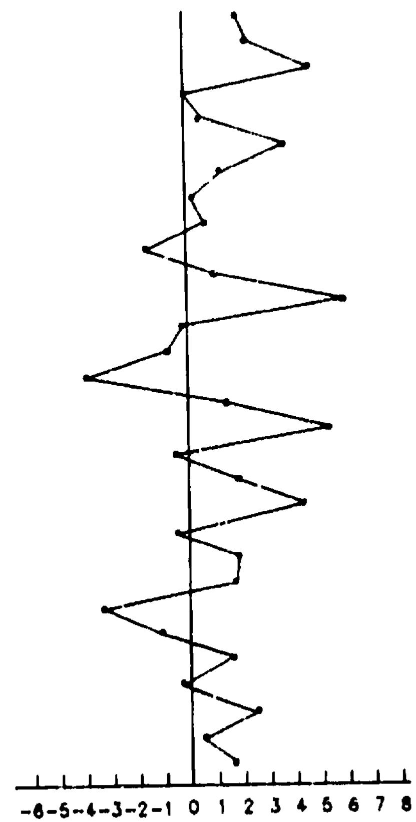
1. Strenght of raw material "environment"
2. Capacity utilization in A and PA plants
3. Ammonia total capacity
4. Phosphoric Acid total capacity
5. Import of Sulphur
6. Production of NPK fertilizers
7. Existence of BB, CG, PRG Plants
8. Total Energy self-sufficiency
9. Energy consumption per capita
10. Total Area of the country
11. Infrastructure and Transport Network
12. Consumption of NPK
13. P:N ratio in fertilizer consumption
14. K:N ratio in fertilizer consumption
15. Forex needed to fill the NPK gap
16. Consumption of NPK as % of Demand 2000
17. Consumption of NPK per ha of Arable Land
18. Arable Land with Permanent Crops
19. Share of Arable Land in Agriculture Area
20. Population suporting capacity of land
21. Effectiveness of fertilizer use
22. Population 2000
23. GDP 2000
24. Net balance of Cereals 2000 per capita
25. Incentive to use fertilizers
26. Import of NPK fertilizers
27. Export of NPK fertilizers
28. Export of N related raw materials
29. Export of P related raw materials
30. Governmental Strategy in FERTIS

GROUP VII.



STRONG DEMAND FOR NPK FERTILIZERS

GROUP VIII.



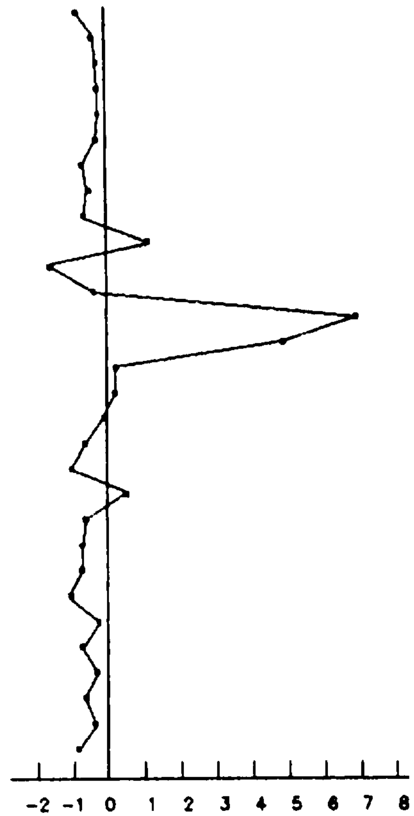
HIGH FERTILIZATION RATES WITH SELF-SUFFICIENCY IN FERTIS

Figure 4.3 (cont.)

FERTILIZER INDUSTRIAL SYSTEM IN AFRICA
PATTERNS OF DEVELOPMENT OF COUNTRY GROUPS

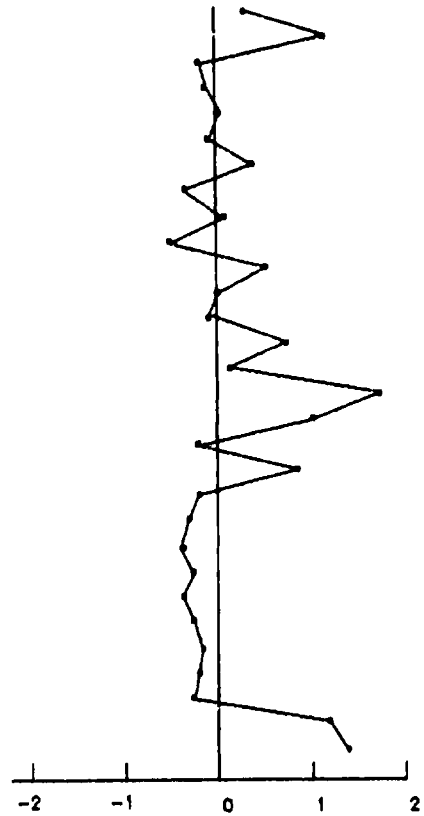
COMPONENTS		VARIABLES
I. NATURAL RESOURCES	1.	Strenght of raw material "environment"
II. PROCESSING TO INTERMEDIARY PRODUCTS	2.	Capacity utilization in A and PA plants
	3.	Ammonia total capacity
	4.	Phosphoric Acid total capacity
	5.	Import of Sulphur
III. PROCESSING TO NPK FERT.	6.	Production of NPK fertilizers
IV. OTHER OPERATIONS	7.	Existence of BB, CG, PRG Plants
V. INDUSTRIAL INPUTS AND SERVICES	8.	Total Energy self-sufficiency
	9.	Energy consumption per capita
VI. STORAGE, TRANSPORT AND DISTRIBUTION	10.	Total Area of the country
	11.	Infrastructure and Transport Network
VII. CONSUMPTION OF NPK FERTILIZERS	12.	Consumption of NPK
	13.	P:N ratio in fertilizer consumption
	14.	K:N ratio in fertilizer consumption
VIII. DEMAND FOR FERTILIZERS YEAR 2000	15.	Forex needed to fill the NPK gap
	16.	Consumption of NPK as % of Demand 2000
IX. FERTILIZER APPLICATION IN AGRICULTURE	17.	Consumption of NPK per ha of Arable Land
	18.	Arable Land with Permanent Crops
	19.	Share of Arable Land in Agriculture Area
	20.	Population suporting capacity of land
X. FERTILIZER IMPACT ON AGRICULTURAL PRODUCTION	21.	Effectiveness of fertilizer use
	22.	Population 2000
	23.	GDP 2000
	24.	Net balance of Cereals 2000 per capita
XI. GOVERNMENTAL POLICIES	25.	Incentive to use fertilizers
XII. GOVERNMENTAL STRATEGY AND PRIORITY IN FERTIS	26.	Import of NPK fertilizers
	27.	Export of NPK fertilizers
	28.	Export of N related raw materials
	29.	Export of P related raw materials
	30.	Governmental Strategy in FERTIS

GROUP IX.



EXCEPTIONAL IN NPK CONSUMPTION RATIO

GROUP X.



PRINCIPAL SUB-SAHARAN FERTILIZER PRODUCERS

4.3 Country groups

4.3.1 Group I

This group includes eight countries located in four geographical regions: West Africa, North-East Africa, East Africa and Southern Africa. These countries also belong to three of the agro-ecological regions described by FAO 15/, namely Sudano-Sahelian Africa, Subhumid and Mountainous East Africa, Subhumid and Semi-Arid Southern Africa. Four countries are land-locked (Mali, Burkina Faso, Niger and Zambia) and four are either partly land-locked (Sudan, Ethiopia) or have a sea-side location (Tanzania, Mozambique).

The group possesses all FERTIS related natural resources, covering the whole nitrogen, phosphorous, sulphur and potassium range. However, the lack of a developed mining industry hinders the exploitation of these raw materials. Tanzania and Mozambique have huge deposits of sulphur-free natural gas. Tanzania, Burkina Faso and Niger currently produce phosphate rock and the latter two countries have good prospects for the development of phosphates due to the size and quality of phosphate rock deposits. Zambia is well endowed with sulphur related raw material. Ethiopia has potash deposits, huge reserves of good quality sylvinite and substantial amounts of carnallite. Both sylvinite and carnallite have good prospects for future development.

In component two, processing of intermediary products (ammonia and phosphoric acid) is limited in Zambia and Tanzania. Both countries face serious problems in maintaining a high on-stream factor in ammonia and phosphoric acid units. Capacity utilization is low and there is a great need for the rehabilitation of existing facilities. Prospects are promising however for the development of ammonia production in Tanzania and Mozambique, as well as Sudan.

In component three, processing of NPK fertilizers has been developed in four countries of group I but is maintained only in Zambia and Tanzania. The Zambian coal-based complex at Kafue is currently under rehabilitation. The Tanzanian phosphate fertilizer complex at Tanga experiences bottlenecks due to a sulphuric acid plant that must be replaced. Modernization and rehabilitation of the complex depends only on project financing. The Sudanese nitrogen ammonia/urea complex near Khartoum lies idle as Sudan faces severe fuel shortages. A new ammonia/urea complex near Port Sudan based on natural gas is under consideration and forms part of a government development programme. Mali, Niger and Burkina Faso are producers of ground and partially acidulated phosphate rock but not phosphate fertilizers.

In component four, relating to other operations connected with the fertilizer industry, group I is the strongest. As is seen in the development profile (figure 4.1), the variable reading on component four is well above the African average. Group I has around half the bulk-blending, granulation compounding, ground phosphate rock facilities found in the countries studied. This indicates both a high fertilizer demand and that the countries of this group are attempting to increase domestic supply. The fifth component relates to the energy sector. A reliable supply of electricity is one of the most important factors to be considered in the development of the fertilizer industry. All countries of this group produce or plan to produce

15/ Atlas of African Agriculture, page 8, FAO, Rome 1986.

hydro-electricity due to their good hydro-electricity potential. However, the group is weak on energy self-sufficiency and energy consumption per capita.

Storage, transport and distribution, component six, are quantified by two variables, country area and distribution related infrastructure. Group I countries are here characterized by a large area and a relatively weak distributional network. This component should be considered one of the group's bottlenecks.

In component seven, as is seen from the development profile, fertilizer consumption is on an average level for the forty three countries. The size of the fertilizer market varies between countries, Niger being the smallest consumer and Sudan and Zambia the largest. The phosphorous/nitrogen ratio is average for the countries studied at around 5:1, although extremes exist in Sudan and Ethiopia. The potassium/nitrogen ratio is similar to that of group VI (Algeria, Libya) although considerable intra-group differences exist.

Component eight relates to projected demand for fertilizers in the year 2000. This group has an average sized demand for fertilizers, estimated at approximately 810,000 mt. Production in 1986 was 25,000 mt of NPK and hence the NPK gap is approximately 785,000 mt. While the foreign exchange needed to cover the NPK gap is of average size it represents a heavy burden for countries such as Sudan, Tanzania and Mozambique.

Fertilizer application, the ninth component, is measured by the consumption of NPK per hectare of arable land with permanent crops, the share of arable land in agricultural area and the population supporting capacity of the land. Consumption of NPK per hectare of arable land is below the African average figure. Arable land potential is the highest of all the groups (a high potential is considered to exist when both the share of arable land in agricultural area is low and the area of arable land under permanent cultivation is high). This factor should be considered an enhancement for FERTIS development. On the other hand this group is also characterized by a share of arable land in the agricultural area that is higher only than that of IV. This factor implies that there is still scope for an increase of arable land, and thus that a potential option exists for extensive rather than intensive agricultural development. The population pressure on land in Zambia, Sudan and Niger is lower than average at 3.12 persons per hectare of arable land. Pressure on land in Ethiopia, Mali,Tanzania and especially Mozambique is above average and should be considered an enhancement to FERTIS development in these latter countries.

Four variables are used in component ten to measure the impact of fertilizer use on agricultural production. Effectiveness of fertilizer use, in terms of kilogrammes of cereals produced per kilogramme of NPK used, is below average for the forty three countries and is not an enhancement to FERTIS development.

With the projected population in the year 2000 higher than average and projected GDP in the year 2000 below average (i.e. GDP per capita considerably below average), this group is expected to have the most limited capacity to supply inputs to agriculture. Nevertheless the group has good prospects for maintaining or improving food self-sufficiency by the year 2000. As can be clearly seen from the development profile, the projected net balance of cereals per capita by the year 2000 shows the most positive trend of any of the groups.[16/]

The incentive to use fertilizers by farmers, component eleven, is lower than the average. This is a constraint on increased fertilizer consumption.

Component twelve relates to government strategy and priority and is characterized by five variables. Apart from Nigeria, group I countries are the biggest importers of fertilizers in Sub-Saharan Africa. Government strategy in FERTIS focuses on import substitution and is an enhancement to FERTIS development. Countries of group I are neither exporters of NPK fertilizers, nor exporters of nitrogen or phosphate related raw materials, since both the fertilizer industry and the fertilizer related raw material base are not yet developed.

4.3.2 Group II

This group includes eleven countries from three geographical regions: West Africa, Central Africa and East Africa. Raw material endowment is poorer than in group I, and is limited to phosphorous and nitrogen related natural resources. A reading below the African average figure is seen on the development profile for group II. No readily explorable sulphur or potash deposits are known of. Rwanda, Ghana and Guinea possess nitrogen related raw materials, while Uganda, Benin and Burundi have phosphorous related raw materials.

There are no processing facilities for intermediary products, ammonia and phosphoric acid, apart from the idle ammonia/urea nitrogen complex in Somalia. Plans and projects related to fertilizer production development in Uganda, Burundi and Rwanda are preliminary and on a small scale. No bulk-blending, compound-granulation, phosphate rock grinding plants are reported to operate in this group.

No country of group II is energy self-sufficient. Ghana and Uganda perform best, with self-sufficiency rates of 36% and 18% respectively. However, both countries are self-sufficient in and net exporters of electricity. Energy consumption per capita in group II is moderate. Liberia and Ghana lead with consumption of around 150 kg of oil equivalent per capita.

The share of arable land in agricultural area is higher here than in groups I, III, IV, VI and IX. This indicates a need to introduce more intensive agricultural methods, with more emphasis on increased yields, and thus higher future rates of fertilization.

As is seen in the development profile, the effectiveness of fertilizer use is higher in group II than in any other group. Although GDP per capita is relatively low, the projected net balance of cereals per capita by 2000 is positive. It is likely that most of the countries of group II will improve their food self-sufficiency. Somalia, Rwanda and Burundi are likely to face shortages due to a lack of foreign exchange.

16/ Projected net balance of cereals per capita by the year 2000 is expressed on the development profiles of each group relative to the African mean figure. This does not imply that the projected balance is positive in absolute terms, in fact only Zimbabwe, Sudan and Malawi have a positive net balance in absolute terms.

The incentive to use fertilizers is greater than in any other group. Imports of NPK fertilizers equals NPK consumption, and is relatively low. Export of fertilizers and related raw materials is minimal. Government strategy in FERTIS involves imports of fertilizers and supportive price policies.

This group should be considered as giving low priority to FERTIS development, although having proper policies in the promotion of fertilizer consumption. Consumption of NPK fertilizers per hectare of arable land is rather low in group II, but shows considerable intra-group variation. Gambia applies 23 kg of NPK per hectare while Uganda, Central African Republic and Guinea, applied less than 1 kg of NPK per hectare in 1986.

4.3.3 Group III

This group includes nine countries from six geographical regions: North-West Africa, West Africa, Central Africa, East Africa, Southern Africa, and the African Islands of the Indian Ocean.

The natural resource base is richer than that of group II, but poorer than that of group I, because it is limited to nitrogen, phosphorous and sulphur related raw materials. No potash deposits are known of.

This group has only limited production facilities. Only Madagascar in group III has a processing facility to ammonia, although this has never become operational. No phosphoric acid plants operate in this group. Côte d'Ivoire is the only producer of NPK fertilizers, but produces, using imported ammonia and sulphur, on a very small scale (around 4,000 MTPY of NPK). Swaziland produced up to 5,000 MTPY of nitrogen during the period 1979-83 although the nitrogen complex is currently being converted into a paper mill. There are four bulk-blending, compound-granulation facilities; in Malawi, Swaziland, Kenya and Côte d'Ivoire.

Energy self-sufficiency varies markedly within the group. Cameroon, Zaire and Côte d'Ivoire are self-sufficient in primary energy and electricity while Chad and Mauritiana are totally dependent on imports of energy. As a whole, group III ranks higher in energy self-sufficiency and energy consumption per capita than groups I and II.

Total country area in group III is near the average reading and storage, transport and distribution of fertilizers are difficult, especially in Zaire, Chad and Mauritiana. General infrastructure and transport facilities are of an average level.

When compared to the foreign trade net balance, the foreign exchange needed to fill the gap between NPK demand in the year 2000 and production in 1986 indicates a lower foreign exchange burden than in group I. Consumption of NPK per ha of arable land is slightly lower than average but varies greatly between countries from as high as 50 kg of NPK per hectare in Kenya and Swaziland to as low as 1-2 kg of NPK per hectare in Chad, Zaire and Madagascar.

Arable land potential is average for the forty three countries. The share of arable land in agricultural area has an average reading. Intra-group variation is again marked. The population supporting capacity of the land is high, and lower only than in group VIII (Egypt). The pressure on arable land however is also high at 9.7 and 8.8 persons per hectare of arable land. This compares to an average figure of 3.1 for the countries studied.

Fertilizer impact on agricultural production shows features similar to those of group I, although with less extreme readings. The effectiveness of fertilizer use is below average as is GDP per capita. The net balance of cereals 2000 per capita is, however, positive for the whole group. Cameroon, Zaire, Swaziland and Madagascar are expected to maintain or improve their food self-sufficiency by the year 2000. Kenya, Chad and Mauritania, with declining food self-sufficiency and foreign exchange shortages, particularly in Kenya and Chad, may face food shortages.

Government policies and strategy are similar to that of group I, the only difference being with regard to the export of nitrogen related raw materials, as both Cameroon and Zaire are medium scale exporters of crude oil. All the other variables in components 11 and 12 are similar to those of group I. There is a negative index expressing the incentive to use fertilizers. Government strategy involves import substitution, although this has met with little success.

In sum, the values on FERTIS variables in group III are nearer to the all Africa mean readings than for any other group.

4.3.4 Group IV

This group includes four countries located in two geographical regions: Central Africa and Southern Africa.

The group's raw material base is richer than in groups I, II and III. Natural resource endowments include all FERTIS related nitrogen, phosphorous, potassium and sulphur raw materials. Angola, Congo and Gabon are natural gas and crude oil producers and Botswana has deposits of coal. Phosphate deposits are located in Angola, Congo and Gabon, while sulphur bearing raw materials exist in Botswana, Angola and possibly in Congo and Gabon. Potash deposits of great value exist in the Congo and Botswana. Africa is deficient in potash ores. Carnallite resources are estimated at 30 million tons, equivalent to 5 million tons of K2O.

There are no ammonia or phosphoric acid plants in group IV, although Angola is studying the possibility of constructing an export-oriented world-scale ammonia-urea complex. Apart from some past production in the Congo, there is no production of NPK fertilizers in this group. Small phosphate rock grinding facilities operate in Angola.

As is evident from the development profile, group IV is very strong in total energy self-sufficiency. This is due to the production of crude oil. Energy self-sufficiency in Angola, Congo and Gabon is in the range of 1000% to 2000%. All the countries of this group are self-sufficient in electricity. Energy consumption per capita in 1986 was as high as: 1141, 225, 430 and 202 kg of oil equivalent in Gabon, Congo, Botswana and Angola respectively.

Country area is below average while the infrastructure and transport network is somewhat better than average. Angola and Botswana are weaker in this component than Gabon and Congo. The latter countries have the additional enhancement of navigable rivers.

Consumption of NPK fertilizers is very low, the limited market being a great constraint on future development. Projected NPK demand for the year 2000 is also low. Projected NPK demand in the year 2000 is equal to around 70% of consumption in 1986. This group will be better placed to import fertilizers than many other groups due to a greater foreign exchange availability, mostly derived from exports of crude oil and diamonds.

Consumption of NPK fertilizers per hectare of arable land is below the average (16 kg of NPK/ha) at 6 kg of NPK/ha in Congo and below 1 kg of NPK/ha in Botswana. The share of arable land with permanent crops is also below average. A particular characteristic of this group is an average share of arable land in agricultural area of around 7.2% (the Africa average is 22%). Population pressure on arable land is also relatively low. These factors may act as constraints to FERTIS development.

Due to low consumption, the effectiveness of fertilizer use is higher than average. The projected net balance of cereals per capita by the year 2000 is negative. However, with GDP 2000 closer to the average than population 2000 this group of countries may experience declining food self-sufficiency while having adequate foreign exchange to import their food needs.

Fertilizer imports are low and equal to consumption of NPK. There is no export of fertilizers, nor phosphorous related raw materials. However, there are significant exports of nitrogen related raw materials such as crude oil which, together with a good natural resource base and energy potential, is the most outstanding feature of group IV.

Government strategy is set on imports of fertilizers. However, there are indications of export-oriented plans in Angola, Congo and Botswana.

Group IV can be described as strong in energy, potassium and nitrogen natural resources. While this provides good prospects for future development, it is unlikely that the fertilizer industry will develop significantly in this group in the short term.

4.3.5 Group V

Tunisia and Morocco belong to this group and are well endowed with relevant natural resources. The phosphate rock deposits belong to the largest in the world. Production of phosphate rock in Tunisia and Morocco amounted to 77% of the total of all forty three African countries and 20% on a world scale. Group V is also moderately endowed with nitrogen related raw materials, natural gas and crude oil. Sulphur bearing raw materials in Morocco, and potash brines from lake Zarzis in Tunisia further reflect the diversified raw material base.

As is strikingly illustrated in the development profile, a very high phosphoric acid capacity - approximately 2.8 million MTPY of phosphorous (P205) - and a capacity utilization rate of around 80% are distinguishing features of this group. No ammonia plants operate in Tunisia or Morocco, although large amounts of MAP/DAP fertilizers are produced from imported ammonia. This group leads in production of NPK fertilizers, producing in 1986 over 50% of the total production of the forty three countries. In phosphate fertilizers the group accounts for 77% of output from the countries studied.

Tunisia and Morocco also operate ground phosphate rock plants.

Both countries have levels of energy and electricity production close to and beyond self-sufficiency and energy consumption per capita is above average. The factors best considered enhancements are that medium sized country areas combine with a well developed infrastructure and transport network. Furthermore, the markets of both countries are considerable, representing together almost 16% of African NPK consumption.

NPK production in 1986 far exceeds NPK demand in the year 2000. Despite the considerable size of domestic production, substantial amounts of foreign exchange will be necessary either for imports of NK fertilizers, or for investments in NK related fertilizer facilities.

Consumption of NPK fertilizers per ha of arable land is much higher than the average figure. Arable land and permanent crops area indicate a higher than average agricultural potential. This may act against the introduction of more intensive agricultural production methods.

These countries are net exporters of fertilizers. Exports of phosphorous related raw materials are significant, particularly in Morocco. Government strategy in FERTIS involves export promotion. Group V may be characterized as being export oriented in phosphate fertilizers.

4.3.6 Group VI

Group VI comprises Algeria and Libya and is very well endowed with relevant natural resources, especially nitrogen related raw materials such as natural gas and crude oil. Algeria is the largest African producer of natural gas, liquefied natural gas and liquefied petrochemical gas, and is at the same time the fourth largest producer of crude oil in Africa after Nigeria, Libya and Egypt. Around 5-6% of world natural gas reserves are found in this group. Phosphate rock production in Algeria is around 1.2 million MTPY of concentrate. Pyrites are also produced in Algeria. Libya does not produce phosphate rock. Both countries may in future be able to recover sulphur from oil and natural gas. Limited quantities of potash reserves exist in both countries but are not exploited at present.

Total ammonia capacity in 1986 in Algeria and Libya was estimated at 1.36 million mt of nitrogen although capacity utilization rates are only 40% on average. This group has very good potential in ammonia manufacturing. Only Algeria produces phosphoric acid but again at low levels of capacity utilization. Algeria is Africa's third largest sulphuric acid producer after Morocco and Tunisia, with a capacity utilization rate above 50%. Algeria and Libya account for 15% of the fertilizers produced in the forty three countries.

Domestic energy supply exceeds domestic energy requirements in the order of four times for Algeria and almost six times in Libya. Algeria and Libya are self-sufficient in electricity, and have very high energy consumption per capita at 1034 kg and 2259 kg of oil equivalent respectively in 1986.

Consumption of 270,000 mt of NPK in Algeria and 40,000 mt in Libya during 1986 indicates that group VI is a large consumer of fertilizers in comparison with Sub-Saharan countries. In Libya, consumption has declined from almost

100,000 MTPY in 1983/84. It should be underlined that Algeria is a net importer and Libya a net exporter of fertilizers, a fact closely related to capacity utilization rates.

The gap between demand 2000 minus production 1986 is connected for Algeria with nitrogen, phosphorous and potassium fertilizers, while for Libya only with phosphorous and potassium fertilizers. Algeria may face difficulties to close the gap unless special measures are undertaken to increase capacity utilization rates in fertilizer plants and/or diversify and/or increase present sources of export revenue. Consumption of NPK per hectare of arable land is higher than the African average.

The share of arable land in the agricultural area is below average in this group. With demand for cereals in the year 2000 expected to rise significantly, substantial efforts may have to be made in favour of the agricultural sector. The incentive to use fertilizers by farmers is also negative, and pricing policy should be reviewed.

Imports of NPK fertilizers far exceed exports of fertilizers in group VI. Export of nitrogen related raw materials, such as natural gas and oil, as well as exports of intermediary products such as liquid ammonia, is the outstanding feature of the group. Group VI might be described as export oriented in nitrogen related raw materials.

4.3.7 Group VII

One country, Nigeria, makes up this group. Nigeria is the largest producer of crude oil and natural gas amongst the countries studied. Production of oil in 1986 amounted to about 75 million mt, the quota set by OPEC. Proven reserves of natural gas amount to 1200 billion cubic meters, and unproven reserves are estimated at around the same magnitude. This places Nigeria together with Libya in natural gas potential after Algeria. Hydrcarbons are the mainstay of the economy, accounting for a large proportion of foreign exchange earnings and government revenues. Nigeria is also endowed with coal reserves and small deposits of phosphate rock. The important complex at Onne was not operational in 1986 and so is not reflected in the development profiles. No bulk-blending, compound granulation or phosphate rock grinding plants are reported to operate in Nigeria.

Self-sufficiency in total energy and in electricity amounts to 643% and 105% respectively. Constraints in storage, transport and distribution of fertilizers, due to country size, are compensated by a relatively well developed infrastructure and transport network, including raw mate[illegible] fertilizer handling facilities in sea-ports at Port Harcourt and La[illegible]

Nigeria presents a large market for fertilizers. Consumption of NPK in 1986 amounted to around 11% of the African total. With an NPK demand in the year 2000 estimated at 850,000 mt, two fertilizer complexes similar to that at Onne could be considered in Nigerian investment plans up to the year 2000.

In 1986 consumption of NPK per ha of arable land was 9.4 kg, below the average of 16 kg. This stems from considerable arable land potential in Nigeria. On the other hand, the share of arable land in the agricultural area is as high as 60%, which is to be taken into account when framing policies for food production increases, and, inter alia, FERTIS development.

With a projected population in 2000 of 164 million, an estimated surplus of cereals per capita in the year 2000, and a declining food self-sufficiency, a relatively strong Nigerian economy will have to support the development of the agricultural sector in order to avoid excessive expenditures on food imports.

As can be seen on the development profile, the incentive to fertilizer use is below average. The creation of superior cost/benefit ratios in favour of increased fertilizer consumption should be considered.

Government strategy involves import substitution and should in the future be directed towards the development of phosphorous and potassium related fertilizer facilities in order to complement the existing, and possibly expanding, nitrogen fertilizer industry. Nigeria is best characterised by its very high demand for NPK fertilizers.

4.3.8 Group VIII

Egypt comprises this group and is very well endowed with relevant raw materials, including nitrogen, phosphorous and sulphur components. Egypt is the third largest producer of crude oil amongst the countries studied. Output of natural gas equivalent is recorded at about 5 million MTPY. Egypt is the fifth largest phosphate rock producer in Africa after Morocco, Tunisia, Togo and Senegal.

Ammonia capacity in 1986 was 920,000 mt of nitrogen. A capacity utilization rate of around 66% compares to that of Libya and exceeds that in Algeria. Phosphoric acid capacity is low.

In 1986 only Tunisia recorded a higher level of NPK production than Egypt. Egypt provided 27% of NPK production from amongst the countries studied. Bulk-blending and phosphate rock grinding plants are also reported to operate.

Energy self-sufficiency stands at 195% and the country is self-sufficient in electricity. Energy consumption per capita in 1986 was 577 kg of oil equivalent, the fourth highest in Africa.

Egypt accounts for 30% of African consumption of fertilizers. The estimated NPK gap is substantial (around 800,000 MTPY). Egypt will find it difficult to close this gap. Consumption of NPK fertilizers per ha of arable land with permanent crops, 320 kg per ha in 1986, is the highest in Africa, and greater than the world average. This is the most outstanding facet of FERTIS development in Egypt and stems from a limited arable land potential and the highest index of irrigated land in Africa. A population pressure of 19.65 persons per ha of arable land is well above the average of 2.12, indicating a very intensive agriculture.

With declining food self-sufficiency and foreign exchange shortages, Egypt will be pressed to cover its needs.

The incentive to use fertilizers is below average and government policies aimed at improving cost/benefit ratios should be considered. The government strategy is set on fertilizer self-sufficiency. Egypt's distinguishing features in FERTIS are a high consumption of fertilizers, a high fertilization rate and a strategy aimed at fertilizers self-sufficiency.

4.3.9 Group IX

Lesotho forms this group. Lesotho's development profile is most like that of group II. No nitrogen, phosphate or potash related raw materials are reported. Possible phosphate deposits could in future be used for rock grinding and applied to soils on slopes and hills, where ground rock gives best results.

There are no bulk-blending, compound granulation, phosphate rock grinding plants or fertilizer production facilities in Lesotho. Although hydro-electricity generating plans are under consideration Lesotho is completely dependent for energy on South Africa. A relatively weak infrastructure and transport network in this mountainous country is a distributional constraint.

While the market for fertilizers is small in absolute terms it is significant by comparison with the other Sub-Saharan countries. A factor which distinguishes Lesotho from other country groups is an exceptional predominance of phosphates in the nitrogen/phosphorous/potassium ratio. Phosphates and then potash were consumed in preference to nitrogen, which is partly understandable in a mountainous country growing potatoes, fruits and vegetables. Less extreme ratios may be maintained in the future. Consumption of NPK fertilizers is totally based on imports from South Africa. There was no production of fertilizers in 1986. Consumption in 1986 is equal to 20% of the NPK demand in the year 2000. It is believed that Lesotho will be able to fill the NPK gap 2000 through imports.

The share of arable land in the agricultural area is 13%, indicating reserves of arable land, though the additional population supporting capacity of the land is low with over five persons per ha of arable land.

A negative net balance of cereals per capita is estimated for the year 2000 and, amongst other measures, the effectiveness of fertilizer use and the incentive to use fertilizers should be examined.

4.3.10 Group X

This group includes four countries: Senegal, Togo, Zimbabwe and Mauritius, located in three geographical regions, West Africa, Southern Africa and the African Islands of the Indian Ocean. The countries of this group also belong to four of the agro-ecological regions defined by FAO: Sudano-Sahelian Africa, Humid and Subhumid West Africa, Subhumid and Semi-Arid Southern Africa and Subhumid and Mountainous East Africa. The raw material endowment of this group varies considerably but is similar to that of group I, although with a somewhat better phosphates potential. Senegal has small deposits of crude oil and a small onshore gas deposit has recently been brought into production. In phosphate rock production Senegal ranks fourth amongst the countries studied and possesses reserves of 125 million tons of phosphate rock. There are no sulphur or potash deposits in Senegal.

Togo is one of the principal African exporters of phosphate rock. The phosphate industry in Togo is based on reserves of around 85 million tons of high grade product. Phosphate production, all of which is exported, totalled about 2.3 million tons in 1986. Development of a new mining site based on known reserves of rock at Dagbati depends on the project to build a phosphoric acid plant and associated fertilizer facilities in Togo. No sulphur or potash deposits are known to exist in Togo.

Zimbabwe has no crude oil or natural gas deposits, but has substantial reserves of gasifiable and good quality coal. There is great potential for future ammonia production. Zimbabwe currently uses hydroelectricity, water and atmospheric nitrogen to produce ammonia by water electrolysis on a small scale. Phosphate deposits will be sufficient for another thirty years. Domestic pyrites ensure more than thirty years production in the phosphate fertilizer industry. No potash deposits are known of in Zimbabwe. Mauritius is the only country of this group not endowed with FERTIS related natural resources. The only possibility that exists is to utilize electricity in order to produce ammonia by water electrolysis. Hydro, thermal and bagasse generated electricity production is adequate to supply the needs of an ammonia minifertilizer plant with a capacity of 5,000 MTPY of nitrogen. It should be noted that biomass from the sugar industry can also be processed to ammonia.

Zimbabwe is this group's only producer of ammonia, producing in a very efficient manner. Zimbabwe also produces phosphoric acid with a very good rate of capacity utilization. Senegal operates a phosphoric acid plant based on local phosphate rock and sulphuric acid produced from imported sulphur, although with a capacity utilization rate of about 65% due to limited foreign demand. Togo and Mauritius do not have ammonia or phosphoric acid plants. However, Togo plans to build a phosphoric acid based fertilizer complex and Mauritius processes imported ammonia for nitric acid and ammonium nitrate.

Zimbabwe, Senegal and Mauritius are producers of fertilizers. Zimbabwe is the largest producer with 121,000 MTPY of NP fertilizers in 1986, followed by Senegal and Mauritius. This group accounts for around 4-5% of total NPK production in the forty-three countries, but around 80% of Sub-Saharan African production and may thus be described as Sub-Saharan FERTIS leaders. Two compound granulation plants exist in Zimbabwe and one in Mauritius.

Energy self-sufficiency in the group is on an average level and should be reckoned a constraint on FERTIS development. None of the countries of this group is self-sufficient in energy, and energy imports vary from 25% in Zimbabwe to 90% in Mauritius and Togo. Only Mauritius is self-sufficient in electricity. Energy consumption per capita varies in the group, ranging through 517, 378, 116 and 52 kg of oil equivalent per capita in 1986 in Zimbabwe, Mauritius, Senegal and Togo respectively.

Group X possesses better than average infrastructure and transport facilities, with access to sea-ports. The fertilizer market of this group is of average size. The nitrogen/phosphorous/potassium ratio markedly favours potash. Consumption of NPK fertilizers per ha of arable land varies greatly, Mauritius having a very high fertilization rate of 237 kg of NPK per ha of arable land with permanent crops, Zimbabwe 57 kg, Togo 8 kg and Senegal 4 kg. The average for the group is considerably higher than that for the forty three countries.

Arable land potential is lower than the average. The population supporting capacity of the land is also below the African average, with the exception of Mauritius which has 9.7 persons per ha of arable land as compared with 3.1 persons per ha for all countries studied.

It is estimated, however, that the countries of group X will maintain their food self-sufficiency ratios by the year 2000 due to efficient economic management.

Imports of NPK fertilizers exceed exports in group X. Exports of nitrogen related raw materials are practically nonexistant. By contrast, export of phosphorous related raw materials is high. Togo, for example, exported about 0.8 million MT of P2O5 in phosphate rock in 1986.

Government strategy aims at self-sufficiency in fertilizer consumption through promotion of exports of raw materials and intermediaries.

5. DEVELOPMENT STRATEGIES FOR THE AFRICAN FERTILIZER INDUSTRIAL SYSTEM

5.1 Group I. Fertilizer import substituting countries: Mozambique, Mali, Sudan, Ethiopia, Burkina Faso, Tanzania, Niger, Zambia

Strategy: Of all the groups identified this group requires investments across the largest range of the items described. The breadth of investment needs is particularly evident in the development of natural resources. This area might constitute a strategic focus of investment activities. This would be due to the group's combination of a relatively wide ranging raw material endowment and a poorly developed mining sector. It should be noted that while the African continent is deficient in potash, this group and group 4 are the only two which possess this raw material. Furthermore, natural gas deposits in Mozambique, Sudan, Tanzania and Ethiopia provide raw material for potential production of ammonia. Similarly, it is clear that Burkina Faso and Niger have good potential for the development of phosphates once the constraint on extraction is removed.

The typology exercise pointed to inadequate transport and distribution infrastructure as a major bottleneck to the fertilizer industry in this group. Consequently, investment activity should aim at ameliorating this constraint through upgrading of road and/or rail networks and the pool of transport vehicles and associated services. Port facilities are likewise an item for attention in this respect. In at least one country of this group, Tanzania, a lack of transport facilities hinders the distribution and sale of crops. Efforts in the development of the industry itself would be of limited value until the distribution constraint is resolved.

A second focus of investment activity might be the energy sector. A reliable supply of cheap electricity is a key element in the development of a fertilizer industry. This group is weak on both energy self-sufficiency and energy consumption per capita. However, the group possesses a good potential for the generation of hydro-electricity and all countries of the group plan to produce or are already producing hydro-electricity.

Given a significant demand for fertilizers and the fact that many of the fertilizer related plants operate with a low on stream factor, rehabilitatory investments and technical assistance would be appropriate. The group could draw particular benefit from technical assistance related to a survey of rehabilitation requirements as well as relevant techno-economic appraisals related to production diversification. It should be noted that various plants have struggled to prevent closure in this group for a number of years due to severe rehabilitation needs. A further element of any strategy must involve an increase in the incentive to use fertilizers by farmers.

5.2 Group II. Little consumption with proper policies in fertilizer application: Liberia, Guinea, Sierra Leone, Ghana, Benin, Burundi, Gambia, Rwanda, Somalia, Uganda, Central African Republic

A strategy for this group would be less wide ranging than for group one on account of a more limited raw material endowment and a near absence of fertilizer related plant. Indeed, in the typology exercise this group is described as placing a low domestic priority on fertilizer industry development. Nevertheless, increases of agricultural production will have to rely, in large part, on more intensive fertilizer application. Due to present low levels of fertilizer application the marginal returns from increased fertilizer use are high. The low demand for fertilizers in this group does not justify large investments in productive plant. A strategy might thus focus on extraction of existing raw materials and the establishment of small scale production facilities. Facilities connected with grinding of own phosphate rock and bulk blending might constitute a first choice. Technical assistance and investment activities would be required for both elements of the strategy. The present policy framework with regard to fertilizer application should be maintained.

5.3 Group III. FERTIS development in line with African mean values: Zaire, Swaziland, Madagascar, Malawi, Cameroon, Côte d'Ivoire, Chad, Kenya, Mauritania

Notwithstanding the group's diversity, a strategy might focus on developing distributional infrastructure to facilitate the movement of fertilizer imports and domestic production, although the latter exists on a small scale. Improved distribution might likewise facilitate the supply of materials to and from bulk-blending and compound granulation facilities. The feasibility of rehabilitating existing plants should be examined. Rehabilitatory activities may be particularly viable in those countries having a high demand for fertilizers by African standards. Such countries include, Cameroon, Côte d'Ivoire and Kenya. In the case of Kenya scope exists for trade related sub-regional co-operation with Ethiopia and Tanzania, both of which plan to build fertilizer facilities in the future. Malawi also has a high demand for fertilizers but as yet no productive plant. With a need for nitrogenous fertilizers Malawi faces two options. Either it can process imported ammonia on a small scale or it might establish a minifertilizer plant for the production of ammonia from water hydrolysis. Investments in the extraction of the group's fertilizer related raw materials may be appropriate, namely in nitrogen, phosphorous and sulphur related materials. A development strategy must likewise improve the incentives for farmers to use fertilizers.

5.4 Group IV. Strong in energy and Potash/Nitrogen related natural resources: Gabon, Congo, Angola, Botswana

Investment and technical assistance activities are quite varied for this group. Such activities should perhaps be concentrated on the extraction of natural resources. The group's raw material base includes all the fertilizer related nitrogen, phosphorous, potassium and sulphur raw materials. Furthermore, Congo and Botswana possess valuable potash deposits, making this group and groups one and five the only ones having significant quantities of that raw material. Assistance in undertaking techno-economic appraisals of potash extraction may be valuable. Export of this raw material may be particularly viable in the African context. The presence of oil reserves would suggest technical assistance in appraising desulphurization of oil, gas and off gases.

The limited size of the domestic market precludes large investments in processing, the only likely exception being possible exports of potash. It should be noted that there is no production of fertilizers in this group. Investments in bulk blending, compound granulation and phosphate rock grinding might be considered. If the central policy dilemma facing decision makers is wether to import fertilizers or invest in industrial plants, it would be logical for this group to continue importing fertilizer requirements on account of a small domestic demand and a relatively high availability of foreign exchange.

5.5 Group V. Export-oriented in Phosphate Fertilizers: Tunisia, Morocco

This group is notable as a large producer and exporter of phosphate rock, phosphoric acid and phosphatic fertilizers. Consequently, the focus of a strategy will differ from those groups with only incipient or no production of fertilizers. Despite existing plant, increased fertilizer production is limited by shortage of sulphur, potash and ammonia. A strategy for this group might thus concentrate on increasing the availability of these substances. In this respect joint ventures might be pursued with Egypt in the extraction of sulphur from natural gas. In a similar vein, trade related co-operation might be sought with countries of group six with a view to trading phosphates for nitrogen. In relieving the raw material bottlenecks some domestic investments and/or technical assistance may be appropriate. It should be noted that Morocco possesses sulphur bearing raw materials while Tunisia has potash brines. The large domestic market for fertilizers adds economic justification to such an intervention. Projected declines in food self sufficiency to the year 2000 underline the need for increased production of productivity enhancing inputs to agriculture. In relation to processing of intermediaries, investments and technical assistance might be sought for optimizing the exisiting processes and/or undertaking process changes in sulphuric and phosphoric acid facilities. Such activities might focus on reducing the negative environmental impact of this industry. Technical assistance could provide additional support to the above mentioned measures through techno-economic appraisals of production diversification.

With this group having a high level of technical sophistication in currently operating facilities while experiencing a number of raw material bottlenecks, scope may exist for co-operation with those groups endowed with the constraining materials, such as group six.

5.6 Group VI. Export-oriented in Nitrogen related raw materials: Algeria, Libya

This group requires a wide range of investment and technical assistance activities, particularly in the area of processing to NPK fertilizers. The need for increasing productivity raising inputs to agriculture is evidenced in the projected negative per capita balance of cereals by the year 2000. Group six is well endowed with natural resources, particularly nitrogen related materials such as natural gas and crude oil. It should be noted that both countries may in future be able to recover sulphur from oil and natural gas. This may constitute a focus of future investment and technical assistance activities as the desulphurization process requires a high degree of industrial sophistication. Investments may likewise be directed towards extraction of the limited potash reserves existing in both countries.

Another element of a development strategy may place priority on investments in the manufacture of ammonia for which there exists a good potential due to the abundance of natural gas. Rehabilitatory investments and technical assistance should be undertaken to increase rates of capacity utilization which are quite low in Algeria. Rehabilitatory interventions are also required following an important industrial accident in 1989.

With a marked export orientation in the fertilizer industry of group six investments should also be directed towards the maintenance and/or upgrading of port and distribution infrastructure.

Any strategy also requires revision of policy affecting the incentives to fertilizer use.

5.7 Group VII. Strong demand for NPK fertilizers: Nigeria

A strategy for Nigeria must rest on an exceptionally broad base of investment and technical assistance activities. This country possesses the greatest potential in the fertilizer industry of any of the Sub-Saharan countries. The question whether to import or to produce must in Nigeria's case favour domestic production of fertilizers. Imports of fertilizers to enhance food production for such a numerous population would make an excessively heavy long-term claim on limited resources of foreign exchange. Low rates of fertilizer application in conjunction with inadequate availability of food for the large and rapidly growing population underline the need for increased production from this industry.

Expansion of nitrogenous fertilizer production is central to a development strategy, all the more so because of propitious industrial conditions. Natural gas, the necessary raw material, is available in abundant supply. Nitrogen is also the nutrient most required by Nigerian soils. The large nitrogen fertilizer plant built recently at Onne likewise provides relevant industrial experience. Increased capacity in nitrogenous fertilizers should be complemented with potassium and phosphorous related facilties. The possibility of a joint venture in the area of potassium production might be considered with a country such as the Congo. The large domestic market for fertilizers provides economic support for such interventions.

As a major producer of crude oil, investments and technical assistance in oil desulphurization would be an important intervention, enhancing the quality of the key export while providing a raw material for the fertilizers industry. In conjunction with this activity projects related to production of sulphuric acid should be considered.

A strategy should attempt to ascertain the commercial viability of exploiting the country's phosphate rock. Technical assistance may be of value in this respect.

A further element of strategy should involve improvement of the incentives for farmers to use fertilizers.

5.8 Group VIII. High fertilization rates with self-sufficiency in FERTIS: Egypt

Significant investments will be required in the fertilizers industry to keep pace with a growing demand for fertilizers, upgrade existing plant and increase product diversification.

As part of a strategy for this large producer of crude oil, investments may be directed towards oil desulpherization projects. Technical assistance may be useful in appraising the techno-economic feasibility of establishing desulpherisation operations.

With a low level of self-sufficiency in cereals increased agricultural production will depend in part on fertilizer application. However, the already high application rates will mean limited marginal returns on further application. Other means of increasing agricultural output, such as extension of the arable frontier through irrigation, may have to take higher priority.

A development strategy must also include an improvement in the incentives to farmers for use of fertilizers.

5.9 Group IX. Exceptional Nitrogen/Phosphorous/Potassium consumption ratio: Lesotho

The range of technical assistance and investment activities contributing to a strategy for Lesotho is the most limited of all the groups. A development strategy should center on investments in bulk-blending, compound granulation and phosphate rock grinding facilities. The development of a phosphate rock grinding capacity may yield a product appropriate to Lesotho's crop pattern and mountainous terrain. A second element of the strategy might concentrate on exploiting the country's hydro-electricity potential, supplying power to any future blending, grinding and granulation plants while reducing dependence on energy imports from South Africa. No production facilities operate at present and it is unlikely that the small domestic market justifies production of fertilizers.

A further element of a strategy would involve an upgrading of distributional infrastructure. Technical assistance might be secured for all of the above mentioned activities.

5.10 Group X. Principal Sub-Sarahan fertilizer producers: Mauritius, Zimbabwe, Togo, Senegal

A diverse range of productive facilities and natural resource endowments requires a comprehensive range of technical assistance and investment activities in this group. Although Zimbabwe, Senegal and Mauritius produce fertilizers, fertilizer imports exceed fertilizer exports. One element of a strategy should focus on securing investments and technical assistance in processing to intermediaries. Zimbabwe might focus on coal based ammonia projects for which it has reserves of good quality coal. However, the installation of a pipeline between Mozambique and Zimbabwe would permit the transport of natural gas to Zimbabwe from Mozambique. Natural gas would be a cheaper source of ammonia than coal and provide an economic benefit to both countries. By contrast Mauritius possesses no fertilizer related raw materials. Technical assistance and investments should here be directed to the production in a minifertilizer plant of ammonia from water electrolysis and atmospheric nitrogen. Technical assistance may also be of use in Mauritius in determining the techno-economic feasibility of ammonia production from the biomass of the sugar industry.

With the size of the domestic market representing a constraint to the industry it is important that a policy framework promote fertilizer use. Scope may exist for co-operation in trade between Senegal, which has difficulties exporting phosphoric acid, and countries having raw materials in which Senegal is deficient, such as ammonia (from Nigeria) and possibly sulphur and potash. In this regard, trade related co-operation between Togo and Nigeria, involving phosphorous and ammonia, might serve to enhance the latter country's phosphate industry.

A further element of a strategy might focus on diminishing the energy constraint on this industry. The group is at a level of development which permits it to seek further production diversification, perhaps with a focus on fluid fertilizers and secondary micronutrients.

Table 5.1 provides a summary of the specific technical assistance and investment activities required by each of the ten groups. Identification of these requirements is a logical extension of the identification of the group-specific development patterns. As with strategy formulation, the consideration of constraint and enhancement variables is a useful aid in formulating investment and technical assistance requirements. The table clearly points up the specificity of each development pattern. Group I for instance is seen to require investments across all items related to exploitation of the natural resource base. By comparison, group X is seen to require investments in only two items relating to natural resources: the survey of secondary nutrients and the survey of micronutrients. It is also evident that a number of investment and technical assistance activities are common to most of the country groups. For example, with regard to processing to intermediaries it is seen that all groups except group IX require investments in sulphuric acid projects. Similarly, most groups require investments in FERTIS related port facilities. Other most commonly required activities include urea related investment projects, SSP/DSP/TSP investments, bulk-blending/compound granulation investment projects, energy projects related to FERTIS, infrastructure related investments and research on the affinities of soils and crops to fertilizer use.

Table 5.1 provides a useful frame of reference for the second stage of the programme approach, namely the formulation of an indicative development programme for a single country. This application of the programme approach involves field work by an expert in one country of a given country group. The chosen country can be thought of as having a development pattern which is "indicative" of the development pattern of the country group to which it belongs. The results of the indicative programme allow a check and/or refinement to be made on the findings of the typology work. Likewise, the expert will begin the mission possessing a considerable amount of operationally useful information resulting from the typology exercise. Having a homogeneous development pattern, the work undertaken in this country will yield results of direct use to other countries of the same country group, assisting them to formulate integrated development programmes in the fertilizers industrial system.

Table 5.1

Pattern specific integrated actions for the Fertilizer Industrial System in Africa

INVESTMENTS	COUNTRY-GROUPS									
	1	2	3	4	5	6	7	8	9	10
NATURAL RESOURCES										
Potash extraction projects	*			*	*					
Sulphur recovery projects	*			*		*	*	*		
Natural gas utilization	*	*	*	*						
Hydroelectricity utilization	*	*	*	*						
Phosphate rock development	*	*	*	*			*			
Survey of secondary nutrients	*	*	*	*	*	*	*	*	*	*
Survey of micronutrients	*	*	*	*	*	*	*	*	*	*
PROCESSING TO INTERMEDIARIES										
Natural gas based ammonia projects	*		*	*		*	*	*		
Fuel oil based ammonia projects		*	*							
Hydroelectricity based ammonia projects	*		*							*
Coal based ammonia projects	*									*
Sulphuric acid projects	*	*	*	*	*	*	*	*		*
Phosphoric acid projects	*				*	*	*	*		*
PROCESSING TO NPK FERTILIZERS										
NA/AN/CAN projects	*		*			*	*	*		*
Urea projects	*	*	*	*		*	*	*		
Ammonium sulphate projects	*		*	*		*		*		
SSP/DSP/TSP projects	*	*		*	*	*		*		*
MAP/DAP/NPK projects	*				*	*	*			*
Nitrophosphates projects					*	*				
MOP/SOP projects	*			*	*					
OTHER OPERATIONS IN FERTIS										
Bulk-Blending/Compound Granulation	*	*	*	*			*	*	*	*
Phosphate Rock Grinding/PAPR process	*	*	*	*					*	*
INDUSTRIAL INPUTS AND SERVICES										
Energy projects rerelated to FERTIS	*		*	*	*		*	*		*
STORAGE, TRANSPORT and DISTRIBUTION										
Projects in infrastructure and the chain in transport network for FERTIS	*	*	*	*			*		*	*

Table 5.1 continued

	COUNTRY-GROUPS									
	1	2	3	4	5	6	7	8	9	10
Port facilities and FERTIS terminals	*	*	*	*	*	*	*	*		*
Network of natural gas	*									*
ADDITIONAL INVESTMENT PROJECTS										
Packaging industry development					*	*	*	*		
Catalysts, additives, fillers projects					*	*	*	*		*
PILOT PLANTS PROJECTS FOR FERTIS										
Minifertilizer plants	*	*	*							
Projects in organic fertilizers		*	*							
Bulk-Blending demonstration unit			*							
TECHNICAL ASSISTANCE ACTIONS										
Survey of rehabilitation projects in existing FERTIS facilities	*	*	*			*				*
Survey of diversification in production programme in FERTIS	*				*	*	*	*		*
Techno-economic appraisals on desulphurization of oil/gas/off-gases	*			*		*	*	*		
Techno-economic appraisals of potash extraction and processing in Africa	*			*	*		*			
Appraisals of introduction new FERTIS sulphur-free processes in Africa such as NITROPHOSPHATES and IMI process	*				*	*				
Appraisals of ammonia production through electrolytic process	*		*							*
Techno-economic studies on introduction KMgS fertilizers and micronutrients					*	*	*	*		*
Training programmes in FERTIS	*	*	*			*	*			*
Training programmes in contracting	*	*	*	*			*			*
JOINED UNIDO/FAO PROGRAMMES										
Research on affinity of local soils to fertilizer used and planned for use	*	*	*	*	*	*	*	*	*	*
Research on crops response to fertilizer including new crop varietes	*	*	*	*	*	*	*	*	*	*