Inorganic Fertilizer Use in Africa: Environmental and Economic Dimensions

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CEC	cation exchange capacity
CDIE	Center for Development Information and Evaluation (USAID)
CFR	Code of Federal Regulations
CIP	commodity import program
DAP	diammonium phosphate
DCM	Development of Competitive Markets program (Ethiopia)
EPAT	Environmental and Natural Resources Policy and Training Project
FAO	Food and Agricultural Organization
FUE	fertilizer use efficiency
IFA	International Fertilizer Industry Association
IFDC	International Fertilizer Development Center
ISM	integrated soil management
K	potassium
M&E	monitoring and evaluation
mt	metric ton
N	nitrogen
NGO	non-governmental organization
NPA	non-project assistance
OECD	Organization for Economic Cooperation and Development
OHV	Opération Haute Vallée
OPG	Operational Program Grant
P	phosphorus
PR	phosphate rock
PVO	private voluntary organization
RSA	Republic of South Africa
SAP	structural adjustment program
SSA	sub-Saharan Africa
SSP	single super phosphate
TA	technical assistance
TSP	triple super phosphate
USDA	United States Department of Agriculture
USAID	United States Agency for International Development
WIIAD	Winrock International Institute for Agricultural Development

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Executive SummaryExecutive SummaryExecutive Summary

Objective. The objective of this review is to synthesize the state of knowledge regarding the positive and potential negative impacts of fertilizer use in sub-Saharan Africa (SSA), in the context of USAID and other assistance programs. The study is intended to shed light on some of the dilemmas which arise in the intensification of agriculture, and to provide insights towards improving sustainable agriculture and natural resource management programming.

Fertilizer consumption in Africa is low, and unlikely to increase dramatically in the near future. Average fertilizer use is 21 kg/ha, but in SSA (excluding the Republic of South Africa) use is only 10 kg/ha. Fertilizer use in SSA increased in the 1980s, but use has been stagnant since 1990. An 18% annual increase is needed to supply the nutrients to produce enough food for the growing population, and to return nutrients to the soil.

Increased fertilizer use can help solve Africa's environmental problems. Lack of inorganic fertilizer has greater negative environmental consequences than increasing use of this fertilizer. Current agricultural practices mine soil nutrients, with average removal of more than 24 kg/ha/year of nitrogen (N), phosphorus (P), and potassium (K). Organic sources are not sufficient to replace these nutrients. Increasing inorganic fertilizer use, consistent with agronomic recommendations, will have few if any adverse environmental impacts, and many positive impacts. Increased inorganic fertilizer use would benefit the environment by reducing the pressure to convert forests and other fragile lands to agricultural uses and, by increasing biomass production, help increase the organic matter content of African soils. This organic material supplies and helps retain soil nutrients.

Inorganic fertilizer use must be combined with other agronomic management practices. For efficient nutrient utilization, inorganic fertilizer must be combined with organic matter, water harvesting, and controlling soil erosion in site-specific integrated soil fertility management strategies. These complementary activities help insure that maximum benefits are derived from each component practice.

Intensification of agriculture is needed, but extensive agriculture is likely to continue. There is limited potential for extensive agriculture (expanding the cultivated area) to provide enough food to feed Africa's growing population. Intensification (increasing the value of crops on the existing cultivated area) is needed to use soil nutrient and water resources efficiently, and to relieve pressure on forests and other fragile lands. However, optimistic scenarios for increasing yields on existing agricultural lands will not provide enough food for the growing population, so extensification of agriculture is likely to continue.

Pricing policy and non-price factors significantly influence fertilizer use. Lack of credit, poor marketing capabilities, high transport costs, lack of availability of fertilizer, inadequate demand to stimulate investment in production and distribution, lack of crop markets, devaluation of domestic currencies, and weak extension services constrain fertilizer use. Lack of credit has been identified as the major determinant of fertilizer use in Ethiopia and other African countries. These factors—along with unpredictable rainfall—are often more important than the price of fertilizer.

USAID's fertilizer-related activities in Africa are unlikely to cause environmental problems. The only recent project which was directly involved in fertilizer use was the Development of Competitive Markets (DCM) program in Ethiopia, which was completed in 1995. The primary objective of this program was to support the policy of opening up the marketing and distribution of agricultural inputs, particularly fertilizer. Fertilizer sales in Ethiopia in 1995 were 236,000 mt, nearly an 80% increase over 1993 (when sales were 132,000 mt), but this quantity was still less than 20 kg/ha—hardly a level which will cause environmental problems.

Non-project assistance (NPA) and agribusiness promotion which result in increased fertilizer use should benefit the environment, not harm it. NPA efforts—which are concerned with economy-wide reforms, agricultural sector reforms, institutional strengthening and policy reforms, and intensification policies and practices—may lead to increased fertilizer use if such use is economically beneficial to individual farmers. NPA efforts which promote economic efficiency in the context of environmental sustainability should thus lead to increased fertilizer use only where such use is environmentally as well as economically beneficial.

USAID's environmental strategy for fertilizer should promote integrated soil fertility management. Current procedures to identify and mitigate negative environmental impacts are sufficient to foresee possible consequences from the inappropriate use of inorganic fertilizer. USAID should promote site-specific integrated soil fertility management which is based on analyses of the following issues:

- **Site-specific nutrient deficiencies.** Soil and water conditions vary greatly, but many nutrients are severely and widely deficient for good crop growth; fertilizer recommendations must be based on site-specific research results. (Sections 3.2, 3.3)

- **Low fertilizer use efficiency.** Low fertilizer use efficiency (FUE) should be considered as a constraint to the use of inorganic fertilizer. (Section 2.1)

- **Nitrogen deficiency.** More inorganic nitrogen fertilizer is needed. (Section 3.2)

- **Phosphate rock as a soil amendment.** Local phosphate rock can be an important soil amendment source of phosphorus, but present constraints may inhibit widespread development. (Section 4.2)

- **Complementary practices.** Complementary agronomic practices (organic matter, nitrogen-fixing legumes used in crop rotations, water harvesting, erosion control) are needed in addition to inorganic fertilizers. The organic content of soils needs to be increased through residue management and other available sources to compensate for the lack of active clays in the soils. (Sections 8.1, 8.2)

•**Fertilizer policies.** Policies on fertilizer use (subsidies, distribution) are key to soil fertility management. (Section 6.0)

•**Macroeconomic policies.** Market development and macroeconomic policies (particularly trade policies) which influence crop output prices are key to increasing fertilizer use. (Section 6.3)

•**Non-project assistance.** Non-project assistance (NPA) can be an effective approach to raising food production by increasing the efficiency of fertilizer use in an environmentally-friendly fashion. (Section 7.3)

One of the key multi-agency efforts in integrated soil fertility management is the World Bank's Soil Fertility Initiative, which USAID supports through the Soil Management Collaborative Research Support Program.

USAID should build on the success of its NPA activities. The DCM project in Ethiopia and the Fertilizer Pricing and Marketing Reform Program in Kenya have been notably successful in encouraging the development of competitive markets for agricultural inputs, particularly fertilizer. Because the environmental consequences of policy and institutional reforms designed to increase agricultural growth depend on how incentives and institutions interact with local conditions, emphasis should be placed on using local organizations' knowledge in the design and implementation of NPA activities.

Environmental guidelines should emphasize the integrated use of inorganic fertilizer in combination with other practices which promote soil fertility. Soil fertility and nutrient losses will continue if inorganic fertilizer use does not increase, but fertilizer is not a complete solution. Great progress can be made by helping smallholders increase their understanding of—and capacity to operate within—the marketplace of ideas, technologies, and commodities. It is better to encourage the development of market systems and the adoption of complementary management practices which make fertilizer use profitable and increase food security, rather than to focus on fertilizer or any other single remedy for Africa's agricultural problems.

Moving towards more productive and sustainable agricultural development in sub-Saharan Africa requires:

•a **favorable enabling environment** (e.g., changing policies whichimpede operation of markets and access to them, or insecure land tenure systems);

•**Development and dissemination of improved technologies & strategies** which support a "doubly green" revolution, e.g., improved varieties, environmentally friendly pest management; investments in "natural capital management which reduce env. damage & enhance the natural resource base; methods for improving nutrient status with natural and chmeical fertilizers; and research on new cropping systems whjich provide mulitple environmental and economic benefits.

•**Revitalization of international and national ag research systems** to focus on sustaining the stream of new and appropriate “doubly green” technologies.

1.0 Objective1.0 Objective1.0 Objective

The objective of this review is to provide a balanced and objective study which briefly synthesizes the state of knowledge regarding the positive and potential negative impacts of fertilizer use, in the context of USAID and other assistance programs in Africa. The study is intended (1) to shed light on some of the dilemmas which arise in the use of inputs in the intensification of agriculture, and (2) to provide insights towards improving sustainable agriculture and natural resource management programming and, in particular, the environmental review and analysis functions of the Bureau for Africa.

2.0 Fertilizer Consumption.0 Fertilizer Consumption.0 Fertilizer Consumption

2.1 Current Consumption.1 Current Consumption.1 Current Consumption

Farmers in Africa used only 3.5 million mt of plant nutrients on nearly 170 million ha of arable land in 1994/95. Five countries (Egypt, Morocco, Nigeria, South Africa, and Zimbabwe) accounted for 72% of this total. The average rate of use in Africa was 21 kg/ha. In sub-Saharan Africa (SSA), excluding South Africa, however, it was only 10 kg/ha. Only 4 countries (Egypt, South Africa, Swaziland, and Zimbabwe) used more than 50 kg/ha, and 31 countries used less than 10 kg/ha (see **Figure 1** and **Table 1**). The world average is more than 90 kg/ha; in the developing countries as a whole (including Africa) it is more than 100 kg/ha (IFDC 1996).

These average rates mask a key characteristic of fertilizer use: fertilizer use on most land is zero, and only moderate amounts are used on cash/export crops (see IFDC 1996).

Africa produces more fertilizer (4.8 million mt in 1994/95) than it uses (3.5 million mt) (see **Table 2**). Most of the production—75%—is in North Africa, and 17% is in the Republic of South Africa. The rest of SSA produces only 8% of Africa’s fertilizer, and produces only 30% of the region’s own fertilizer consumption (calculations based on IFDC 1996). In SSA excluding RSA, only seven countries produce fertilizer (Burkina Faso, Cote d’Ivoire, Mauritius, Nigeria, Senegal, Zambia, and Zimbabwe); Nigeria produces 46% of the (non-RSA) SSA total (see **Table 3**). These countries often export fertilizer even though their own use is quite low; Senegal—where average fertilizer use is only 9 kg/ha—exports most of the fertilizer it produces.

Although a considerable portion of Africa’s fertilizer consumption is standard fertilizers (such as urea, ammonium sulfate, ammonium nitrate, diammonium phosphate [DAP], single super phosphate [SSP], triple super phosphate [TSP], and potassium chloride), much of it is also complex (chemicals containing more than one nutrient) and compound (mixtures of more than one nutrient) fertilizers (see **Box 1**). Of the 22 SSA countries for which information is available on the types of fertilizer used, only four—Ethiopia, Kenya, Malawi, and Sudan—use mostly straight (single nutrient) fertilizers. In Malawi, compound (multiple nutrient) fertilizers are granulated locally using straight fertilizers as raw material (IFDC 1995). (For a discussion of the agronomic advantages and disadvantages of various fertilizer products, see Byrnes 1995.)

Box 1. Characteristics of Fertilizer Use in AfricaBox 1. Characteristics of Fertilizer Use in AfricaBox 1. Characteristics of Fertilizer Use in Africa (from Bumb 1991)

1.Fertilizer use shows wide annual fluctuations. Economic, institutional, and climatic changes seem to have produced these changes.
2.Many countries use rather small quantities of nutrients. This prevents many countries from investing in production facilities or benefiting from economies of scale in bulk imports.
3.Fertilizer use is highly concentrated in a few countries. Five countries (Nigeria, Zambia, Zimbabwe, Kenya, and Ethiopia) account for about two-thirds of the total fertilizer use in sub-Saharan Africa [excluding the Republic of South Africa].
4.Many SSA countries depend on fertilizer imports. Because of the debt crisis and foreign exchange shortages, a large proportion of fertilizer imports is donor financed.*
5.Export crops account for much of the fertilizer use in SSA. This is the result of the higher profitability and better marketing arrangements.
6.Many African countries use compound and complex fertilizers. Most of these are brought in from abroad in small quantities, resulting in high fertilizer costs.

*Aid-financed fertilizers provided about two-thirds of the fertilizer imports in 1985 and one-third in 1987. Although the ratio of fertilizer aid to fertilizer imports for sub-Saharan Africa decreased between 1985 and 1987, the dependence on fertilizer aid remained high for many countries. For 20 countries, all fertilizer imports were financed through donor programs. Another seven countries received donor funding for more than 50% of their fertilizer imports.

There is both research and anecdotal evidence to support the conjecture that farmers who have taken measures to conserve moisture or increase soil organic matter are more likely to use inorganic fertilizer. (Sanders, Nagy, and Ramaswamy 1988 provides data for the fertilizer-water conservation interaction in Burkina Faso.) Anecdotally, farmers in the Opération Haute Vallée (OHV) zone of Mali know about increases in fertilizer use efficiency from the addition of compost and residue management (possibly attributable to greater cation exchange capacity [CEC], buffering, or increased moisture).

When farmers in some areas have capital, they often invest first in increasing moisture retention and/or increasing soil organic matter and secondly in inorganic fertilizer. They may do this because they are risk averse, or they may do it to increase fertilizer use efficiency (FUE) (M. McGahuey, USAID/AFR/SD, personal communication, 1997).

Farmers increase their use of fertilizer when investing more money in fertilizer is seen to be the best available option. This increase may result from changes in any of the following: fertilizer price, crop price, fertilizer availability, water availability, seed availability, knowledge about fertilizer use, or cropping pattern. If (perceived) fertilizer use efficiency (FUE) is low, FUE can be a constraint to greater use of inorganic fertilizer (other constraints include the lack of capital and lack of inputs markets). Farmers may not use fertilizer on dry fields even if the fertilizer is subsidized; they may have capital and invest in moisture retention or manuring before investing in fertilizer. This behavior is evidence of the importance of FUE.

Figure 1. Fertilizer Use in Africa, 1994/95Figure 1. Fertilizer Use in Africa, 1994/95Figure 1. Fertilizer Use in Africa, 1994/95 (kg/ha)

Source: IFDC 1996.

Table 1. Total Fertilizer Use per Hectare of Arable LandTable 1. Total Fertilizer Use per Hectare of Arable LandTable 1. Total Fertilizer Use per Hectare of Arable Land (kg/ha)

Country	**1970**	**1975**	**1980**	**1985**	**1990**	**1991**	**1992**	**1993**	**1994**
Algeria	18	18	34	41	19	13	13	17	16
Angola	4	1	6	7	3	2	3	3	3
Benin	5	2	1	8	8	8	11	12	12
Botswana	4	6	4	1	2	2	2	2	2
Burkina Faso	0.3	0.5	2	4	6	6	6	6	7
Burundi	1	1	1	2	2	0	5	4	3
Cameroon	4	2	5	10	3	3	3	4	5
Cape Verde	0	3	3	3	0	0	0	0	0
Central African Republic	1	1	1	2	0.5	0.5	1	1	1
Chad	1	2	0.3	2	2	3	3	2	2
Comoros	0	0	0	0	0	1	1	1	1
Congo	58	18	4	34	11	10	14	14	13
Côte d’Ivoire	12	21	27	17	15	18	23	22	26
Egypt	137	186	290	375	422	425	347	342	274
Equatorial Guinea	15	1	1	0	0	0	0	0	0
Ethiopia	0.4	2	3	5	8	8	10	13	4
Gabon	0	2	0.3	10	4	2	2	1	1
Gambia	2	5	13	24	3	5	4	5	5
Ghana	3	23	7	6	7	3	4	3	4
Guinea	5	3	0.5	1	2	3	1	3	2
Guinea-Bissau	0	1	1	0	2	2	1	1	2
Kenya	14	12	16	27	29	24	25	26	35
Lesotho	1	4	15	12	15	19	18	19	19
Liberia	18	39	25	12	2	0	0	0	0
Libya	7	21	30	34	43	47	49	58	37
Madagascar	7	3	4	4	4	4	3	4	4
Malawi	9	12	25	24	29	42	44	44	22
Mali	3	1	7	10	7	7	10	10	8
Mauritania	1	6	7	10	19	26	36	22	20
Mauritius	220	244	267	280	277	276	266	260	292
Morocco	12	23	27	39	37	35	32	36	34
Mozambique	2	2	10	1	1	2	2	1	2
Niger	0.1	0.3	1	1	1	0.2	0.4	0.4	0.3
Nigeria	0.3	2	6	10	13	14	17	17	13
Reunion	238	278	85	280	257	304	343	350	400
Rwanda	0.4	0.4	0.1	2	4	2	1	4	1
Senegal	3	20	8	9	5	7	7	11	9
Seychelles	0	0	0	0	0	0	0	0	0
Sierra Leone	6	7	4	8	3	1	3	6	6
Somalia	3	4	1	4	3	0	0	0	0
South Africa	45	61	86	71	64	60	59	68	67
Sudan	3	8	7	7	7	7	6	4	6
Swaziland	40	56	110	55	68	61	66	62	71
Tanzania	7	14	16	17	17	17	16	17	13
Togo	0.2	1	1	5	6	6	6	5	5
Tunisia	10	15	20	30	29	34	36	32	30
Uganda	2	0.4	0.2	0	0	0.2	0.2	0.4	0.5
Zaire	1	2	1	1	1	1	0.3	1	1

Zambia	7	11	15	15	11	12	16	16	11
Zimbabwe	46	60	70	63	65	55	39	57	62
Sub-Saharan Africa	4	6	8	9	10	10	11	11	10
Africa	11	15	21	23	22	22	21	24	21

Data for sub-Saharan Africa do not include the Republic of South Africa. Source: FAO, cited in IFDC 1995, 1996.

Table 2. Africa Fertilizer Statistics, 1994/95 (mt)**Table 2. Africa Fertilizer Statistics, 1994/95 (mt)Table 2. Africa Fertilizer Statistics, 1994/95 (mt)**

	Production	Imports	Consumption	Exports
North Africa				
N	1780808	145467	986799	896974
P	1799381	31100	328883	1481798
K	0	104040	104240	0
Total	3580189	280607	1419922	2378772
SSA				
N	275398	506264	640604	94000
P	113200	419925	390488	32000
K	0	268164	248831	0
Total	388598	1194353	1279923	126000
RSA				
N	428000	41000	395179	71000
P	403000	21000	307000	68000
K	0	123000	130000	0
Total	831000	185000	832179	139000
Africa				
N	2484206	692731	2022582	1061974
P	2315581	472025	1026371	1581798
K	0	495204	483071	0
Total	4799787	1659960	3532024	2643772

N = nitrogen; P = phosphorus; K = potassium; RSA = Republic of South Africa. Source: IFDC 1996.

Table 3. Sub-Saharan Africa Fertilizer Statistics, Producing Countries, 1994/95 (mt)**Table 3. Sub-Saharan Africa Fertilizer Statistics, Producing Countries, 1994/95 (mt)Table 3. Sub-Saharan Africa Fertilizer Statistics, Producing Countries, 1994/95 (mt)**

	Production	Imports	Consumption	Exports
Nitrogen				
Burkina Faso	0	11000	11000	0
Côte d'Ivoire	0	34000	34000	0
Mauritius	15398	4000	11800	4000
Nigeria	151000	114000	186000	79000
Senegal	12000	6000	7000	11000
Zambia	3000	35000	38000	0
Zimbabwe	94000	27000	92878	0
Total	275398	231000	379878	94000
Phosphorus				
Burkina Faso	300	7700	8300	0
Côte d'Ivoire	1000	15000	0	0
Mauritius	0	3000	3189	0
Nigeria	27900	88000	116000	0
Senegal	42000	0	10000	32000
Zambia	0	13000	13000	0
Zimbabwe	42000	3000	42348	0

Total	113200	129700	192837	32000

Changes in stocks are not included in these figures. Source: IFDC 1996.

2.2 Imperatives.2 Imperatives.2 Imperatives

To feed its growing population, Africa must increase its food production by 4% per year for the next 10 years. To accomplish this, the use of chemical fertilizer must increase from an average of 10 kg/ha to 50 kg/ha—organic sources of soil nutrients will not be sufficient (Seckler, Gollin, and Antoine 1989; Williams and Schultz 1990). This means that the use of inorganic fertilizers must increase at the rate of 18% per year, which is significantly more than the increases observed in South Asia (13%) and Southeast Asia (9%) from the early 1960s to the late 1980s (Harold, Larson, and Scott 1994). Moreover, these increases must be achieved under much more difficult conditions than Asian farmers faced, particularly with respect to soil conditions, water availability, and access to input and output markets (Winrock International 1991; EPAT/Winrock International 1993).

A more realistic target for increases in inorganic fertilizer use is probably 30 kg/ha. The elasticity of food production with respect to fertilizer use has been estimated at 0.4-0.5 (that is, a 1.0% increase in fertilizer use results in a 0.4-0.5% increase in food production). With this response, an 8-10% annual increase in fertilizer use would be sufficient to achieve a 4% annual increase in food production (B. Bumb, IFDC, personal communication).

2.3 Parameters.3 Parameters.3 Parameters

The key to increased chemical fertilizer use is farmers' ability to achieve a profit from using this input. Potential profit, in turn, is affected by soil type, rainfall (and other water sources), cropping pattern (cash/subsistence), and access to (input and output) markets; these parameters are themselves interrelated. More fertilizer is used on clay soils, and where there is more water. Fertilizer is more effective in soil containing clay than in sandy soil, and fertilizer without sufficient water is virtually useless.

Fertilizer use has high returns on average. Its use by farmers, however, is constrained by its high cash cost and risky returns. Fertilizer use is risky for two reasons. First, yields and output prices can vary widely on a year-to-year basis, so farmers fear that in any given year their crop income will not be high enough to cover their fertilizer costs. Second, yields vary widely with the climate: rainfall is highly uncertain; in drought years the crop response to fertilizer can be practically nonexistent, and in fact may be negative if measures are not taken to harvest water. (Phosphorus fertilizers, which promote root growth, may thereby help plants survive limited periodic droughts [D. Hellums, IFDC, personal communication].)

Farmers use fertilizer on cash crops which are grown for local markets or export, and on hybrid maize, which responds to chemical fertilizer. In both cases farmers are responding to the profit potential. Fertilizer is hardly used on traditional food crops such as millet and sorghum. In the countries for which data on fertilizer use by crop are available, fertilizer is used on 46-100% of the cotton, sugarcane, and tobacco crops; it is used on 8-100% of the maize, wheat, and rice crops. In contrast, fertilizer is used on only 0-23% of the millet and sorghum crops (IFDC 1995). High input and transport costs for agrochemicals make the use of inorganic fertilizers on staple food crops uneconomical for some farmers (Hudgens 1996).

Agroclimatic constraints, fertilizer availability, and government policies can all limit growth in fertilizer consumption. Sparse, unpredictable rainfall causes subsistence farmers to be risk-averse in their use of fertilizer. Inadequate supply, untimely local availability, and lack of credit prevent farmers from purchasing the fertilizer they want. Reductions in fertilizer subsidies in the late 1980s also decreased fertilizer demand, sometimes dramatically (Harold, Larson, and Scott 1994).

African governments have not invested in the transport infrastructure which would make the use of fertilizer profitable for many farmers. As a result, transport systems in Africa are often poor or non-existent. Inputs cannot move to the farmers, and farmers cannot get their outputs to consumers. Local prices of grains fluctuate greatly throughout the year because of the lack of storage and marketing infrastructure. Transport costs can easily double the cost of fertilizer, and similarly halve the price of crops. Parastatal marketing organizations also affect farmers' access to input and output markets. Unfortunately, these organizations have often been inefficient, constraining market access more than they have promoted farmers' interests. Donor policies and interventions can directly influence access to input and output markets more than they can influence any other parameter. This can be done both through projects which improve transportation infrastructure and through programs which promote fertilizer sector reform.

2.4 Forecasts, Trends and Factors Influencing These Trends.4 Forecasts, Trends and Factors Influencing These Trends.4 Forecasts, Trends and Factors Influencing These Trends

Although total fertilizer use in Africa increased at an average rate of 1.7% per year (from 3.4 to 4.0 million mt) from 1983/84 to 1993/94, and at 4.0% in SSA (from 1.0 to 1.5 million mt), the upward trend is less than even these low numbers suggest. Fertilizer use actually declined slightly between 1985 and 1992 for Africa as a whole, increased sharply in 1993/94, and declined in 1994/95. Per-hectare fertilizer use has increased in only half the countries (in both North Africa and sub-Saharan Africa) since 1985 (IFDC 1995). The long-term trend in fertilizer use may be up; but it is weak and not uniform.

2.5 Donor Policies and Interventions.5 Donor Policies and Interventions.5 Donor Policies and Interventions

Donor policies have changed course in the past decades. Commodity imports, price subsidies, and other supply programs which encouraged fertilizer use have been followed by structural adjustment programs which raised (previously subsidized) fertilizer prices. Fertilizer sector reform programs which have attempted to liberalize fertilizer market structures have had mixed results with respect to fertilizer consumption. When credit and fertilizer subsidies were removed in Senegal and Zimbabwe, fertilizer use declined dramatically. On the other hand, when distribution costs were reduced, demand increased in Cameroon and Kenya. When reforms are incomplete, as in the privatization efforts in Ghana, there may be little change in fertilizer supplies (Matteson and Meltzer 1995). A World Bank review of donor activities concluded (see **Box 2**):

In 16 of the 29 countries reviewed, fertilizer subsidies were reduced or eliminated, and virtually total decontrol of fertilizer marketing achieved. Although the uptake of fertilizer does not appear to have been substantially affected by the reduction in subsidies, fertilizer use remains extremely low in sub-Saharan Africa, at just over 15 kg of plant nutrients per hectare of arable land, compared with over 74 kg/ha in India and 300 kg/ha in China. Part of the reason for this is irrigation, which is much higher in Asia. Serious fertilizer supply constraints are still in place in many countries of SSA. (Donovan 1996, p. ix)

Box 2. Lessons from Fertilizer Marketing Reform**Box 2. Lessons from Fertilizer Marketing Reform****Box 2. Lessons from Fertilizer Marketing Reform** (Donovan 1996)

The experience reviewed here was of a set of countries, most of whom entered the 1980s with public distribution systems for fertilizers, extensive controls on fertilizer imports and domestic sales, and systems of subsidies, either general or targeted. These countries moved towards liberalization of there fertilizer importing and marketing, reducing over time the restrictions on access to foreign exchange and attempting to phase out subsidies. An important lesson of that experience was that, to be effective, reforms relating to fertilizer had to be implemented in close harmony with more general reforms relating to agricultural production and marketing. A second lesson was that, besides subsidies, continued donor in-kind fertilizer aid also kept governments heavily involved with fertilizer importing, pricing, marketing and distribution, hindering private sector development in these areas. A third lesson was that liberalization of marketing was not enough to ensure that an efficient, competitive private sector would emerge to deal with bottlenecks on the supply side. Explicit encouragement was needed to establish such a private sector over time, including addressing their needs for training, credit, and a supportive regulatory framework.

The most comprehensive attempt to foster such development and implement a coordinated set of measures to address fertilizer supply and uptake is the [World Bank] program in Ethiopia, which is only just beginning. Among other things, it includes reducing subsidies, decontrolling prices, access to foreign exchange, procuring imports at the most competitive prices, training of dealers and farmers, financial assistance to the private sector including cooperatives, a program of on-farm fertilizer trials, investments in dockside facilities, roads, and soil laboratories, and various means of promoting fertilizer use. In all of this, a final important lesson is that inorganic fertilizer alone is not a solution to the problems of fertility experienced in African soils. Programs to promote fertilizer use must also encourage means of building up organic matter in soils.

In African countries where much of the fertilizer is supplied through donor arrangements, changes in donor policies and procedures can have dramatic effects on fertilizer use. Some of the root problems underlying low fertilizer use (rudimentary transport infrastructure, weak extension services for communicating site-specific research-based fertilizer recommendations) are long-term problems requiring sustained commitment from national governments. Donor initiatives can assist governments which want to attack these problems, but donors cannot substitute their good intentions for sustained commitment by African governments and private sector organizations.

Current (non-USAID) donor initiatives in the fertilizer sector are perhaps typified by the World Bank-funded National Fertilizer Project in Ethiopia, which seeks to phase out the fertilizer subsidy and increase efficiency in fertilizer importation and distribution with increased private sector participation. Eliminating subsidies is easier than increasing efficiency in fertilizer importation and distribution and increasing private sector participation. However, in Ethiopia the reasons for non-use of fertilizer are, in order of importance: high cost of fertilizer, unavailability of fertilizer, limited knowledge about the benefits of fertilizer, and limited information on how to use fertilizer (KUAWAB 1995).

3.0 Fertilizer and the Environment.0 Fertilizer and the Environment.0 Fertilizer and the Environment

3.1 Relevance and Importance.1 Relevance and Importance.1 Relevance and Importance

The potential environmental impacts of increased fertilizer use in Africa must be considered in light of the critical need to increase food production and reduce soil degradation, and the major role that inorganic fertilizer is likely to play in meeting that need (see **Box 3**). Inorganic fertilizer rarely causes environmental problems. Nevertheless, attempts by donors to solve agricultural problems with imported chemicals will be viewed by some as ecologically destructive, both because of problems with pesticides in other countries and because people tend to consider fertilizers and pesticides together as harmful agricultural chemicals. (Fertilizer and pesticide policies do share many common issues. For an analysis of pesticide policy reform, see Meltzer and Szmedra 1996.) Some people also worry that Africa's farmers may become dependent on external inputs. However, this concern seems overshadowed by the need to increase food production and by the fact that Africa already produces more fertilizer than it uses.

Sustainable agricultural intensification is not only important to increased employment and income, but also is critical to protecting the environment. Sustainable intensification of land currently under cultivation will reduce the pressure on farmers to push onto more fragile lands or to rely on labor-intensive gathering activities off-farm (Cleaver & Schreiber 1994). Sustainable intensification of farm production through the use of improved inputs that raise productivity and sustain increases in land productivity is a major food security and economic growth issue in Africa, given growing land constraints and soil degradation. Progress is being made on various fronts, notably in the development of apropriate policy change, "doubly green" technologies and strategies, and improved research and development systems (Christensen and Knausenberger 1995)(see Section 10.4).

3.2 Arguments for Increased Fertilizer Use.2 Arguments for Increased Fertilizer Use.2 Arguments for Increased Fertilizer Use

3.2.1Inorganic fertilizer is economical.2.1Inorganic fertilizer is economical.2.1Inorganic fertilizer is economical

Inorganic fertilizer is the only economical way to supply enough nutrients to increase food production. Several studies have noted that Africa cannot hope to produce enough food to feed its growing population without using inorganic fertilizer. One study indicated that per-hectare annual nutrient losses exceeded 10 kg N, 4 kg P, and 10 kg K in nearly all of the 38 SSA countries studied. Depletion rates were highest in East Africa, exceeding 40 kg N, 15 kg P, and 40 kg K (Stoorvogel and Smaling 1990). Offtakes in crops are normally several times these numbers, which include fallow periods with no offtake.

Organic sources cannot overcome these nutrient deficits. It has been estimated that two ha of land planted to leguminous plants are needed to provide the nitrogen for one ha of maize. As much as 120 to 360 ha of land are required for grazing animals to provide sufficient manure to 1 ha of maize land to sustain the nitrogen balance (Seckler 1994). Africa does not have enough land or soil nutrients to devote to producing organic nutrients to replace soil deficits.

Organic matter alone cannot provide all the phosphorus requirements in an intensive production context. Even if organic matter is available, it does not provide enough phosphorus for cereal yields exceeding 4 mt per hectare, and it does not provide sufficient potassium, calcium, or magnesium for intensive, high-yield agriculture (P. Antoine, WIIAD, personal communication).

Organic nutrients provide other benefits in addition to contributing directly to crop growth:

While legume green manures have proven to provide protective ground cover, conserving soil moisture, reducing erosion and lowering labor costs for weeding, they can also contribute nitrogen to succeeding crops, reducing the need for supplemental inorganic fertilizers. However, green manure crop management requires special attention to species compatibility with microclimatic conditions and soil physical, chemical, and biological factors. The amount of nitrogen accumulation in legume biomass is dependent on successful seedling establishment, the length of the legume growth cycle, and the incorporation of legume residues into the soil. The mineralization of legume residues releases nitrogen more gradually over a period of time than inorganic fertilizers (Hudgens 1996).

3.2.2Inorganic fertilizer can help reduce pressure on forests.2.2Inorganic fertilizer can help reduce pressure on forests.2.2Inorganic fertilizer can help reduce pressure on forests

Inorganic fertilizer and agriculture intensification can reduce pressure on forests and other marginal and fragile lands. The more food that is produced by increasing output on existing cropland, the less the pressure to convert forests and other marginal and fragile lands to agricultural uses. Inorganic fertilizer use and agriculture intensification will not eliminate the demand for more cropland, but it can dampen this demand.

3.2.3Fertilizer use can help increase soil organic matter.2.3Fertilizer use can help increase soil organic matter.2.3Fertilizer use can help increase soil organic matter

Increased biomass resulting from fertilizer use can increase soil organic matter. Increased fertilizer use will increase crop residues, and a larger portion of them can be left on the soil to increase its organic matter, protect soils from erosion, and improve soil structure. Because of low yields, crop residues are now used for fuel, fodder, and building material. These demands will certainly continue, but with higher yields some residues can remain on the soil.

Box 3. Agricultural Productivity, Sustainability, and Fertilizer UseBox 3. Agricultural Productivity, Sustainability, and Fertilizer UseBox 3. Agricultural Productivity, Sustainability, and Fertilizer Use (Parish 1993; Conway and Pretty 1991)

The elimination or even the reduction of fertilizer use in developing countries would result not only in the starvation and malnutrition of millions but also in an increased degradation of the environment through deforestation, soil erosion, and desertification, as has occurred worldwide in past centuries. In the vast majority of agricultural areas of developing countries, the certain benefits of fertilizer use to the environment overwhelmingly outweigh any of the possible but uncertain detrimental effects. Sound soil fertility management is the key to human survival. So far as the small-scale farmers of the developing countries are concerned, time is too short for the polemics of organic farming of low-input farming to constrain the development of an agricultural base on scientifically proven techniques of soil-nutrient management, which balance need with natural resource conservation. These scientific techniques will exploit the native fertility of the soil and the plant nutrients contained in the available biomass, as well as those biological factors that can enhance crop-nutrient supplies; they will also effectively use those fertilizer nutrients to maintain the fertility of the soil in an economically and environmentally sound way. For the developing countries, only an integrated, multidisciplinary approach to all aspects of fertilizer use research will ensure that maximum benefits are obtained from what is the most powerful yield-increasing technology available to man.

Major issues concerning the need for and use of fertilizers. The use of chemical fertilizers integrated with sound crop nutrient management practices is the key to increased yields per unit area and the maintenance of these yields in a sustainable manner. Increased yields in themselves reduce the pressure for extension of cultivated areas and thus the encroachment of agriculture into marginal areas and fragile environments; in this light, fertilizer is not only essential but also environmentally beneficial. Careful use of fertilizer based on sound soil and crop-production knowledge can reduce any adverse environmental effects these products may have.

The environment and fertilizers. The effects of fertilizer on the environment need to be kept in perspective, particularly by ensuring that the adverse environmental effects of industry, the massive urbanization of good agricultural lands, and the expansion of low-production systems into forest areas and marginal lands are separated from specific fertilizer-use effects on the environment. Additionally, agricultural activities, such as simple cultivation of the soil, decomposition of leguminous crop residues, and use of animal manure, can all have environmental impact; thus, these effects also must be quantified.

Pollution of surface and ground waters. There are few reports of serious nitrate contamination in developing countries. Sewage effluents have been the major source of high nutrient levels in rivers and lakes in Zimbabwe and Zambia. As yet there is little evidence of rising nitrate levels due to fertilizer use. An eight-year study of water draining a sugar estate in Zimbabwe found only negligible contamination by nitrate, despite an annual application of about 130 kg N/ha fertilizer. However, streams near a fertilizer factory at Que Que in Zimbabwe were found to have concentrations of up to 11,500 mg/l.

There are increasing reports of nitrate contamination of groundwater in the tropics but, as with surface waters, the causes are usually factors other than fertilizers. In the Shemankar River basin of Central Nigeria, where some 50 per cent of village wells exceed concentrations of 45 mg/l, the maximum value in the villages of 400 mg/l contrasts strongly with the maximum of only 6 mg/l from wells in the fields. In Botswana, nitrate levels as high as 600 mg/l have been recorded in village water supplies, where the sources are principally septic tanks and pit latrines.

Fertilizers and greenhouse gases. The impact of fertilizers on CO_2 evolution is insignificant compared with other sources such as the energy industry, tropical forest destruction, and the losses from soil organic matter due to cultivation. Fertilizers do contribute to an increase in methane production; however, this is an indirect effect due to their role in increasing the biomass of rice paddies. N_2O production from nitrogenous fertilizers, although significant, is small in comparison with N_2O production from crop legumes and tropical forests.

3.3 Arguments Against Inappropriately Increased Fertilizer Use.3 Arguments Against Inappropriately Increased Fertilizer Use.3 Arguments Against Inappropriately Increased Fertilizer Use

3.3.1 What constitutes inappropriate fertilizer use?.3.1 What constitutes inappropriate fertilizer use?.3.1 What constitutes inappropriate fertilizer use?

Inappropriate fertilizer use may result from farmers not raising the level of other management practices (variety, tillage, crop establishment, pest control) in balance with fertilizer use, or not following recommended agronomic practices. Fertilizer may be applied at the wrong rate, applied in the wrong way, or at the wrong time. As long as complementary integrated soil management practices are followed (including incorporation of organic matter and water harvesting), there appears to be little if any environmental risk associated with increasing chemical fertilizer use from 10 kg/ha to 30 kg/ha. Threshold parameters for problems may exist, but the economics of fertilizer use under African conditions will constrain fertilizer use long before environmental problems arise. Environmental problems can be avoided quite easily if farmers have access to and understand relevant information about effective and efficient fertilizer use.

3.3.2Excess fertilizer use can result in potential pollution3.3.2Excess fertilizer use can result in potential pollution3.3.2Excess fertilizer use can result in potential pollution

The application of fertilizers in excess of crop uptake results in potential pollution. The pollution of ground waters by nitrate has occurred principally on light-textured soils with high fertilization and/or manuring rates, particularly in areas subject to high rainfall or intensive irrigation, and on organic soils drained for agricultural use (Byrnes 1990). Few if any areas in Africa have these characteristics—little fertilizer is used on Africa's sandy soils, and there is little rainfall there. There is little evidence of rising nitrate levels in tropical rivers resulting from fertilizer use. (See **Box 3**; also see Conway and Pretty 1991 for an extended discussion of fertilizer and pollution.)

3.3.3Fertilizer recommendations must be site-specific.3.3Fertilizer recommendations must be site-specific.3.3Fertilizer recommendations must be site-specific

Africa has wide variations in climate, soil types and fertility; recommendations regarding the use of particular nutrients must be site-specific. This may seem obvious, but inappropriate application of fertilizer or soil amendments can waste resources, cause water pollution, and damage soils. General recommendations for dry vs. humid, sandy vs. clay, acidic vs. non-acidic, and soils with varying cation exchange capacities must be supplemented with particular knowledge of individual sites.

One recent study uses the digitized FAO Soil Map of the World to assess the quality of Africa's soil resource base and the risks to sustainable agriculture and soil productivity:

> The study of Eswaran et al. (1997a [Eswaran, Almaraz, van den Berg, and Reich]) is used as the basis for the following evaluation of soil quality in relation to sustainability of food production systems. **Table 4** gives the framework under which low, intermediate, and high input conditions are assessed for the evaluation of sustainability under different levels of technology. Only the biophysical resources are considered in this assessment. The socioeconomic conditions are not considered because of unavailability of suitable databases. The quality of the soil and the current population density are considered as first level variables that determine sustainability. (Eswaran et al. 1997)

Table 4. Definition of Levels of Inputs Table 4. Definition of Levels of Inputs Table 4. Definition of Levels of Inputs (FAO 1982, cited in Eswaran et al. 1997)

Attribute	Low Input Level	Intermediate Input Level	High Input Level
Production system	Rainfed cultivation of presently grown mixture of crops.	Rainfed cultivation with partial change to optimum mixture of crops.	Rainfed cultivation of optimum mixture of crops with supplemental irrigation when needed.
Technology employed	Local cultivars. No fertilizer or chemical pest, disease, and weed control. Fallow periods. No soil conservation practices.	Improved cultivars as available. Limited fertilizer application. Some chemical pest, disease, and weed control practiced. Some fallow. Some conservation.	High yielding cultivars. Optimum fertilizer application. Appropriate pest, disease, and weed control. Minimum fallow. Appropriate conservation practices.
Power sources	Manual labor; hand tools.	Manual labor and animal traction; some improved implements.	Complete mechanization, including harvesting.
Labor intensity	High, essentially family labor.	High, with some hired labor.	Low.
Ecosystem management	Nil.	Responsive if excess capital available.	Generally appropriate investments.
Capital intensity	Very low to low.	Intermediate, depending	High. Maximum

		on availability of credit.	utilization of credit.
Market orientation	Subsistence production.	Subsistence with commercial sale of surplus.	Commercial.
Infrastructure	Family based.	Some market accessibility.	Dependent on markets.
Technology availability	Usually none.	Occasional visits from extension service.	Frequent exchanges with extension service and peers.
Land holdings	Fragmented.	Sometimes consolidated.	Consolidated.
Land titles	Societal (usually no legal).	Mixed.	Usually owner operated or absentee landlord.

Box 4. Soil Quality and Soil Productivity in AfricaBox 4. Soil Quality and Soil Productivity in AfricaBox 4. Soil Quality and Soil Productivity in Africa (Eswaran et al. 1997).

More than four decades of research and development work in Africa have not resulted in the 3-5% annual increase in agricultural growth necessary for most African countries to ensure sustainability of agriculture and the promise of food security in the next decade. The present study evaluates the quality of the soil resource base of Africa and also the risks to sustainable agriculture and soil productivity on a continent-wide basis. Fifty-five percent of the land in Africa is unsuitable for any kind of agriculture except nomadic grazing. These are largely the deserts, which includes salt flats, dune and rock lands, and the steep to very steep lands. Though these lands have constraints to sustainability, about 30% of the population or about 250 million people are living, or are dependent on these land resources. About 16%of the land has soils of high quality and about 13% has soils of medium quality. This 9 million km^2 of land in Africa currently supports about 400 million people or about 45% of the people. (p.75) ... The soils are relatively free of major constraints, and rainfall is usually stable and adequate for one major crop. Moisture stress ranges are minimal and when present, confined to the dry season. The zones with adequate rain during the year, and generally with a dry season of less than one or two months, have some form of plantation agriculture or are under forests.(p.82)

[T]here are significant areas of good, high, and medium quality soils which currently have low population densities. In principle, such lands offer an opportunity for expansion of agriculture, but this has to be in the context of the competing uses.(p.84)

The potential for sustainable agricultural use increases with levels of input, as long as there is a rational use of inputs. Sustainable use is also a function of the population stress on the land and ... this is taken into consideration using the most recent population density information. ... [T]he potential for sustainable use of the land resources are evaluated and presented in [**Table 5**]. Under current conditions prevailing in sub-Saharan Africa, lands with high outputs are of local importance. Stability of production is generally high (except in the areas with highly erratic rainfall) due to generation-tested techniques of the farmers; the production level is very low and the propensity to degrade the resource base is concomitantly high. Yet with minimal technological innovations such as providing some fertilizers to the women farmers, about 43% of the land area can be brought into a moderate level of sustainability. If input levels can be enhanced and farmers trained to use these in a judicious manner, about 11 million km^2 or 35% of the land surface has the potential for highly sustainable agricultural use. With medium to high levels of inputs and with the associated services and facilities, Africa's food security problem could be resolved for a long period.(p.86)

There are compelling reasons for African nations to return to fundamentals. It is not a coincidence that every country with highly productive agriculture also has a long tradition in resource assessment programs with continuing research and development work. Those countries with subsistence agriculture have had minimal efforts in acquiring and managing information about their resource conditions. ... The "green revolution" had minimal impact in Africa and one reason for this stems from the assumption that the formula for Asia is applicable to Africa. The green revolution succeeded in Asia in those countries where there was a serious effort to match technology with resource conditions and where advances in development and use of high-yielding cultivars were accompanied by appropriate soil, water, and nutrient management.(p.91)

The other constraints to agricultural sustainability considered were water holding capacity, P fixing soils, saline and alkaline soils, soil pH, effective soil depth, water erosion potential, wind erosion potential, and desertification potential (Eswaran, Almaraz, van den Berg, and Reich 1997, pp.12-14). **Box 4** summarizes the findings of Eswaran et al. 1997. The other constraints to agricultural sustainability considered were water holding capacity, P fixing soils, saline and alkaline soils, soil pH, effective soil depth, water erosion potential, wind erosion potential, and desertification potential (Eswaran, Almaraz, van den Berg, and Reich 1997, pp.12-14). **Box 4** summarizes the findings of Eswaran et al. 1997.

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Table 5. Potential for Sustainable Use of Soil Resources: Land area in Africa (1000 km^2, %) under different levels of input in relation to potential for sustainable use (Eswaran et al. 1997)

Potential for Sustainable Use	Low Input	Medium Input	High Input
High	0 (0%)	6681 (22%)	10789 (35%)
Moderate	13241 (43%)	4137 (14%)	2728 (9%)
Low	683 (2%)	6007 (20%)	3249 (11%)
Very Low	16459 (54%)	13609 (44%)	13609 (44%)
Water Bodies	266 (1%)	266 (1%)	266 (1%)
Total	30649 (100%)	30649 (100%)	30649 (100%)

Maps provide a striking visual summary of the “tension zones” for sustainable use of soil resources (see **Figure 2**).

Figure 2. Potential for Sustainable Use of Soil ResourcesFigure 2. Potential for Sustainable Use of Soil ResourcesFigure 2. Potential for Sustainable Use of Soil Resources

Figure 2a. Low Level of Inputs

Source: Eswaran et al. 1997.

Figure 2b. Medium Level of Inputs

Source: Eswaran et al. 1997.

Figure 2c. High Level of Inputs

Source: Eswaran et al. 1997.

4.0 Alternatives and Adjuncts to Commercial Inorganic Fertilizers.0 Alternatives and Adjuncts to Commercial Inorganic Fertilizers.0 Alternatives and Adjuncts to Commercial Inorganic Fertilizers

4.1 Organic Nutrients.1 Organic Nutrients.1 Organic Nutrients

Increasing the use of commercial inorganic fertilizers will not by itself solve Africa's soil nutrient and food production problems. Organic nutrients may eventually provide a sustainable alternative to chemical fertilizers (see **Box 5**), and rock phosphate may be a useful soil amendment in some parts of Africa.

Box 5. Sustainable Alternatives to Chemical FertilizersBox 5. Sustainable Alternatives to Chemical FertilizersBox 5. Sustainable Alternatives to Chemical Fertilizers (McGuinness 1993)

How Chemical Fertilizers Work. One of the primary strategies that plants use to obtain nutrients and water is to actively seek them out by having a root system that is continuously expanding. In this light, chemical fertilizers are a brilliant idea. They bring about an increase in plant productivity by insuring that the roots will encounter sufficient nutrients, no matter how well the roots grow in the soil. From an ecological viewpoint, however, chemical fertilizers are a brute force approach, since nutrients are made available to plants without accounting for how the ecosystem will respond to the sudden input of nutrient. Chemical fertilizers may supply nitrate, but they do not supply the energy necessary to cause its storage (immobilization) by microbes in organic matter. Phosphorus may be applied in such large quantities that the soil's fixation capacity is exceeded, but due to crop harvest, very little of it enters the biologically active pool. Potassium ions may be added in abundance, but chemical fertilizers do nothing to ensure that there is enough cation exchange to store them. In short, fertilizer nutrients are not integrated into the nutrient cycles, because they do not supply energy for microbes or the raw materials for the creation of humus.

Because chemical fertilizers are used without regard for how they fit into the ecosystem, they are used inefficiently. Typically 25 to 50% of the applied compounds are likely to be taken up by the crop, even when efficiencies are high. Much of the extra is likely to end up as pollution. Thus, the inefficiency and pollution by chemical fertilizers results from the fact that these compounds fail to fit into soil nutrient recycling. In fact, were it not for the biological activity that exists within most soils, chemical fertilizers would probably not have such a good track record. After all, soil organisms sequester a portion of the nutrients applied as fertilizer, making them biologically active or storing them for future use. Were it not for microbial immobilization of fertilizer nutrients a considerable portion would be lost through export or fixation. Mineralization of these scavenged nutrients at a point later in the growing season when crops can make use of them thereby increases the efficiency of fertilizer usage. (pp.159-160)

The Role of Chemical Fertilizers. Perhaps the biggest problem with chemical fertilizers is that too much has been expected of them; they have been viewed as a panacea for soil fertility problems. To the extent that they replace exported nutrients, chemical fertilizers may often be a necessity in achieving high yields. On the other hand, since they do not improve soil physical structure or enhance soil biological activity, they are, by themselves, usually insufficient to maintain soil fertility. They must be used in conjunction with strategies that are designed to manage and maintain soil organic matter levels. (p.179) [Author's note, based on personal communication from M. McGahuey (USAID/AFR/SD, 1997): Phosphorus can be used to enhance soil biological activity.]

Interestingly, the enhancement of fertility factors by using organic fertilizers causes an immediate improvement in the utilization of chemical fertilizers. Increased water availability, for example, improves the utilization of fertilizer by crops. This points out one of the primary advantages of using organic fertilizers in developing countries: their use does not lock the user into a technology that cannot be improved as his/her financial situation improves. In fact, because organic and chemical fertilizers have a complementary effect, the investment required to purchase chemical fertilizers will have even higher payoffs when an organic fertilization scheme has been utilized. Such large returns on investment are often necessary to entice risk-averse, traditional farmers into using new technologies. (pp.183-184)

4.2 Phosphate Rock as a Soil Amendment.2 Phosphate Rock as a Soil Amendment.2 Phosphate Rock as a Soil Amendment (D. Hellums, IFDC, personal communication)

Although Africa has a large number of phosphate rock (PR) deposits, outside of the North African deposits (Morocco, Tunisia) and the deposits in South Africa, Togo, Senegal, and Zimbabwe, most others are and will continue to be insignificant. Morocco and Tunisia are major producers/exporters in the global phosphate fertilizer industry. Likewise, Togo and Senegal export much of their production to markets in Western Europe, whereas production in South Africa is used domestically and exported. In the past, production in Zimbabwe was used to meet internal demand but with markets opening in this region there is a question as to whether the industry can compete with their neighbors in South Africa. While many of the remaining countries in SSA have PR deposits, most cannot be economically used to meet their need for phosphorus fertilizers in the foreseeable future. These deposits are not used for various reasons, including:

- Overall costs relative to benefits associated with developing/mining the deposit are prohibitive.

- Many deposits have problem ores which require expensive separation and beneficiation processes to improve their ability to provide P to plants.

- Reactivity[1] of the PR prohibits it from supplying sufficient amounts of P to meet crop needs therefore it cannot be used for direct application to crops. [There are some experiments in Burkina Faso on using compost to acidulate rock phosphate. Incorporating PR into compost improves solubility; this is a cheap and efficient way to utilize the phosphorus (Personal communications, M. McGahuey, USAID/Africa Bureau, and P. Antoine, WIIAD).]

- Deposits may be small.

- Infrastructure to support transport of PR or its beneficiated products from mine sites to agricultural areas is lacking. For example, in Mali (medium reactive PR) and Burkina Faso (low to medium reactive PR) where indigenous deposits are mined, transport costs are a major factor in limiting where the material can be profitably used relative to imported P fertilizer. With present-day supply levels and prices it is difficult for indigenous water-insoluble PRs to compete well with imported water-soluble P fertilizers as a source of P for food crops.

Phosphate rock's reactivity is determined by the mineralogy of the particular phosphate rock. In turn, reactivity is indicative of that P will be released/dissolved from the PR for plant uptake in acid soils. Based on its solubility in neutral ammonium ci S. P_2O_5), PRs are classified as being very low (C.S. P_2O_5 < 1.1%), low (C.S. P_2O_5 1.1-3.4%), medium (C.S. P_2O_5 3.4-5.9% (C.S. P_2O_5 > 5.9%) in reactivity. Low reactive PRs will not supply sufficient P to support crop growth, whereas medium and l tive PRs can respectively supply significant or sufficient levels of P on acid soils for certain crops. (D. Hellums, IFDC, pers munication, 1997)

To summarize, in SSA even though a country may have a PR deposit, in most cases this does not represent a cheap source of P fertilizer. For now in SSA, most local deposits should be seen as having limited value in meeting the annual P requirements of food crops.

4.3 Avoidance of "Fertilizer Addiction"

Some have portrayed excessive fertilizer use as equivalent to an addiction. McGuinness (1993) notes in passing, that the addictive tendency of chemical fertilizers has been recognized, although not widely disseminated, for a long time. In 1987, I.P. Roberts compared chemical fertilizer use by farmers to alcohol addiction: "to stop meant collapse, but to go on implied constantly increased use" (Pariquin 1984). L.L. Van Slyke (1912) understood that addiction occurred because farmers could ignore the ecological factors that confer soil fertility. He pointed out that:

> The most serious disadvantage in the use of commercial fertilizers, as they are actually needed in most cases, is that farmers are not stimulated to acquire needed information in regard to plant-foods and their proper use. Many farmers use commercial fertilizers blindly in somewhat the same way people use patent medicines. In the hope of increasing yield of crops, without definitely learning why crops are decreasing, commercial fertilizers are tried, some brand being tried in accordance with the recommendation of a neighbor or a seller of fertilizers. It is easy to acquire the "fertilizer habit" and difficult to abandon it. This blind, slavish use of fertilizers deadens the intellectual activity and in many cases has led to actually decreased productivity of soil when sole dependence has been placed on their use for long-continued periods (pp.182-183).

Nevertheless, both inorganic and organic fertilizers must be applied to most soils to achieve the level of soil nutrients necessary to increase yields. Worldwide, inorganic fertilizers supply nearly 40% of the nutrients used by crops. The other sources are releases from soil nutrient reserves (46 percent), organic fertilizers (6 percent), biological nitrogen fixation (10 percent of nitrogen) and atmospheric deposition. The present heavy reliance on soil reserves for plant nutrients is not sustainable and highlights the amount of soil mining occurring at a global level (Harold et al. 1994).

5.0 Agricultural Intensification and Extensification.0 Agricultural Intensification and Extensification.0 Agricultural Intensification and Extensification

Food production—more precisely, the value of agricultural output—can increase either by extending the area of cropped land (extensification), or by increasing the value of crops on the existing cropped area (intensification). That is, the value of agricultural output can increase either by increasing the land input (extensification) or by increasing other inputs on existing agricultural land (intensification). There are benefits and costs associated with each alternative.

5.1 Extensification.1 Extensification.1 Extensification

One of the main environmental costs of extensification is deforestation, including benefits of permanent vegetation, such as protecting wildlife habitats, biodiversity and the global climate, maintaining hydrological balances, controlling floods, and protecting topsoil against erosion. Forest area declined on average by 0.5% per year in SSA as a whole in the 1980s (UNDP/World Bank 1992). Land which is good for crops is already being cultivated; expansion of cultivated area usually takes place on marginal land areas, especially in arid zones.

5.2 Intensification.2 Intensification.2 Intensification

Intensification involves increasing the *value* of crops on the existing cropped area, not necessarily increasing the *yield* of the crops. This is an important distinction, because the value of the crops may be higher if the risk of crop failure is reduced than if the potential (or even the expected) yield is increased. Subsistence farmers are usually risk-averse, sometimes preferring traditional varieties with stable low yields to improved varieties with variable high yields (low mean, low variation preferred to high mean, high variation). This preference can influence a wide variety of investments related to intensification.

Intensification can include labor investments in contour dikes, terraces, or composting, as well as capital investments in fertilizer or improved varieties. Farmers may make capital investments in water harvesting works or in agroforestry instead of in inorganic fertilizer if reducing risk (increasing the lowest possible yield) is more important than maximizing yield (increasing the potential or expected yield).

Intensification relieves pressure on forests and other fragile lands. Intensification can also take advantage of relatively better soils and areas with geographical advantages, such as areas with relatively better access to markets. However, intensification of agriculture is not the same as conservation of forests and habitats. Intensification can—but will not necessarily—reduce pressure on fragile lands. Intensification and conservation can be related but they are not the same thing.

Kerr and Crosson (1995) note:

Nutrient mining is potentially the most serious threat to sustainability associated with agricultural intensification. The fragile soils that predominate in most of Africa have limited natural fertility;

they can only sustain cropping for short periods followed by lengthy fallow periods. In the intensification process, as land becomes scarce the pressure to cultivate a given plot increases, and fallow periods decrease.

Erosion can also increase during the process of agricultural intensification. First intensification implies shortened rotations and reduced fallowing, so the soil will be more exposed to the elements. Second, in more advanced stages of intensification, farmers tend to shift from intercrops to monocrops. This reduces the crop cover during the course of each season, again increasing the likelihood of erosion.

On the other hand, with intensification comes the incentive to invest in land improvements, such as terraces and bunds, that are likely to reduce erosion. Intensification also implies higher inputs, leading to higher yields that contribute to higher crop cover. Also, intensification implies that output per hectare is higher than under extensive systems, so for a given level of food production, less area is under cultivation and hence a smaller area is susceptible to erosion.

Intensification alone is not likely to be sufficient to provide Africa's food needs. Current yields of cereals in SSA are about 1 mt/ha/yr. To meet the target of 4% annual growth on existing agricultural land (three times the growth rate of production in the 1980s), yields would have to increase to 2.2 mt/ha/yr. by 2025. This is higher than the 1.6 mt/ha/yr now achieved by India, which has considerably more irrigated land, fertilizer, and other inputs. Although some researchers hope that the 4% annual increase can be achieved with 3.5% yield increases and 0.5% area increases, others believe that a 2%-2% split is more realistic (Seckler 1994).

A study of the linkages between the environment, population, and development in Madagascar states:

The battle to protect Madagascar's biodiversity will be won or lost on agricultural land away from the forest, because the battle in which rural populations are engaged is about production and land use, not about the environment. In this battle, environmental outcomes are the by-product of land management and production decisions.

Traditional land management practices rely on extensive agriculture, which must continually bring new land into production to feed a growing population. … If forests are being destroyed for short-term reasons of food and income, then sensitizing populations to the long-term benefits of conservation will not be sufficient to effect a change in their behavior. It will also be essential to fundamentally alter the agricultural production equation in favor of land management systems which can *produce more* on *less land*—intensified systems. To be widely adopted, intensification must be sufficiently attractive in terms of income and security that the majority of rural households view it as being *in their own economic self-interest.*" (Shaikh et al. 1995)

A World Bank report on strategies for SSA is optimistic about the prospects for agricultural growth:

There are several reasons why high agricultural growth rates may be obtained in sub-Saharan Africa. Agriculture here has a lower base from which to grow—crop yields are incredibly low. Fertilizer use is a small fraction of fertilizer used in other countries. Irrigated area is about 20 percent of potential. Infrastructure development lags far behind that of most other developing countries.

Most of the 1.7 to 1.9 percent per annum average agricultural growth that has occurred has been due to expansion of cultivated area, not yield increases. There are many reasons for this. For one, there has been little investment in irrigation, which was a main input into Asia's Green Revolution. In addition, unlike Asia, there has been little demand by farmers for yield-increasing agricultural technologies." (Cleaver 1993).

A comprehensive analysis of the population, agriculture, and environment nexus in sub-Saharan Africa notes:

A key conclusion of this study is that far more emphasis needs to be placed on efforts designed to promote effective *demand* for sustainable and environmentally benign farming technologies, for family planning services, and for resource conservation. In most past sectoral development efforts, emphasis has been placed largely on the supply side (efforts to develop and deliver technology and services), while the need to generate demand has remained largely unrecognized—or at least poorly served. The synergies inherent in the nexus provide considerable potential for addressing the demand side of these important problems.

Lack of demand by farmers for new agricultural technology is as important as lack of supply of appropriate technology in explaining slow agricultural growth. Lack of demand is related to several factors [including]:

•In much of sub-Saharan Africa poor agricultural and economic policies, combined with currently low world prices for many agricultural products, have reduced the profitability of farming, and hence the incentive to intensify farming. They have often restricted farmers' ability to participate fully in land management, marketing, or price setting.

•Appropriate improved agricultural technology [such as better-adapted, higher-yielding seed varieties] for farmers is often locally unavailable or unknown; there can be no effective demand for what does not exist or is not known to exist. (Cleaver and Schreiber 1994)

6.0 Price Policy and Non-Price Factors.0 Price Policy and Non-Price Factors.0 Price Policy and Non-Price Factors

High transport costs, lack of availability when needed, inadequate demand to stimulate investment in production and distribution, lack of credit, and weak extension services constrain fertilizer use. These factors—along with unpredictable rainfall—are often more important than the price of fertilizer.

6.1 Incentives for Intensification.1 Incentives for Intensification.1 Incentives for Intensification

A recent analysis of investments for sustainable intensification of African agriculture (Reardon et al. 1995) noted that:

Incentives and capacity to invest in more intensive cropping technologies have declined during the past decade:

1.Cuts in subsidies and government-run input programs reduced farmers' incentive to use fertilizer, improved seed, and animal traction.

2.The reduction or elimination of agricultural credit programs has severely reduced the capacity of farmers to invest in these technologies.

3. Despite the increasing need for conservation investments, it does not yet pay farmers to invest. Existing incentives do not incorporate the net social benefit of these measures.

Identifying cost-effective ways to increase the farmer's incentive and capacity to use chemical fertilizer, organic matter, improved seed, and equipment is crucial. Addressing this need will require [among others]:

• Reexamining the taboo subject of selective subsidies for fertilizer and even soil conservation investment that are a net benefit to society.

6.2 Fertilizer Price Subsidies.2 Fertilizer Price Subsidies.2 Fertilizer Price Subsidies

In contrast to the usual economic arguments against price subsidies, one study by the Organization for Economic Cooperation and Development (OECD) recommends subsidies (**Box 6**).

Box 6. Fertilizer Subsidies: The Efficiency/Distortion Argument Reconsidered**Box 6. Fertilizer Subsidies: The Efficiency/Distortion Argument Reconsidered****Box 6. Fertilizer Subsidies: The Efficiency/Distortion Argument Reconsidered** (Fontaine and Sindzingre 1991)

Considerable concern has been expressed as to possible distortions induced by fertilizer subsidy schemes. Although textbook microeconomics unambiguously established that subsidies and price manipulations induce misallocations of productive resources, one should ask what, in practice, are the inefficiencies dreaded in this precise context. Or, to put it another way, what are the distortions that subsidies can bring about.

The first is over-consumption. But the major problem in Africa is quite the opposite—i.e., under-consumption. Since even the highest recommendations for fertilizer use in SSA agricultures are well below the point of diminishing return, "distortions" induced by subsidy necessarily push in the right direction.

This suggests that the distortion argument should be reconsidered. If, disregarding the reasons for under-consumption of fertilizers, actual behaviors of farmers are taken as a datum, and if the policy objective is to increase utilization of fertilizers, then attitudes leading to under-consumption should be considered as "distortions"—because they result in private decisions which move the equilibrium point away from optimality, or contradict the "social preference function." The general principle that correction should be applied at the point where distortion originates should then lead to recommendations in favor of an active policy of fertilizer subsidy.

Another distortion lies in possible *misuse of fertilizers*. But action on prices is not likely to correct this misuse, since it results practically from lack of knowledge. This is clearly an issue calling for reform or intensification of the extension network, and does not depend on pricing policies. Furthermore, even taking into account that no "all-purpose" fertilizer is available, but given the generalized level of under-consumption, misutilization (e.g., applying a given fertilizer to the wrong crop) still exerts positive effects, except (in rare cases) where misuse results in aggravation of soil condition. In any case, controlling such misuse by price increase alone will imply reduction of misutilization through reduction of utilization, which is a very drastic cure.

Leakages from subsidized to unsubsidized programs are often considered as a wastage of resources, and as a possible cause for misutilization. One should, however, note that leakages result not from subsidy, but from discrimination. Subsidy schemes as such are not responsible for leakages which occur only if multiple distribution programs for fertilizer co-exist, some of which are subsidized while others are not. They would disappear if the same policy were implemented throughout a country—or in neighboring countries. If one seeks to unify fertilizer policy at country or regional level, the simplest and cheapest policy will be to curtail subsidies altogether. If specific schemes have to be kept in operation, however, then costs of leakages, if unavoidable, should be weighed against possible advantages. The decision will depend on the nature of the argument against leakages, viz. whether it is one of economic efficiency, or of equity.

If economic efficiency considerations prevail, then costs of leakages should be taken into consideration *ex ante* and considered as part of the budgetary costs of targeted programs.

Furthermore, education regarding fertilizer utilization could reduce leakages. If the small farmers find it more profitable to use the subsidized fertilizer to increase production rather than to resell it to larger farmers, the motive for leakage could be reduced. Improved extension (information about ways to apply fertilizer most productively) would increase profitability to small-holders, and hence further contribute to reduce leakages.

6.3 Non-Price Factors.3 Non-Price Factors.3 Non-Price Factors

Increasing fertilizer use can be achieved in a variety of ways, not just by lowering its price. The expected gains from using more fertilizer can also be increased through improved land tenure policies, better dissemination of research results and technology, and improved transport infrastructure. Reardon et al. (1994) advocate a "middle path" to raise farm productivity:

> Promotion of improved input use will need to be innovative in order to be consistent with widespread fiscal constraints and the goals of structural adjustment.
>
> In the past in many cases input use has been promoted in ways that are not economically sound, that in the long run are not fiscally sustainable. Yet the reduction of government programs and subsidies associated with structural adjustment appears to have discouraged the use of modern inputs (improved seed, fertilizer, animal traction), by raising cost and reducing availability.
>
> The upshot is that farm input costs must be reduced without returning to fiscally unsustainable subsidies. We advocate a "middle path" between fiscally unsustainable government outlays and complete government withdrawal from support to agriculture. This middle path implies substantial public and private investment in agricultural research, human capital, and production and market infrastructure. Policy reform alone (exchange and interest rate policy, market liberalization, privatization), while important, is not sufficient to spur higher agricultural productivity; resource, technology, and market constraints on agricultural growth must be tackled directly by allocating government and donor resources to overcoming them.
>
> Public investment should be such that it complements and spurs private investment on-farm, in the input distribution system, and in primary input processing. It is essential that government and donors invest in understanding how to promote the economic use of the tools of sustainable intensification—fertilizer, animal traction, organic inputs, and soil conservation investments.
>
> Thus the debate should be reopened on identifying cost-effective ways of increasing access to inputs, by improving the delivery of inputs and giving farmers the means to pay for them. This effort is especially appropriate in countries whose macroeconomic environment has become more favorable through structural adjustment. This should be a priority policy issue in Africa in the 1990s and beyond.

More broadly, perhaps an effective way to increase crop production would be to reduce excessively large seasonal output price fluctuations by promoting more efficient marketing and storage of produce. Farmers could then focus their skills on producing more, secure in the knowledge that low output prices would not be a problem at harvest time.

7.0 USAID Activities in Africa.0 USAID Activities in Africa.0 USAID Activities in Africa

There have been at least 34 USAID projects related to fertilizers and soil fertility in Africa (see **Table 6**). These projects include commodity import programs (CIPs), structural adjustment programs (SAPs), fertilizer sector reform programs, and more general agricultural policy and production activities. Commodity import programs which provided fertilizer temporarily relieved supply constraints for this important input, but generally did not significantly increase long-term fertilizer use. For example, Zambia has had several CIPs, yet its use of fertilizer remains below that of neighboring Tanzania, which had no such programs; other factors influence fertilizer more than CIPs. In addition, these commodity programs can inhibit local dealer development. SAPs often decrease fertilizer use when price subsidies are reduced or removed (Senegal in the early 1980s shows this quite clearly). Agricultural policy and production activities, although less directly targeted on fertilizer use, may increase fertilizer use the most in the long term by helping to reduce market inefficiencies and improving the knowledge base upon which farmers make their production decisions.

7.1 Lessons Learned.1 Lessons Learned.1 Lessons Learned

Recent fertilizer-related activities provide important lessons:

- The USAID Fertilizer Pricing and Marketing Reform Program in Kenya created a growing demand for diammonium phosphate (DAP) fertilizer, particularly among maize, wheat, and horticulturist growers. This program increased fertilizer use by small farmers through improved efficiency in marketing. Reforms resulted in fertilizer price decontrol in 1990. (USAID/Kenya 1995, 1996; see Allgood and Kilungo 1996 for an appraisal of the fertilizer market in Kenya).

- In Malawi, USAID support was instrumental in eliminating all fiscal seed and fertilizer subsidies and creating a level playing field for all players in the input supply business. Most fertilizer marketed throughout Malawi is now sold by a number of private companies and individuals. (USAID/Malawi 1996).

- USAID efforts under the Development of Competitive Markets (DCM) program helped to open up and sustain private sector participation in the fertilizer import and distribution market. USAID's close coordination with other donors supported World Bank efforts to reach agreement with the government to deregulate fertilizer prices (by 1998), to eliminate fertilizer subsidies (by 1998) and to sell, transfer or close all of the government-owned fertilizer marketing centers by 1997. USAID supported private fertilizer dealers in lobbying the government to drop a policy that excluded private dealers from being able to sell fertilizer through the national fertilizer dealer program. This led to increased fertilizer sales through private dealers, expansion of the demand for fertilizer credit, and expansion and strengthening of these new private sector distribution channels. (USAID/Ethiopia 1995).

Table 6. USAID Fertilizer-Related Projects in Africa**Table 6. USAID Fertilizer-Related Projects in AfricaTable 6. USAID Fertilizer-Related Projects in Africa**

Country	Title	Cost	Year	Description
Cameroon	Small Farmer Fish Production	$0.6 M	1980-1983	Increase fish pond production by upgrading ability of extension service to provide fingerlings and TA.
Cameroon	Fertilizer Subsector Reform Program	$1.5 M	1987	Studies and monitoring of the privatization of fertilizer distribution and marketing.
Cameroon	Fertilizer Subsector Reform Program	$17 M	1987	Support of efforts to remove fertilizer subsidies and privatize fertilizer distribution and marketing.
Chad	Lake Chad Irrigated Agriculture	$1.3 M	1977	Improve and expand irrigated agriculture around Lake Chad.
Ethiopia	Development of Competitive Markets	$67 M	1992-1995	Reforms which encourage greater private sector participation in fertilizer distribution.
Ghana	Agricultural Extension and Production	$3.7 M	1957-1973	Increase production (rice, maize) through availability of essential inputs (seed, fertilizer, techniques).
Ghana	Managed Input and Agricultural Services	$15 M	1976-1979	Six components including fertilizer procurement.
Ghana	Agricultural Productivity Promotion	$20 M	1988-1990	Reduce/eliminate fertilizer subsidies and privatize fertilizer sales over time.
Kenya	Agricultural Sectoral Development	$20 M	1980-1983	Grant is provided to help relieve trade balance deficit by financing the purchase of fertilizer.
Kenya	Agricultural Sector Grant	$4.4 M	1982	Commodity Import Program to provide BOP and budgetary support to finance imports of fertilizer.
Kenya	Structural Adjustment Program Grant	$76 M	1983-1985	Remove restrictions on importation of major agricultural inputs and make foreign exchange automatically available for such imports.
Kenya	Structural Adjustment Program Grant II	$53 M	1986-1993	Fertilizer Market Development Program; Commodity Import Program (CIP); and TA.
Kenya	Fertilizer Pricing and Marketing Reform	$58 M	1989-1991	CIP to increase fertilizer use by promoting a fertilizer market network at prices that include adequate profits to importers and distributors.
Lesotho	Agricultural Policy Support Program	$3.4 M	1988	Development of competitive market for agricultural inputs, and elimination of fertilizer subsidies.
Liberia	Upper Bong County Integrated Rural Devel	$6.6 M	1977	Establishing co-ops to provide farm inputs, credit, and marketing services.
Malawi	Agricultural Sector Assistance Program	$12 M	1991-1996	Studies on smallholder crop production/marketing, input availability, equity, and crop diversification.
Mali	Action Ble	$2.1 M	1978-	Fund to provide farmers with credit to purchase

Country	Title	Cost	Year	Description
			1981	pumps and inputs such as seeds and fertilizers.
Mali	Semi-arid Tropics Research (ICRISAT)	$0.6 M	1979-1981	Research will be expanded to address such areas as natural and organic fertilizers.
Senegal	Senegal Cereals Production Project II	$7.7 M	1980-1983	Off-station research on peanut and sorghum, fertilizer, insect problems of cowpea, and dry season plowing.
Senegal	Agriculture Development	$5 M	1983	Import 12,000 mt of urea for distribution and 5,000 mt of sulfur for an existing fertilizer mixing plant.
Senegal	Agriculture Development Support	$20 M	1987-1989	Increase cereals production by privatizing agricultural input distribution and seed multiplication.
Sudan	Commodity Import Program IV	$60 M	1983	CIP funds to purchase fertilizer, jute and lubricants, capital equipment, chemicals, and technical services.
Tanzania	Village Environmental Improvement OPG	$0.4 M	1981	Operational program grant provided to Lutheran World Relief (LWR) to launch an integrated rural development program.
Uganda	Commodity Import Program	$3 M	1979	Grant to finance imports, including fertilizer, to increase the production of cash crops in the small farm agricultural sector. CARE or other private voluntary groups will distribute these inputs.
Zaire	Commodity Import Loan	$10 M	1976	Foreign exchange for imports of U.S. goods, including $1 million for fertilizer.
Zaire	North Shaba Maize Production	$19 M	1976-1985	Research and extension, cooperatives, intermediate technology, credit, transportation, M&E.
Zambia	Commodity Import Program	N/A	1980	CIP funds used to import commodities for the agricultural sector, primarily fertilizer.
Zambia	Commodity Import Program	$15 M	1981	Loan to help redress BOP problems and to accelerate agricultural development through fertilizer imports.
Zambia	Commodity Import Program	$10 M	1982	Loan for use in importing about 33,000 mt of fertilizer compounds.
Zambia	Commodity Financing	N/A	1983	CIP will fund agricultural imports, especially fertilizer.
Zambia	Commodity Import Program	$15 M	1984	Program funds will be used to import fertilizer, fertilizer raw materials, and agricultural spare parts.
Zambia	Multi-Channel Agricultural Marketing	$25 M	1985-1988	Non-project assistance grant to support maize and fertilizer marketing liberalization
Southern Africa	Blantyre-Mwanza-Mozambique Border	$0.7 M	1984	Reduce the cost and time of transporting goods (specifically maize and fertilizers) over the road

Country	Title	Cost	Year	Description
Regional	Section			between Malawi, Mozambique, and Zimbabwe.
African Regional	Israeli African Support	$1.5 M	1986	Increase the use efficiency of nitrogen and phosphate fertilizers applied to corn and wheat in Malawi.

N/A: Not available in CDIE database.

7.2Environmental Problems Are Unlikely.2Environmental Problems Are Unlikely.2Environmental Problems Are Unlikely

USAID's fertilizer-related activities in Africa are unlikely to cause environmental problems. The only ongoing project which is directly involved in fertilizer use is the Development of Competitive Markets (DCM) program in Ethiopia. The primary objective in this program is to support the policy of opening up the marketing and distribution of agricultural inputs, particularly fertilizer. Fertilizer sales in Ethiopia in 1995 were 236,000 mt, nearly an 80% increase over 1993 (when sales were 132,000 mt), but this quantity is still less than 20 kg/ha—hardly a level which will cause environmental problems.

7.3 Non-Project Assistance.3 Non-Project Assistance.3 Non-Project Assistance

Non-project assistance (NPA) and agribusiness promotion efforts which result in increased fertilizer use should benefit the environment, not harm it. NPA efforts—which are concerned with economy-wide reforms, agricultural sector reforms, institutional strengthening and policy reforms, intensification policies and practices—should lead to increased fertilizer use only if such use is economically beneficial to individual farmers. NPA efforts which promote economic efficiency in the context of environmental sustainability should thus lead to increased fertilizer use only where such use is environmentally as well as economically beneficial. Local NGOs are especially likely to be concerned about the environment. This concern can help USAID identify any consequences of increased inorganic fertilizer use.

A recent study concluded:

> The Africa Bureau's experience demonstrates that NPA provides an important, unique complement to the provision of U.S. technical assistance. USAID's NPA is *not* balance of payment support for macroeconomic structural adjustment. It is support to leverage reform in a particular sector. In all cases, NPA is accompanied by targeted project support to reinforce the systemic changes, undertaken by the government. Perhaps most importantly, NPA promotes African ownership. NPA puts the onus of reform on the Africans. Often reforms are born out of national, participatory deliberations which result in long-term sector objectives and institutional and human capacity building. And NPA empowers advocates committed to sound sectoral policy reform. In countries that are committed to reform but lack the capacity to implement specific, targeted policy reforms, NPA ensures the financial flexibility for African governments to allocate the critical resources needed to cover the short-term transition costs in order to make long-term systemic reforms, benefitting African people at the most local level. (USAID/Bureau for Africa 1996, p.15)

Catterson (1996), in a review of environmental concerns related to NPA food aid programming, concludes that "the prime focus for developing the capabilities and responsibilities for environmental review of food aid programs should be at the field level" (p.37). This is equally true for NPA efforts which may result in increased fertilizer use. As noted above, agronomic conditions in Africa vary widely, and there is no substitute for on-the-spot monitoring of the impacts of changes in agricultural practices. Catterson further suggests that non-governmental organizations (NGOs) and private voluntary organizations (PVOs) offer excellent potential for being the focus of USAID efforts to enhance environmental review capabilities—this is also equally true for the review of agricultural programs involving fertilizer.

8.0 USAID Environmental Strategies and Procedures.0 USAID Environmental Strategies and Procedures.0 USAID Environmental Strategies and Procedures

USAID's current strategies and procedures related to the environmental effects of fertilizer use include two important documents:

Knausenberger et al., eds., Environmental Guidelines for Small-Scale Activities in Africa (Office of Sustainable Development, Bureau for Africa, Technical Paper No.18, June 1996).

22 CFR Part 216, Environmental Procedures: The Initial Environmental Examinations of fertilizer-related activities conducted under these procedures have usually resulted in Threshold Decisions (formal decisions which determine whether a proposed action is a major action significantly affecting the environment) that Environmental Assessments and Environmental Impact Statements are not required.

8.1 Integrated Soil Fertility Management.1 Integrated Soil Fertility Management.1 Integrated Soil Fertility Management

USAID's environmental strategy for fertilizer should promote integrated soil fertility management. Current procedures to identify and mitigate negative environmental impacts are sufficient to foresee possible consequences from the inappropriate use of inorganic fertilizer. The current lack of projects means that these strategies and procedures are not actively implemented in the context of encouraging environmentally sound fertilizer use. If USAID increases the number of its agricultural programs, and specifically of fertilizer-related projects, it should insure that activities that encourage fertilizer use do so in the context of integrated soil fertility management, including appropriate fertilizer doses, water management, use of organic matter, and measures to control erosion.

The World Bank notes:

> Three basic soil management techniques can be applied individually or in combination for ISM [integrated soil management]: Conservation tillage—any tillage method that leaves at least 30 percent of the previous crop residue on the surface after planting can be considered conservation tillage; varieties include no-tillage, minimum tillage, or ridge-tillage. Nutrient recycling—This is achievable through crop rotation, inter-cropping and other crop methods that favor the use of available nutrients and water at different soil depths as well as the accumulation of vegetative residues and mulch. Landscape unit management—This uses vegetative contours (such as vetiver grass and seabuckthorn) and agroforestry systems that favor soil erosion control while maintaining enough land area for crop and animal production (World Bank 1994).

More specifically, integrated soil fertility management is a set of environmentally friendly technologies that enables the sustained production of crops grown through the management of the soil's physical and chemical properties—taking maximum advantage of nutrient recycling, biological sources and processes, good conservation farming practices, and technically sound use of inorganic and organic fertilizers (World Bank 1995).

8.2 Soil Fertility as a Capital Investment.2 Soil Fertility as a Capital Investment.2 Soil Fertility as a Capital Investment

Soil fertility is often viewed as a long-term capital investment worthy of donor attention (see **Box 7**).

Box 7. Soil Fertility Replenishment in AfricaBox 7. Soil Fertility Replenishment in AfricaBox 7. Soil Fertility Replenishment in Africa (Sanchez et al. 1995)

The Problem. Soil fertility depletion in smallholder farms of sub-Saharan Africa is probably the fundamental biophysical limiting factor responsible for the declining per-capita food production of the continent. The magnitude of nutrient mining is huge. It has been estimated to average a net *loss* of about 700 kg of N, 100 kg P, and 450 kg K per hectare during the last 30 years in about 100 million hectares of cultivated land. These figures are the balance of nutrient inputs, including fertilizers minus nutrient outputs, primarily crop harvest removals.

The Concept of Nutrient Capital. Nutrient capital can be defined as the stocks of nitrogen, phosphorus and other essential elements that become available to plants in the medium term, say 25 years. Soils vary drastically in their initial levels of nutrient capital, but all suffer depletion of that capital when brought into cultivation.

The basic resources plants use are light, water, and nutrients. Developments in water for agriculture, such as reservoirs and irrigation systems, have long been considered a capital investment, paid for by governments and development banks, while users pay the recurrent costs such as maintenance of canals and drainage ditches in the farm. **Replenishing plant nutrients can also be viewed as a capital investment.** Bringing back nitrogen and phosphorus, the two most limiting nutrients, to their original levels in the soil, in a way the resource is maintained and used for many years, is a capital investment. Recapitalization is not feasible with nutrients that are easily lost from the soil such as potassium, but mechanisms exist to build up the nitrogen and phosphorus capital of soils that have been depleted of these elements. The “interest” from such capital is used for crop production for years, and with good management the “principal” can remain at a high level. Nitrogen and phosphorus however, behave differently in terms of their recapitalization strategies.

9.0 Key Issues in Fertilizer Use in Africa.0 Key Issues in Fertilizer Use in Africa.0 Key Issues in Fertilizer Use in Africa

Eight issues summarize the African fertilizer situation:

- **Site-specific nutrient deficiencies.** Soil and water conditions vary greatly, but many nutrients are severely and widely deficient for good crop growth; fertilizer recommendations must be based on site-specific research results.

- **Low fertilizer use efficiency.** Low fertilizer use efficiency (FUE) should be considered as a constraint to the use of inorganic fertilizer.

- **Nitrogen deficiency.** More inorganic nitrogen fertilizer is needed.

- **Phosphate rock as a soil amendment.** Local phosphate rock can be an important soil amendment source of phosphorus, but present constraints may inhibit widespread development.

- **Complementary practices.** Complementary agronomic practices (organic matter, nitrogen-fixing legumes used in crop rotations, water harvesting, erosion control) are needed in addition to inorganic fertilizers. The organic content of soils needs to be increased through residue management and other available sources to compensate for the lack of active clays in the soils.

- **Fertilizer policies.** Policies on fertilizer use (subsidies, distribution) are key to soil fertility management.

- **Macroeconomic policies.** Market development and macroeconomic policies (particularly trade policies) which influence crop output prices are key to increasing fertilizer use.

- **Non-project assistance.** Non-project assistance (NPA) can be an effective approach to raising food production by increasing the efficiency of fertilizer use in an environmentally-friendly fashion.

10.0 Implications for USAID Programming.0 Implications for USAID Programming.0 Implications for USAID Programming

10.1Integrated Soil Fertility Management.1Integrated Soil Fertility Management.1Integrated Soil Fertility Management

USAID's environmental strategy for fertilizer should promote integrated soil fertility management. Current procedures to identify and mitigate negative environmental impacts are sufficient to foresee possible consequences from the inappropriate use of inorganic fertilizer. USAID should promote site-specific integrated soil fertility management which is based on analyses of the seven issues listed above.

One of the key multi-agency efforts in integrated soil fertility management is the World Bank's Soil Fertility Initiative, which USAID supports through the Soil Management Collaborative Research Support Program. This initiative hopes to establish a framework for the restoration of soil fertility, within which organizations including bilaterals, international organizations, and NGOs can collaborate to reverse the currently deteriorating trend in soil fertility:

> Opportunities abound in African countries to revitalize agriculture and become food secure. But present trends in food production and stewardship of natural resources must change rapidly to reduce poverty and increase household incomes in rural areas. The factor which impedes agricultural growth the most fundamentally is continuous mining of soil nutrients throughout Africa. Until this problem is overcome through implementable actions on the ground, any other efforts to raise crop yields will not change the current trend of declining per capita food production and depletion of natural capital. Without restoration of soil fertility, Africa faces the prospects of serious food imbalances and widespread malnutrition and likelihood of eventual famine. There is heightened urgency now for African countries to implement actions involving all stakeholders at the local and national levels. At the same time, there is a pressing need for the world community to establish a strong partnership among donor agencies, agricultural research institutions, academia, centers of excellence, NGOs, and Africans to promote cooperation and support to address this important development issue. (World Bank 1996, p.1)

10.2NPA Activities.2NPA Activities.2NPA Activities

USAID should build on the success of its NPA activities. The DCM project in Ethiopia has successfully encouraged the development of competitive markets for agricultural inputs, particularly fertilizer. A recent review of policy and institutional change and the environment, which focussed on the environmental impacts of non-project assistance (Rock 1995), had the following conclusion with respect to reforms in agriculture:

- The environmental consequences of policy and institutional reforms designed to increase agricultural growth in sub-Saharan Africa depend on how the right incentives and institutions interact with local (agroecological, village, and individual farm household) conditions.

This conclusion reinforces the need to use local organizations' knowledge in the design and implementation of NPA activities.

10.3Integrate Fertilizer Use with Other Practices.3Integrate Fertilizer Use with Other Practices.3Integrate Fertilizer Use with Other Practices

Environmental guidelines should emphasize the integrated use of inorganic fertilizer in combination with other practices which promote soil fertility. Soil fertility and nutrient losses will continue if inorganic fertilizer use does not increase, but fertilizer is not a complete solution. Great progress can be made by helping smallholders increase their understanding of—and capacity to operate within—the marketplace of ideas, technologies, and commodities. It is better to encourage the development of market systems and the adoption of complementary management practices which make fertilizer use profitable and increase food security, than to focus on fertilizer or any other single remedy for Africa's agricultural problems.

10.4Moving towards more productive and sustainable agricultural development in sub-Saharan Africa

Virtually all assessments of Africa's future conclude that its agricultural performance is critical in the transition to increasingly industrialized economies. Agricultural productivity will have to be the main vehicle for achieving increases in production. Most production growth will have to come from intensification of production on currently cropped land. In many SSA countries, there is not enough new land to create the required increases in production, and in many areas, expansion into marginal lands is already a source of severe environmental degradation.

Sustainable agricultural intensification is thus not only important to increased employment and income, but also is critical to protecting the environment. Sustainable intensification of land currently under cultivation will reduce the pressure on farmers to push onto more fragile lands or to rely on labor-intensive gathering activities off-farm. Sustainable intensification of farm production through the use of improved inputs that raise productivity and sustain increases in land productivity is a major food security and economic growth issue in Africa, given growing land constraints and soil degradation. Progress is being made on various fronts (Christensen and Knausenberger 1995):

•**Development of a favorable enabling environment**. Policies which have been identified as high priority for change in this regard include:

- policies which impede operation of markets and access to them,
- insecure land tenure systems, which reduce incentives to invest in the natural resource base;
- centralized government control of natural resources assets (e.g., forest, water, land) which creates disincentives to more sustainable practices; and

- subsidies which distort resource pricing.

- **Development and dissemination of improved technologies & strategies** which support a "doubly green" revolution, e.g., improved varieties, environmentally friendly pest management; investments in "natural capital management which reduce environmental. damage & enhance the natural resource base; methods for improving nutrient status with natural and chemical fertilizers; and research on new cropping systems which provide multiple environmental and economic benefits.

- **Revitalization of international and national agricultural research systems** to focus on sustaining the stream of new and appropriate "doubly green" technologies, mainly by appropriate strategic plannng and customer-focussed research, development and technology transfer throughcommercialization of technologies (Gelaw et al. 1997).

11.0 Literature Cited and Other References.0 Literature Cited and Other References.0 Literature Cited and Other References

11.1 Cited References.1 Cited References.1 Cited References

Allgood, J.H., and Kilungo, J., "An Appraisal of the Fertilizer Market in Kenya and Recommendations for Improving Fertilizer Use Practices by Smallholder Farmers: Field Report," USAID, September 1996.

Bumb, B.L., "Trends in Fertilizer Use and Production in Sub-Saharan Africa, 1970-95: An Overview," *Fertilizer Research* 28: 41-48, 1991.

Byrnes, B.H., "Environmental Effects of N Fertilizer Use—An Overview," *Fertilizer Research* 26: 209-215, 1990.

Byrnes, B.H., "Agronomic Advantages and Disadvantages of Fertilizer Products," International Fertilizer Development Center, Muscle Shoals, Alabama, 1995.

Catterson, T.M. and W.I. Knausenberger, "Environmental Review and Public Law 480 Food Aid Programming," prepared for the USAID/Africa Bureau (AFR/SD/PSGE), September 1996.

Christensen, C. and W.I. Knausenberger, "The Future of Sustainable Agricultural Development in Africa," USDA/ERS & USAID Africa Bureau. Paper presented at the African Studies Association Annual Meeting, Panel on "Future of African Agriculture," Nov. 1996.

Cleaver, K.M., "A Strategy to Develop Agriculture in Sub-Saharan Africa and a Focus for the World Bank," World Bank Technical Paper 203, Washington, DC, 1993.

Cleaver, K.M., and G.A. Schreiber, *Reversing the Spiral: The Population, Agriculture, and Environment Nexus in Sub-Saharan Africa*, World Bank, Washington, DC, 1994.

Conway, G.R., and J.N. Pretty, *Unwelcome Harvest: Agriculture and Pollution*, Earthscan Publications Ltd., London, 1991.

Donovan, W.G., "Agriculture and Economic Reform in Sub-Saharan Africa," AFTES Working Paper No.18, The World Bank, January 1996.

Eswaran, H., R. Almaraz, E. van den Berg, and P. Reich, "An Assessment of the Soil Resources of Africa in Relation to Productivity," *Geoderma* 77 (1997), pp.1-18.

Eswaran, H., R. Almaraz, P. Reich, and P. Zdruli, "Soil Quality and Soil Productivity in Africa," *Journal of Sustainable Agriculture*, Vol. 10(4), 1997, pp.75-94. [In the text, this reference is cited as Eswaran et al. 1997.]

Environmental and Natural Resources Policy and Training Project/Winrock International, *Agricultural Transformation in Africa*, Proceedings of the Seminar on Agricultural Transformation in Africa, 1993.

Fontaine, J., and A. Sindzingre, "Macro-Economics Linkages: Structural Adjustment and Fertilizer Policy in Sub-Saharan Africa," Paris, OECD Development Center Technical Paper No. 49, December 1991.

Food and Agricultural Organization, "Potential Population Supporting Capacities of Lands in the Developing World," Technical Report of Project INT/75/P13, Rome, Italy, 1982.

Harold, C., B. Larson, and L. Scott, "Fertilizer Consumption Remains Low," *Africa and the Middle East*, International Agriculture and Trade Reports, Situation and Outlook Series, USDA Economic Research Service, WRS-94-3, July 1994, pp.32-37.

Hudgens, R.E., "Sustaining Soil Fertility in Africa: The Potential for Legume Green Manures," 15th Conference of the Soil Science Society of East Africa, August 1996, Nairobi, Kenya.

International Fertilizer Development Center, *Africa Fertilizer Situation*, September 1995.

International Fertilizer Development Center, *Africa Fertilizer Situation*, November 1996.

Kerr, J., and P. Crosson, "Natural Resource Management and Sustainable Agriculture in Sub-Saharan Agriculture: Issues for Discussion, Draft, June 3, 1995.

Knausenberger, W.I., G.A. Booth, C.S. Bingham, and J.J. Gaudet, eds., "Environmental Guidelines for Small-Scale Activities in Africa: Environmentally Sound Design for Planning and Implementing Humanitarian and Development Activities," Technical Paper No.18, SD Publication Series, Office of Sustainable Development, Bureau for Africa, USAID, June 1996.

KUAWAB Business Consultants/Development Studies Association, "Fertilizer Marketing Survey," October 1995, Addis Ababa, Ethiopia.

McGuinness, H., *Living Soils: Sustainable Alternatives to Chemical Fertilizers*, Consumer Policy Institute, Consumers Union, 1993.

Matteson, P.C., and M.I. Meltzer, "Environmental and Economic Implications of Agricultural Trade and Promotion Policies in Kenya: Pest and Pesticide Management," Environmental and Natural Resources Policy and Training (EPAT) Project, April 1995.

Meltzer, M., and P. Szmedra, "Pesticides and Productivity: Opportunities and Dilemmas in an Era of Agricultural Policy Reform in Africa," Environmental and Natural Resources Policy and Training (EPAT) Project, August 1996.

Parish, D.H., “Agricultural Productivity, Sustainability, and Fertilizer Use,” IFDC Paper Series P-18, May 1993.

Reardon, T., E. Crawford, V. Kelly, and B. Diagana, “Promoting Farm Investment for Sustainable Intensification of African Agriculture,” Research Findings, USAID/Bureau for Africa, Office of Sustainable Development, December 1995.

Reardon, T., V. Kelly, E. Crawford, K. Savadogo, and T. Jayne, “Raising Farm Productivity in Africa to Sustain Long-Term Food Security,” Michigan State University, Department of Agricultural Economics, November 1994.

Rock, M.T., “Policy and Institutional Change and the Environment: A Perspective on What Is Known and Not Known,” Environmental and Natural Resources Policy and Training (EPAT) Project, Winrock International Environmental Alliance, July 1995.

Sanchez, P.A., A. Izac, I. Valencia, and C. Pieri, “Soil Fertility Replenishment in Africa: A Concept Note,” Draft, June 28, 1995.

Sanders, J.H., J.G. Nagy, and S. Ramaswamy, “Developing New Agricultural Technologies for the Sahelian Countries: The Burkina Faso Case,” Purdue University, December 1988.

Seckler, D., “Nutrient Mining and a Fertilizer Strategy for Sub-Saharan Africa,” Winrock International, 1994.

Seckler, D., D. Gollin, and P. Antoine, “Agricultural Potential of Mid-Africa: A Technological Assessment,” Winrock International, 1989. Reprinted in *Agricultural Technology in Sub-Saharan Africa*, World Bank Discussion Paper 126, Washington, DC, 1991. Also reprinted as Winrock International Center for Economic Policy Studies Discussion Paper No. 5, July 1992.

Shaikh, A., T. Reardon, D. Clay, and P. DeCosse, “Dynamic Linkages in Environment, Population and Development in Madagascar, draft preliminary assessment, June 6, 1995.

Stoorvogel, J.J., and E.M.A. Smaling, “Assessment of Soil Nutrient Depletion in Sub-Saharan Africa: 1983-2000,” Volume I: Main Report (2nd ed.), Report 28, the Winand Staring Center, Wageningen, The Netherlands, 1990.

UNDP/World Bank, *African Development Indicators*, 1992.

USAID/Bureau for Africa, “Non-Project Assistance (NPA) in Africa: Case Studies on Benin, Ghana, Malawi, Uganda and Zimbabwe,” February 1996.

USAID/Ethiopia, “Results Review 1995.”

USAID/Kenya, “Assessment of Program Impact,” February 24, 1995.

USAID/Kenya, “Results Report: Managing for Results,” March 1, 1996.

USAID/Malawi, “Results Review FY 1995,” March 1996.

Williams, D.W., and J.J. Schultz, *A Fertilizer Supply Strategy for Sub-Saharan Africa*, Proceedings from workshop, Center for Applied Studies in International Negotiations (CASIN), 1990.

Winrock International, *African Development: Lessons From Asia*, Proceedings of a seminar on Strategies for the Future of Africa, 1991.

World Bank, “Integrated Soil Management for the Tropics,” Agriculture Technology Notes, No. 7, November 1994.

World Bank, “Integrated Soil Fertility Management,” Agriculture and Natural Resources Department, September 1995.

World Bank, “Natural Resource Degradation in Sub-Saharan Africa (SSA): Restoration of Soil Fertility,” Africa Region, January 1996.

11.2 Other Sources of Information.2 Other Sources of Information.2 Other Sources of Information

Abt Associates, "Ethiopian Agricultural Policy and Information Systems: Assessment and Recommendations," Draft report prepared for Agricultural Policy Analysis Project, Phase II, June 21, 1995.

Bonsu, M., K.Y. Fosu, and P.K. Kwakye, "Soil Management Action Plan for Ghana," Final Technical Report Prepared for the World Bank, May 1996.

Bumb, B.L., and C.A. Baanante, "The Role of Fertilizers in Food Security and the Environment: Trends to 2020," Paper prepared for IFPRI's 2020 Vision for Food, Agriculture and the Environment, Draft, January 1995.

Byrnes, B.H., and B.L. Bumb, "Population Growth, Food Production and Nutrient Requirements," *Journal of Crop Production*, Vol. 1(2), 1997.

Carr, S.J., "Improving Cash Crops in Africa: Factors Influencing the Productivity of Cotton, Coffee, and Tea Grown by Smallholders," World Bank Technical Paper No. 216, 1993.

Christensen, C., "Agricultural Research in Africa: A Review of USAID Strategies and Experience," Technical Paper No.3, SD Publication Series, Office of Sustainable Development, Bureau for Africa, December 1994.

Clay, D.C., F. Byiringiro, J. Kanasniemi, T. Reardon, B. Sibomana, L. Uwamariya, and D. Tardic-Douglin, "Promoting Food Security in Rwanda through Sustainable Agricultural Productivity; Meeting the Challenges of Population Pressure, Land Degradation, and Poverty," SD Publication Series, Office of Sustainable Development, Bureau for Africa, Technical Paper No. 28, August 1996.

Clay, D.C., T. Reardon, and A. Shaikh, "Population, Environment, and Development in Africa: Dynamic Linkages and Their Implications for Future Research and Development Programming," USAID/SD/PSGE/NRM, Draft, June 1996.

Elwell, H.A., and J.M. Rook, "Soil and Water Conservation Technology in Four Selected Countries in Southern Africa (Malawi, Mozambique, Zambia and Zimbabwe)," Vol. I: Main Report, World Bank, April 1996.

English, J., M. Tiffer, and M. Mortimore, "Land Resource Management in Machakos District, Kenya 1930-1990," World Bank Environment Paper No. 5, 1994.

Environmental and Natural Resources Policy and Training (EPAT) Project, "Proceedings: Colloquium on Promoting Sustainable Agriculture in Sub-Saharan Africa," Winrock International Environmental Alliance, August 1995.

Erdmann, T.K., "An Analysis of 10 African Natural Resources Management Practices," Technical Paper No. 8, ARTS Publication Series, Office of Analysis, Research, and Technical Support, Bureau for Africa, USAID, October 1993.

Fiebig, W., "A Literature Review on the Potential for an Increase in Agricultural Productivity in Niger, West Africa," Rodale Institute, August 18, 1995.

Food and Agricultural Organization/International Fertilizer Development Center/International Fertilizer Association, *Fertilizer Use by Crop*, 1994.

Gilbert, E., L. Phillips, W. Roberts, M. Sarch, M. Smale, A. Stroud, and E. Hunting, "Maize Research Impact in Africa: The Obscured Revolution," SD Publication Series, Office of Sustainable Development, Bureau for Africa, Technical Paper No. 7, December 1994.

Heisey, P.W., and M. Smale, "Maize Technology in Malawi: A Green Revolution in the Making?" CIMMYT Research Report No.4, Mexico, D.F., 1995.

Kiome, R.M., F.N. Muchena, A.M. Kilewe, and L.N. Wambuguh, "Soil Management in Kenya," Draft report, 11 September 1995 (World Bank).

Manu, A., A. Bationo, and S.C. Geiger, "Fertility Status of Selected Millet Producing Soils of West Africa with Emphasis on Phosphorus," *Soil Science,* Vol. 152, No.5 (November 1991), pp.315-320.

McGahuey, M., "Solicited Response to the Review Draft of 'Natural Resources in Sub-Saharan Africa: Review of Problems and Management Needs'," Chemonics International, February 1987.

Pieri, C.J., *Fertility of Soils: A Future for Farming in the West African Savannah*, Springer-Verlag, New York, 1992.

Pieri, C., J. Dumanski, A. Hamblin, and A. Young, "Land Quality Indicators," World Bank Discussion Paper 315, 1995.

Saka, A.R., R.I. Green, and D.H. Ng'ong'ola, "Soil Management in Sub-Saharan Africa: Proposed Soil Management Action Plan for Malawi," World Bank, June 1995.

Sanders, J.H., B.I. Shapiro, and S. Ramaswamy, *The Economics of Agricultural Technology in Semiarid Sub-Saharan Africa*, The Johns Hopkins University Press, Baltimore, 1996.

Speirs, M., and O. Olsen, "Indigenous Integrated Farming Systems in the Sahel," World Bank Technical Paper No. 179, 1992.

Srivastava, J.P., P.M. Tamboli, J.C. English, T. Lal, and B.A. Stewart, "Conserving Soil Moisture and Fertility in the Warm Seasonally Dry Tropics," World Bank Technical Paper No. 221, 1993.

Tobin, R.J., "Malawi's Environmental Monitoring Program: A Model that Merits Replication?" Environmental and Natural Resources Policy and Training (EPAT) Project, January 1997.

USAID, "Strategic Framework for Agricultural Technology Development and Transfer in Sub-Saharan Africa," ARTS/FARA, Bureau for Africa, December 1992.

USAID/Ethiopia, "Strategic Plan 1995-99," CPSP Concept Paper.

United States Department of Agriculture, *Agricultural Policy Reform: Issues and Implications for Africa,* S. Rosen, ed., Economic Research Service, Foreign Agricultural Economic Report No. 250, September 1993.

Woomer, P.L., and M.J. Swift, eds., *The Biological Management of Soil Fertility,* John Wiley and Sons, 1994.

Woomer, Paul L., Nancy Wangari, Mary W. Kinyanjui, and Alice Ndung'u, *The Biology and Fertility of Tropical Soils: Bibliography and Abstracts,* Tropical Soil Biology and Fertility Program, UNESCO-ROSTA, Nairobi, Kenya, October 1995.

World Bank, "Staff Appraisal Report, Ethiopia National Fertilizer Sector Project," April 24, 1995, Agriculture and Environment Division, Eastern Africa Department, Africa Region. Report No. 13722-ET.

World Bank, *Sub-Saharan Africa: From Crisis to Sustainable Growth,* Washington, DC, 1989.

World Bank, "Sustainable Agriculture," Agriculture Technology Notes, No. 13, December 1995.

Zimmerman, R.C., "Recent Reforms in Natural Resources Management in Africa: Trends in the Role of Public-Sector Institutions," Technical Paper No. 9, ARTS Publication Series, Office of Analysis, Research, and Technical Support, Bureau for Africa, USAID, October 1993.

Annex: Environmental GuidelinesAnnex: Environmental GuidelinesAnnex: Environmental Guidelines

The following modifications are suggested for the information pertinent to soil fertility and nutrient losses presented in Section 3.1 of the Africa Bureau Environmental Guidelines (Knausenberger et al. 1996), especially Tables 3.1 “Soil and Water Conservation Practices” and 3.2 “Control of Nutrient Losses”:

Add to Table 3.2:

Phosphate rock can be a cost-effective (depending on transport costs), available source of phosphorus which can be used as a soil amendment; it does not work well in arid climates on short-duration crops or soils with pH > 5.5. Incorporating phosphate rock into compost may be an efficient way to utilize the phosphorus.

Water harvesting (to make efficient use of applied fertilizer).

Use of moderate amounts of lime to reduce soil acidity.

Modify Table 3.2:

Omit or modify “Eliminating excessive fertilizer”—this is rare. A focus on following research-based, site-specific fertilizer recommendations would be better.

Omit references to nitrate leaching—this is rarely a problem (leaching occurs only when there is high fertilizer use, sandy soils, excess moisture, and insufficient crop uptake to use the nitrogen).

Under “Using animal wastes”, modify “Can cause [human] health problems”—in African agriculture it is rare that there is enough animal waste and water together to cause problems.