E C O N O M I C S

Working Paper 96-01

Fertilizer Use and Maize Production in Sub-Saharan Africa

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CIMMYT

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Abstract: In sub-Saharan Africa, greater use of mineral fertilizers is crucial to increasing food production and slowing the rate of environmental degradation. Regional growth rates in fertilizer consumption have never been particularly high, in part because the real price of fertilizer is higher in Africa than in many other developing regions. As subsidies have been removed and exchange-rate distortions corrected over the past decade or more, relative prices paid by farmers have risen to reflect more closely the economic cost of fertilizer. Consumption growth has thus slowed even more. Nonetheless, during the period of declining growth in consumption, fertilizer use on cereals, particularly maize, has become relatively more important than use on cash crops. Strategies for increasing fertilizer use should thus direct more attention to maize and other important staples. In higher potential areas, some fertilizer use on maize is often economically profitable even at higher relative prices of fertilizer. Additional research on the limiting nutrient under farmers' conditions or on the interactions between nutrients and other crop-management factors could help to increase profitability. Policy analysis for Africa's fertilizer sector has tended to focus on subsidies and to neglect other important issues, such as solving credit problems at many points in the marketing channel, supporting appropriate agricultural research, and developing and maintaining infrastructure. Agricultural sector strategies that give sufficient attention to these issues must be developed. Although subsidy removal must be one ultimate policy objective, we recommend gradual withdrawal in countries where fertilizer consumption levels are relatively high. Because many African governments require time and stability to develop policy capacity, detailed institutional analyses can help design second-best solutions to problems of fertilizer policy.

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Introduction

As is well known, food production in sub-Saharan Africa continues to lag population growth. Although large populations and relatively high income growth in developing countries could give Asia the largest net deficit in cereals over the next decade, per capita cereals deficits in Africa[1] will be much greater. And unless present trends are reversed, 25 years from now Africa will have the world's largest net deficit in cereals, both in absolute and in relative terms. Importing food supplies adequate to offset these deficits will not, in all likelihood, be economically feasible (Mwangi 1995).

Soil fertility must be managed more efficiently if Africa is to overcome its food-production problems. Mineral fertilizers and improved nutrient management strategies are crucial to such efficiency. So too are new nutrient sources and more responsive crop varieties. Maize combines widespread importance as a food staple with relatively high fertilizer responsiveness. As a result, maize production and fertilizer use are likely to become even more closely linked than they have been in the immediate past.

This paper reviews information on fertilizer use in Africa, particularly on maize. It summarizes incentives for, and constraints to, increased fertilizer consumption, and it outlines key issues in current fertilizer policy. Section II provides an overview of fertilizer's role in agricultural development, the crucial role it might play in Africa, and the complications involved in developing an appropriate fertilizer policy. Section III reviews data on fertilizer use, particularly on maize. Section IV summarizes factors influencing farmers' use or non-use of fertilizer. Section V focuses on supply constraints to fertilizer use in Africa and on past and current policy responses. Section VI presents fertilizer policy options. Section VII presents conclusions.

An Overview of Africa's Fertilizer Problem

Though the appropriateness of seed-fertilizer technology for sub-Saharan Africa will continue to be debated, the continent can no longer be regarded as land-abundant. That characterization has been one of the major arguments against relying on a seed-fertilizer strategy for agricultural development. Though conditions vary widely (Byerlee and Heisey, forthcoming), many African countries can now be classified as land-scarce (Binswanger and Pingali 1988). Yield increases, rather than area expansion, will thus become progressively more important as a means of increasing crop production.

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[1] We shall sometimes use *Africa* as shorthand for *sub-Saharan Africa*, defined as Africa minus North Africa (i.e., countries on the Mediterranean Sea) and South Africa. Although South Africa shares some food-consumption characteristics with other parts of Africa, differences in agricultural production structures have led us to exclude South Africa from this analysis.

Mineral fertilizers must be included in any agricultural development strategy with a hope of reversing Africa's unfavorable food-production trends. As a result of declining real prices over much of the past century, fertilizer has been vital to the rapid increases in world crop production (Tomich, Kilby, and Johnston 1995). Since the mid-1960s, 50-75% of the crop-yield increases in non-African developing countries have been attributed to fertilizers (Viyas 1983). Fertilizers also complement other major inputs and practices (e.g., improved seeds, better water control) that have had the greatest impact on yield.

Soil nutrient depletion is a common consequence of most African agriculture (Smaling 1993; Stoorvogel, Smaling, and Janssen 1993).[2] Improved organic techniques of nutrient supply will undoubtedly contribute to future soil health and productivity (Kumwenda et al., forthcoming), but relying only on nutrient recycling, however efficient, will not generate the food-production increases required in sub-Saharan Africa, nor will it restore depleted soils (Janssen 1993). For the foreseeable future, "the environmental consequences of continued low use of fertilizers" through nutrient mining and increased use of marginal lands "are more inevitable and devastating than those anticipated from increased fertilizer use" (Dudal and Byrnes 1993, p. 152; Matlon and Spencer 1984).

In light of these considerations, many observers have called for increases in sub-Saharan fertilizer consumption of 15% or more per annum (Mellor, Delgado, and Blackie 1987; Vlek 1990; Desai and Gandhi 1990; Larson 1993). Based on the experience of other developing-world countries, where aggregate fertilizer consumption has increased far more rapidly than in sub-Saharan Africa, such expansion rates will not be easy to achieve in an economically efficient fashion.

Some inherent fertilizer characteristics help to explain both the difficulty of devising optimal policies and the reason such policies are likely to vary in time and space. Fertilizer, like improved seed, is divisible and thus in theory likely to diffuse rapidly—even among small farmers—when agronomic responses and price ratios are favorable. In practice, however, fertilizer costs are a considerably larger part of production-related cash outlays and thus likely to subject the farmer to greater financial risk than do improved seed costs. Even after fertilizer is adopted, the information requirements of determining optimal fertilizer types and application rates pose considerable challenges to agricultural research systems. Farther back in the marketing channel, seasonal demands and bulkiness of product lead to relatively slow stock turnover and considerable storage requirements, which, in turn, result in high financing charges. Distributors are faced with their own credit requirements, as well as the need to offer credit to end users or to work closely with credit agencies (Shepherd 1989).

2 Although the information base for the nutrient balance models used in these calculations is not particularly strong, a simple macro exercise yields the same conclusion. Nutrients lost to the system through export crops leaving the continent and locally produced cereals consumed by non-farmers are considerably greater than those added at current consumption rates of mineral fertilizers (P.L.G. Vlek, personal communication). Both micro and macro nutrient balance models are insufficient bases for recommendations concerning fertilizer application rates.

In addition, fertilizer production is characterized by considerable economies of scale. To operate at maximum efficiency, for example, an ammonia/urea plant needs to produce about 500,000 metric tons of urea per year.[3] Plants take three or four years to come on-line and another two years to reach full capacity. The economics of fertilizer-production investment depend heavily on potential domestic demand, the availability of local feedstocks, the cost of capital, and ex-factory pricing policy (Segura, Shetty, and Nishimizu 1986; Vlek 1990). Most fertilizer-producing countries tend to plan output to meet domestic demand, with exports occurring as a residual. As a result, world fertilizer prices have tended to be more volatile than those for other commodities, making the decision about whether to rely on the world market or to initiate domestic production a particularly difficult one, even for countries where potential demand is large (Ahmed, Falcon, and Timmer 1989).[4]

Many knowledgeable observers conclude that "perhaps more than any other important component of the rural economy, fertilizer use in developing countries is in a continuous state of disequilibrium" (Ahmed, Falcon, and Timmer 1989, p. 26; Desai and Stone 1987) and that supply side constraints are often more important than demand factors in limiting growth of consumption. In numerous writings (e.g., Desai and Gandhi 1990), Gunvant Desai emphasizes four processes that determine changes in fertilizer consumption: 1) those that influence the agronomic potential for fertilizer use; 2) those that convert the potential into farmers' effective demand for fertilizer; 3) those that determine the growth of aggregate fertilizer supply; and 4) those that develop the fertilizer distribution system. The stylized interactions between these processes are depicted in Figure 1. Although their relative importance is likely to vary among countries and world regions, the framework is nonetheless useful. Policy analysts often focus on price policy, but this has its strongest influence on process 2, with more limited influence on processes 3 and 4. Policy measures affecting process 1 are largely those that determine the amount and type of agricultural research.

The disequilibriating features of the fertilizer economy are perhaps even more problematic in most sub-Saharan African countries than in the rest of the developing world. First, in much of Africa, water control, a major complementary factor, is more costly. Second, even for rainfed agriculture, production environments in sub-Saharan Africa may be somewhat more variable over time and space (Kumwenda et al., forthcoming; Byerlee and Heisey, forthcoming); such variation increases the cost of developing information about agronomic potential and of transmitting this information to farmers. Third, because the fertilizer market in many African countries will remain small for the forseeable future, those countries must rely on the world market through trade or aid. Fourth, infrastructure is less developed in much of Africa, which raises the real costs of fertilizer distribution above levels for much of the developing world, reduces farm-level product prices, and in general

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[3] This would account for 30% of sub-Saharan Africa's total nitrogen consumption in 1993—if it were all supplied by urea.

[4] Tomich, Kilby, and Johnston (1995) contend, however, that "for twenty-seven of the past thirty years, the maximum point of [world] price variation for nitrogen fertilizer fell below the [economic] cost of domestic manufacture" in developing countries.

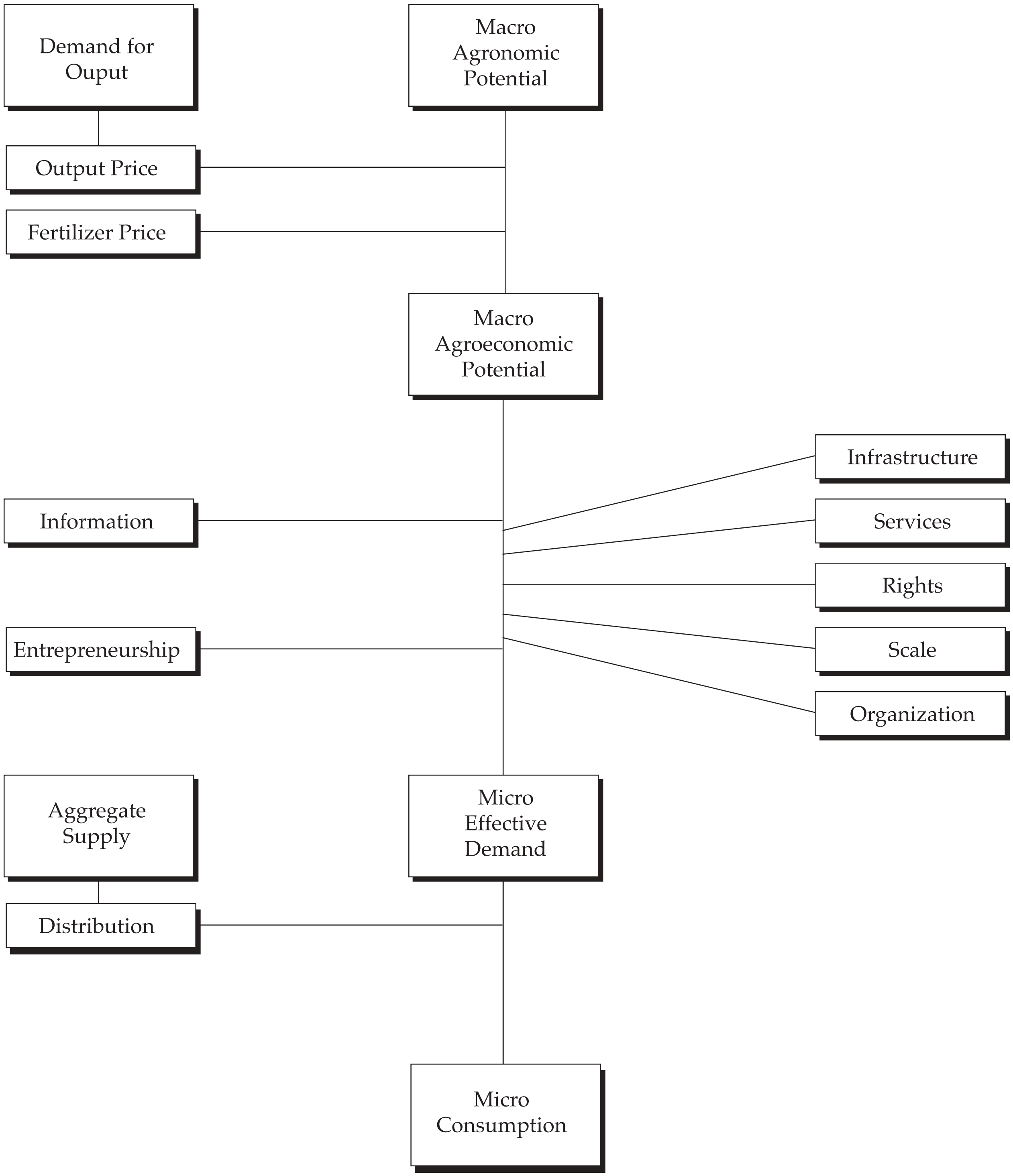

Figure 1. Elements determining a country's fertilizer consumption.

Source: Based on a description in Gunvant M. Desai and Bruce Stone, Fertilizer Market Development and National Policy in China and India: A Comparative Perspective (paper prepared for the IFA FADINAP Southeast Asia and Pacific Regional Conference, Kuala Lumpur, Malaysia, 22-25 July 1987).

leads to greater price variability for both agricultural inputs and outputs. Finally, legal and institutional infrastructure in Africa, as well as policy planning capacity, may lag somewhat behind that of other developing countries.

Fertilizer Use on Maize

Fertilizer Use in Sub-Saharan Africa[5]

Despite difficulties in measuring arable land,[6] this much is clear: fertilizer application rates are considerably lower in Africa (10 kg/ha in 1993) than in the developing world as a whole (83 kg/ha in 1993). Table 1 indicates the year in which various countries first reached the 10 kg/ha application rate. Over the past 30 years, however, fertilizer consumption in sub-Saharan Africa has increased. In recent years, growth in fertilizer use on cereals, particularly maize, has contributed substantially to this increase. Nonetheless, current application rates remain low: farmers started from a low base, and annual increases have been relatively small, averaging 6.7% per year in total consumption and 5.7% per year in consumption per cropped hectare (Figure 2).[7]

Table 2 shows growth rates in fertilizer nutrient consumption per hectare of cropped land, as well as current application rates, broken down for specific countries and sub-regions as well as time periods. This breakdown attempts to correct for difficulties in measuring arable land and land in permanent crops. Nutrient use per hectare for Africa in the aggregate is still low with this method, but we feel these figures are somewhat more realistic. Growth rates over time show similar patterns

Table 1. Year aggregate fertilizer application rate reached 10 kg/ha[a] (NPK).

Country	Year
Japan	before 1880
U.S.A.	1940-1945
China	1958?
Philippines	before 1961
Vietnam	before 1961
Guatemala	before 1961
Colombia	before 1961
Peru	before 1961
South Africa	before 1961
Zimbabwe	before 1961
Mexico	1964
Honduras	1965
Ecuador	1967
Brazil	1967
Venezuela	1968
India	1968
Pakistan	1968
Indonesia	1968
Kenya	1969
Malawi	1971
Zambia	1971
Thailand	1972
Cote d'Ivoire	1972
Tanzania	1974
Nepal	1983
Nigeria	1989
Argentina	1993
Paraguay	1993
Ethiopia	1993
Ghana	never reached

Sources: FAO Agrostat PC data files; Hayami and Ruttan (1985); Stone (1993).
[a] Hectarage calculated as total of "arable land and permanent crops."

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5 Aggregate data in this paper are usually presented in the form of total NPK consumption, or NPK per hectare, where phosphorous and potassium use are recorded in their oxide forms (P_2O_5 and K_2O respectively).

6 FAO statistics show application rates (kg fertilizer nutrients per hectare of arable land and permanent crops) to be relatively low in Zambia. Until recently, application rates on actual cropped area have been considerably higher.

7 Over the same period, application rate has grown by 6.0% per year when calculated by the conventional method, which uses arable land and permanent crops in the denominator (Figure 2).

regardless of which estimation is used, but calculation using cropped area rather than arable land shows more clearly 1) the stagnation of nutrient consumption per hectare in early users such as Kenya and Zimbabwe, 2) declines in use for some countries over the past decade, and 3) a slowdown in the increase of region-wide nutrient application rates.

Fertilizer Use in Maize Production

Analysts of fertilizer use in sub-Saharan Africa (e.g., Tshibaka and Baanante 1988) often contend that export or plantation crops (primarily cotton, sugar, tea, and coffee) receive the bulk of the region's fertilizer. Although this was true in the mid-1970s (Mudahar 1986), and continues to be true in some countries (particularly countries in Francophone West Africa where cotton is important, and in Kenya), for sub-Saharan Africa as a whole, fertilizer consumption has shifted to cereals, particularly maize (Desai and Gandhi 1988; Gerner and Harris 1993; Table 3; Figure 3).[8] Maize drives fertilizer consumption in much of southern Africa. In East Africa, cereals also dominate fertilizer consumption, although the pattern is more diverse, with a large proportion going to teff in Ethiopia, to wheat in Sudan, and to non-cereal export crops in Kenya. Even in West Africa, maize and other cereals now account for the majority of total fertilizer consumption, although these results are caused by apparent large increases in Nigerian consumption over the 1980s.[9] In most maize-producing

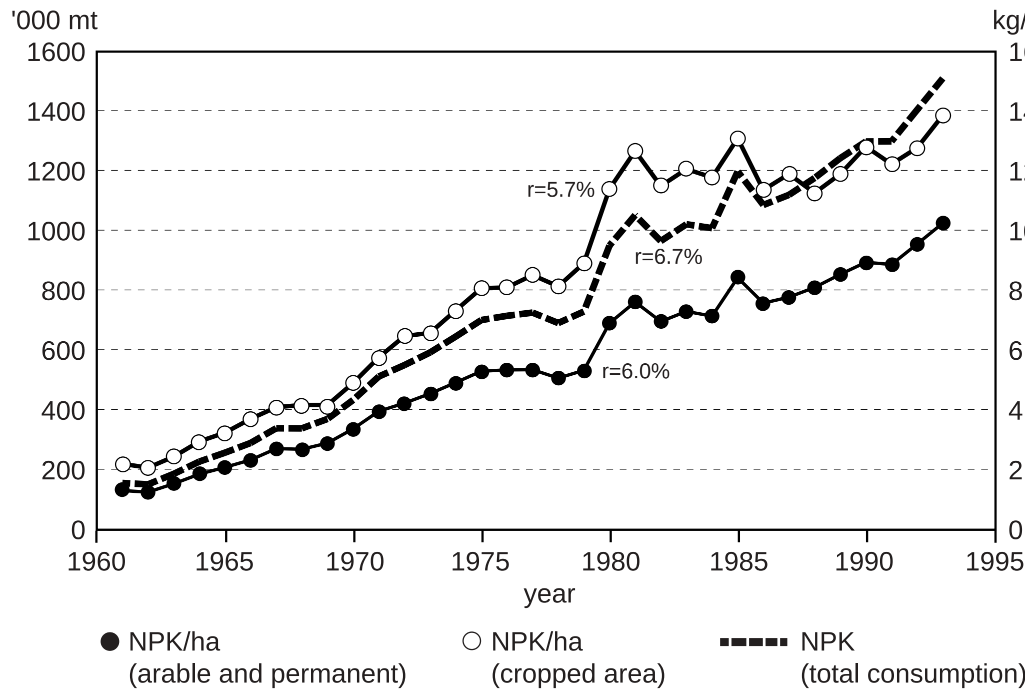

Figure 2. Fertilizer consumption in sub-Saharan Africa.

8 The countries aggregated in Figure 3 include all of those in Table 3, plus Sudan, Senegal, Lesotho, and Madagascar. Essentially our data set is the same as that used by Gerner and Harris, with additional information included for Kenya, Malawi, Zambia, Ghana, and Cameroon, and with Nigeria's data updated to 1990 based on information in Smith et al. (forthcoming). Major maize-producing countries for which information is not available (Zaire, Mozambique, and Uganda) are in general low consumers of fertilizer.

9 Overall Nigerian fertilizer use has increased enormously, as has use on maize. Nonetheless, accurate information for Nigeria is difficult to obtain, for a number of reasons. For example, low, highly subsidized prices in Nigeria led to the smuggling of considerable amounts of fertilizer into neighboring countries (J. Smith, personal communication; C. Dowswell, personal communication).

African countries, the proportion of maize fertilizer consumption in total consumption by cereals tends to equal or exceed the proportion of maize area in total cereal area. In other developing countries, maize shows a slight tendency to receive less than its share of total nutrient consumption (Appendix A).

Despite the increasing importance of maize in African fertilizer consumption, application rates at the aggregate level generally remain low compared to application rates on maize in other developing countries (Table 4; Appendix A). However, in five African countries—Nigeria, Kenya, Malawi, Zimbabwe, Zambia— about half or more of the maize area was already being fertilized by around 1990; in all these countries, application rates on fertilized areas ranged from two-thirds to over twice the nutrient application rates on rainfed maize in India. But in general the proportion of fertilized area in these countries was lower than it

Table 2. Growth in fertilizer consumption per hectare of cropped land[a] and current use, sub-Saharan Africa.

	Growth in NPK/ha, cropped land			kg NPK/ha	
Country[b]/ Region	1961-70	1971-80	1981-90	Cropped land mean[c] 1989-93	Arable land/perm. crops mean[c] 1989-93
Tanzania	17.0	4.0	4.5	8.7	14.1
Nigeria	19.7	36.6	1.7	23.2	13.7
Kenya	13.4	-1.0[d]	0.8[d]	34.5	24.3
Malawi	6.2	10.3	5.9	28.6	39.6
Zimbabwe	8.8	-0.7[d]	-0.2[d]	65.1	52.0
Ethiopia	19.5	20.1	11.0	16.1	8.5
Zambia	10.7	10.4	-4.9	60.3	14.1
Cote d'Ivoire	6.6	2.8	-1.1[d]	8.8	12.3
Ghana	4.5[d]	21.3	-11.9	2.7	2.2
West and Central	13.4	14.5	0.8[d]	10.0	7.8
East	10.8	1.8[d]	4.1	12.0	8.0
Southern	7.7	2.6	-0.9	26.8	17.5
Sub-Saharan Africa	9.5	6.0	0.6[d]	12.8	
Sub-Saharan Africa (denominator arable land and permanent crops)	10.9	4.4	2.7		9.3

Source: Calculated from FAO Agrostat PC data files.
Note: All growth rates are calculated using semi-logarithmic regression.

[a] For each country-year combination, the denominator in all calculations was the sum of all harvested cropped areas. This may still understate application rates in countries with substantial intercropping. In the last row the usual convention of using area in arable land and permanent crops was followed.

[b] Major maize producers in terms of production (over 500,000 mt) or area (over 500,000 ha) excluded from the individual country table include Zaire, Uganda, Mozambique, and Angola, where fertilizer use has remained very low. Regional aggregates include all countries in the region.

[c] Five-year means are presented to abstract from fluctuations in fertilizer use. For the region as a whole, the five-year mean can be compared to data for the latest available year (1993) as shown in Figure 2.

[d] Difference from zero statistically insignificant.

was in Asia or Latin America.[10] In the immediate past, fertilizer use in Malawi has been curtailed by policy changes at both the micro and macro level (HIID/EPD 1994; Heisey and Smale 1995). In Zambia, fertilizer use has been declining for a decade or more, and may fall

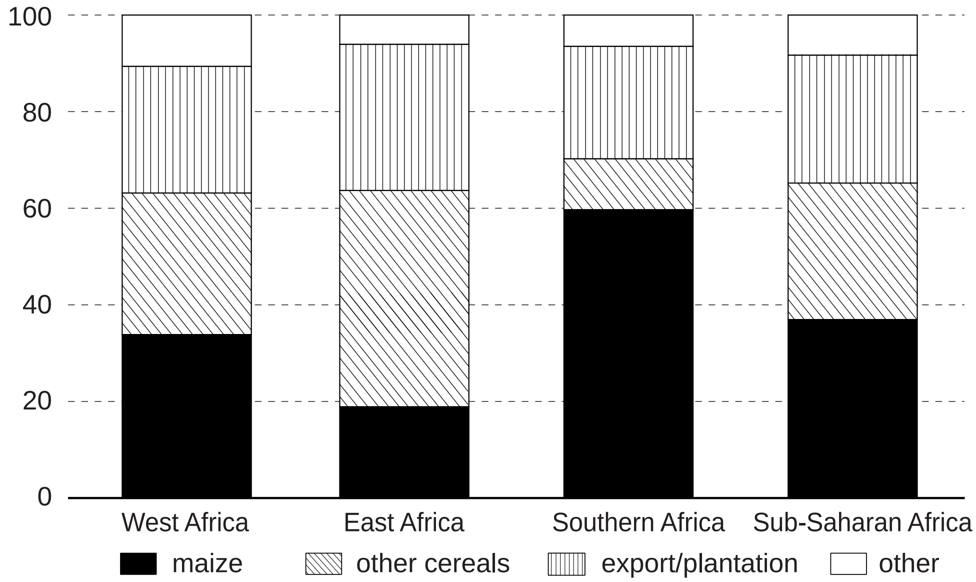

Figure 3. Percentage nutrient (NPK) consumption by crop.

Table 3. Fertilizer use by crops, sub-Saharan Africa.

Country	Maize area 1990-92 '000 ha	—% Fertilizer (nutrients) applied to— maize	other cereals	plantation/ export crops	other crops	Maize area: % of total cereal area	Maize fert. as % of fert. to all cereals	Year
Tanzania	1796	77	2	21	0	61	97	1990
Nigeria	1517	43	35	13	9	14	55	1990
Kenya	1428	20	3	61	16	80	87	1983
Malawi	1365	74	0	26	0	95	100	1990
Zimbabwe	1044	39	16	34	11	73	70	1990
Ethiopia	1000	9	81	10	0	19	10	1988
Angola	750	82	0	0	18	83	100	1991
Zambia	681	90	5	5	0	84	95	1987
Cote d'Ivoire	675	6	12	68	15	49	33	1989
Ghana	525	64	16	5	15	52	79	1991
Benin	413	6	2	92	0	70	75	1989
Togo	273	23	10	66	1	44	70	1990
Cameroon	220	4	11	67	18	27	nc	1985
Burkina Faso	201	3	40	57	<1	7	nc	1991
Total	11888	41	24	27	8	36	63	

Sources: IFA/IFDC/FAO (1992); calculated from data in Smith et al. (forthcoming), Nigeria; Lele, Christiansen, and Kadireisan (1989), Kenya and Cameroon; Tshibaka and Baanante (1988), Zambia; Bumb et al. (1994), Ghana; authors' estimates, Malawi.

[10] Note, however, the low application rates in the two Latin American commercialized producers with substantial use of maize hybrids, Brazil and Argentina. As a point of comparison with all developing countries, maize in industrialized nations tends to be fertilized at rates of 250-350 nutrient kg/ha.

Table 4. Fertilizer application rates to maize, sub-Saharan Africa and other developing countries.

Country	% maize area receiving NPK	kg NPK/ha on area receiving fertilizer	kg NPK/ha total maize area	Maize yield 89-93 (mt/ha)
Tanzania	20	71	14	1.39
Nigeria	64	176	113	1.27
Kenya[a]	50	37	18	1.62
Malawi	50	52	26	1.02
Zimbabwe	45	122	55	1.47
Ethiopia	15	33	5	1.69
Angola	8	137	11	0.34
Zambia	65	108	70	1.64
Cote d'Ivoire	5	103	5	0.77
Ghana	26	52	14	1.34
Benin	na	na	1	0.96
Togo	16	63	10	1.02
Cameroon	na	na	3	1.84
Burkina Faso	na	na	3	1.43
Total[b]	37	96	36	
Total[c]			33	
Other Developing Countries				
India (all)	84	69	58	
India (irrigated)	95	83	79	
India (rainfed)	74	52	38	
Philippines	66	85	56	
Indonesia	na	na	61	
Thailand[d]	61	125	76	
Mexico	76	109	83	
Asia[e]	74	80	59	
Latin America[f]	65	124	80	
Commercialized Maize Producers				
China	100	118	118	
Brazil	na	na	39	
South Africa	100	88	88	
Argentina	na	na	1	

Sources: IFA/IFDC/FAO (1992); authors' calculations (Tanzania, Nigeria, Kenya, Malawi, Ethiopia, Zambia, Ghana, Benin, Cameroon); D. Byerlee, personal communication, India; Martinez (1990), Argentina. Sources consulted in making authors' calculations include FAO Agrostat PC statistics, Smith et al. (forthcoming); Lele, Christiansen and Kadiresan (1989); Tshibaka and Baanante (1988); Howard (1994); Bumb et al. (1994); GGDC (1991).

[a] Micro-level studies (e.g. Hassan and Karanja, forthcoming) suggest application rates may be somewhat higher.
[b] Includes all African countries in the table with complete information.
[c] Includes all African countries in the table.
[d] Micro-level information suggests considerably lower application rates (L. Harrington, personal communication).
[e] Includes India, Philippines, Thailand, Pakistan, and Nepal. Overall application rates to maize in Indonesia may also be about 60 kg/ha. China is excluded.
[f] Includes Mexico, Ecuador, Colombia, Venezuela, Honduras, Paraguay, Peru, Nicaragua. Brazil and Argentina are excluded.

even further with recent policy shifts (Howard and Mungoma, forthcoming). Consumption in Kenya, Zimbabwe, and Nigeria has been erratic over the same period, with little discernible trend in Kenya and Zimbabwe. In countries where fertilizer policy suddenly alters, reductions in fertilized area may be a more prominent short-run aggregate phenomenon than reductions in application rates on fertilized area.

Within sub-Saharan countries, maize fertilizer rates vary considerably. Major conditioning factors include agroecological zone (particularly in Zimbabwe, Kenya, and Nigeria); length of fallow preceding the maize crop (Ghana); structural factors such as the division between large-scale commercial producers and smallholders (Zimbabwe and Zambia); and maize variety (hybrid vs. local maize in Malawi). Partly because of the low overall application rates, partly because of variability within countries, and partly because of other conditioning factors,[11] there is no immediately observable direct relationship between fertilizer application rates and maize yields at the country aggregate level. Within-country micro-data can show the expected relationship: more fertilizer leads to higher maize yields.

Technical Response to Fertilizer in Maize

Several complications affect estimates of fertilizer-response. This section summarizes some reported information on so-called "agronomic efficiency," defined as kilograms of grain obtained by applying one kilogram of plant nutrient; our focus will be on nitrogen, the most widely used and most commonly limiting nutrient.[12] Our aim is to examine responses at 0 kg/ha of applied nutrient. Many cases in the literature, however, are unclear about whether the reported data refer to 1) marginal response at 0 kg/ha of applied nutrient; 2) average response approximating marginal response at 0 kg/ha of applied nutrient; 3) marginal response at current or recommended, non-zero, level of applied nutrient; or 4) average response approximating marginal response at current or recommended, non-zero, level of applied nutrient (Lele, Christiansen, and Kadiresan 1989). All these possibilities could be interpreted economically. In more than a few cases, however, the analyst appears simply to divide increase in grain yield from a (usually large) recommended application rate by that application rate, without any consideration about whether response is indeed linear up to the recommended level.

Another complication involves the representativeness of conditions under which response is measured. Many analysts contend that fertilizer response on experiment stations is considerably higher than on farmers' fields, because of greater complementary inputs and practices (e.g., timely weeding). Others argue that, under certain conditions, responses are higher on farmers' fields because fertility at experiment stations is high, and as a result, the nutrient being tested is not really limiting. Depending on the empirical situation, either argument can be valid.

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[11] One important factor is the altitude at which most of a country's maize is grown.

[12] Data on nitrogen response are also the most universally available. Nonetheless, maize responses to other nutrients—notably phosphorous, sulfur, zinc, and potassium—have been documented in different parts of the continent (G. Edmeades, personal communication).

Cropping system or rotational effects may also affect fertilizer response. In Ghana, for example, nitrogen response on depleted soils that have been continuously cropped can be twice as high as on soils with high natural fertility that have lain fallow for a number of years (Edmeades, Dankyi, and Marfo 1991). Soil type, planting date, and application method are other conditioning factors. Weather variability may make moisture limiting in some years, and response may differ markedly as a result.[13]

Nonetheless, under rainfed conditions, maize in Africa tends to be more fertilizer responsive than other cereals, with the possible exception of rice. Such responsiveness is undoubtedly one reason maize production appears positively linked with fertilizer consumption.[14] Viewed with the above-mentioned qualifications in mind, the data in Table 5 suggest a crude classification. *High response* areas are those where the marginal response at 0 kg/ha nitrogen is 25 kg of grain or more per 1 kg of nutrient; *intermediate response* areas are those where the equivalent figure is 15 kg of grain per 1 kg of nutrient; and *low response* areas are those where "agronomic efficiency" is 5 kg of grain per 1 kg of nutrient. A cursory examination of response data for maize in India and Mesoamerica reveals no marked difference from African response data.[15]

Factors Influencing Farmers' Adoption and Intensity of Fertilizer Use

Demand and supply factors are hard to separate when evaluating farmers' decisions to adopt fertilizer and their subsequent decisions about application rates. For example, many key influences discussed in the adoption literature (farm size, access to credit, membership in cooperatives, contact with extension, access to outside information, availability of inputs, and distance to markets) may be related at least as much to supply side constraints as to farmer demand factors (Mwangi 1995). This section focuses on demand issues, the next on problems of supply.

Basic Price Factors

Theoretically, the decision to adopt fertilizer is determined by the interaction between agronomic response and the nutrient-grain price ratio. Agronomic response, in turn, is determined by soil characteristics and climatic factors. If the marginal agronomic response at a level of 0 kg/ha of applied nutrient is greater than the nutrient-grain price ratio, in theory the farmer should adopt fertilizer. In practice, other factors often prove important: the cost of operating capital for the cropping season; information and learning costs; and, perhaps, the effects of risk aversion (considered below) (CIMMYT 1988). Many observers

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[13] In situations where marginal response is calculated from an estimated response function, different functional forms can also generate widely varying results for the same data.

[14] That relative responsiveness is not the only determinant of fertilizer consumption is well illustrated in Ethiopia, where teff—the cereal least responsive to fertilizer—receives the highest aggregate amount of fertilizer, partially because it is a relatively high-value crop with a somewhat more stable market (Makken 1993).

[15] On the other hand, measured marginal maize responses (at 0 kg nutrient per hectare) to applied nitrogen in the U.S., the world's largest maize producer, appear to vary from 0 kg grain per kg of nutrient to about 75 kg grain per kg of nutrient. The greater range in the U.S., for both experimental and farmer data, may result from more careful control of management factors, rotation, and environmental differences—all of which can affect response. Maize cultivars used in the U.S. may also be more responsive to fertilizer.

contend that marginal agronomic response must be at least twice the nutrient-grain price ratio (i.e., the marginal rate of return on working capital invested in fertilizer must be at least 100%) for significant adoption to occur.

These issues have important implications for the *high, intermediate,* and *low* agronomic responses described above. Let us assume that these responses have been measured under conditions similar enough to those faced by farmers so that a yield reduction of 20% indicates the response farmers will actually achieve (CIMMYT 1988). If we also assume that the marginal rate of return must be at least 100%, the implication is that where 25 kg of grain can be obtained with the application of 1 kg of nutrient, farmers will adopt fertilizer as long as the nutrient-grain price ratio is 10 or lower. In areas with an intermediate response, the nutrient-grain price ratio must be 6 or lower for widespread adoption to occur. Where response is low (5 kg of grain for 1 kg of nutrient), the threshold price ratio is 2.

In the absence of subsidies, nitrogen-maize price ratios for sub-Saharan Africa are considerably higher than the median for the rest of the developing world (Table 6).[16] Nonetheless, comparing Tables 5 and 6 suggests that there should be considerable high and intermediate potential maize area where some fertilizer use is profitable. Since calculated farmer profitability can be quite sensitive to assumptions about both input and output

Table 5. Reported "agronomic efficiencies" for maize in Africa.

Country	kg grain/kg nutrient (usually nitrogen)	Mean
Tanzania—southern highlands	18-43	25?
Tanzania—north	13-18	15?
Tanzania—dry	8-10	9?
Nigeria	4-22	na
Kenya	7-36	18
Malawi—local maize	8-38	15?
Malawi—hybrid maize	8-52	27?
Zimbabwe	6-26	na
Ethiopia	9-17	13
Zambia—local maize[a]	11	
Zambia—hybrid maize[a]	18	
Ghana	0-35	na
Cameroon	7-32	na
"West Africa"	10	

Sources: Ministry of Agriculture/FAO fertilizer trials, Ethiopia and Tanzania; Fertilizer Use Response Project (FURP), Kenya; Oyovbisere and Lombim (1991), Nigeria; various sources cited by Heisey and Smale (1995), Malawi; Maturuka, Makombe, and Low (1990), Zimbabwe; Jha and Hojjati (1993), Zambia; Bumb et al. (1994), Edmeades, Dankyi, and Marfo (1991), Ghana; Lele, Christiansen, and Kadiresan (1989), Cameroon; Shalit and Binswanger (1985), "West Africa."

[a] These "response rates" were calculated by comparing a particularly high application rate—162 kg/ha—with no fertilizer.

[16] Fertilizer is subsidized in many of these countries as well, but differentials in nutrient-grain price ratios would be likely to remain even in a completely unsubsidized world.

prices, however (Table 7), it is important to consider both these sets of assumptions and the prospects for improving price ratios in favor of fertilizer use.

Assumed input prices are affected by whether the effects of subsidies and exchange rate overvaluation are taken into account (Martin and Lele 1992) or whether the nutrient source is low- or high-analysis (Marfo and Tripp, forthcoming; HIID/EPD 1994). Assumed output prices can be affected by subsidies and exchange rate overvaluation as well (Martin and Lele 1992; Howard and Mungoma, forthcoming), but maize prices may also be lowered by implicit taxation caused by marketing board policy (Franzel et al. 1989). In countries with wide consumer-producer price margins, whether or not the household is a net consumer will also affect output prices (Table 7).

What factors affect current and future nutrient-grain price ratios in African countries? At the world level, real fertilizer prices and the real prices of major cereals have both fallen for much of this century, driven by technical change (Tomich, Kilby, and Johnston 1995). From the early 1970s to the early 1990s, there has been an insignificant, slightly downward trend

Table 6. Nitrogen-maize price ratios, sub-Saharan Africa and other developing countries.

Country or Region	Time period	Nitrogen-maize price ratio (median)
Tanzania	1980-1985	2.6
Tanzania	1995	7.0
Nigeria	1985-92	2.0
Nigeria	post-subsidy removal[a]	7.0
Kenya	1980-95	7.3
Malawi	1977-1987	10.7
Malawi	1988-1994	7.7
Malawi	1995 on	?
Zimbabwe	1980-1994	6.4
Ethiopia	1983	6.4
Ethiopia	1992	1.9
Zambia	1971-1989	3.3
Zambia	1990-1994	5.4
Cote d'Ivoire	1980-1992	5.4
Ghana	1982-1987	2.2
Ghana	1991-1994	10.2
Asia	1980-1992	2.7
Latin America	1980-1992	3.8

Sources: CIMMYT World Maize Facts and Trends, various issues; Smith et al. (forthcoming); Marfo and Tripp (forthcoming); J. Howard, personal communication; S. Waddington, personal communication; Heisey and Smale (1995).

[a] Subsidies have not yet been removed in Nigeria but Smith et al. (forthcoming) calculate the nitrogen price ratio would be around 7 were subsidies removed.

in the ratio of world urea prices (f.o.b. Rotterdam) to world maize prices (f.o.b. U.S. Gulf).[17] Nitrogen prices may rise somewhat in the late 1990s as capacity lags demand, but cereal prices may stop falling too, making future trends in world price ratios hard to predict. Real border fertilizer-maize price ratios for most African countries have not increased over time, nor are they likely to increase significantly in the immediate future.

Instead, fertilizer costs in Africa are inherently high, because of the infrastructural and marketing constraints discussed below. As subsidies are removed and exchange rates liberalized, sharp and relatively rapid increases in the nutrient-maize price ratios almost inevitably follow (Table 6). In some countries, Ethiopia for example (Franzel et al. 1989), liberalization of maize markets can improve maize prices and more than compensate for increased input prices. In other countries, however, liberalization does not appear to halt declines in the real price of maize (Howard and Mungoma, forthcoming; Jayne, Mukumbu, and Jiriyengwa, forthcoming). Thus the overall effect of "liberalization" policies on price ratios should be determined empirically.

Risk Aversion and Credit Constraints

Risk aversion is commonly assumed to play an important part in technology adoption decisions. Many observers conclude, however, that after adoption, risk aversion can reduce fertilizer applications by no more than 20% of the "optimal" rates (Binswanger and Sillers

Table 7. Effect of price assumptions on the profitability of alternative maize technologies in 110 on-farm demonstrations, Lilongwe, Malawi, 1990 and 1991.

	Local maize with fertilizer	Hybrid maize with fertilizer
Fertilizer applied (kg nutrient/ha)	55	145
Yield increase observed over unfertilized local maize (kg/ha)	750	2,400
	——*Marginal rate of return (%)* [c]	——
Subsidized input prices[a]		
Maize-deficit households[b]	133	237
Maize-surplus households[b]	64	136
Unsubsidized input prices		
Maize-deficit households[b]	79	145
Maize-surplus households[b]	27	72

Source: Authors' calculations, based on data provided by the Ministry of Agriculture/UNDP /FAO Fertilizer Demonstration Program.

[a] Subsidy of 25% on fertilizer and about 40% on hybrid seed.
[b] The price of maize in households that purchase maize is about 40% above the farm gate selling price.
[c] Marginal rate of return on input expenditures. A return above 100% is usually assumed to be necessary for widespread farmer adoption.

[17] This downward trend is even less impressive when one takes into account the speculative nitrogen price rise during the world food and oil crises of the early 1970s.

1983; Shalit and Binswanger 1985; Roumasset et al. 1989). As noted, however, African production conditions for rainfed maize may vary somewhat more than conditions in non-African developing countries. Within Africa, production risk is apt to be considerably more important in marginal areas, such as drought-prone sections of Kenya (McCown et al. 1992) or southern Zimbabwe.[18] Furthermore, Ahmed, Falcon, and Timmer (1989) argue that the studies cited above usually focus only on production risk, not price risk in a general equilibrium context. Certainly output price instability constitutes a risk for fertilizer users in western Africa (Vlek 1990; Byerlee et al. 1994). In eastern and southern Africa, maize prices are probably more stable than prices for certain other cereals (e.g., sorghum, millet), but less stable than maize prices in other developing regions of the world. These details suggest the need for more careful risk assessment in Africa as compared to those other regions.

Constraints on cash or credit availability often cause farmer behavior that looks like risk aversion (Masson 1972; Binswanger and Sillers 1983). For many African smallholders, fertilizer expenditures can represent a considerable proportion of the total cash expense for crop production. In Malawi, a liquidity crisis in the smallholder production credit system, not a change in the fertilizer-maize price ratio per se, caused a dramatic reduction in smallholder fertilizer use between the 1992/93 and 1993/94 seasons (HIID/EPD 1994; Heisey and Smale 1995).

Availability

Despite differences of opinion on other issues, many analysts of fertilizer use and policy in Africa and the rest of the developing world contend that basic problems of availability (i.e., getting the right fertilizer to the right place at the right time) are at least as important as price-response interactions in determining fertilizer use (Fontaine 1991; Pinstrup-Andersen 1993; Blackie 1995). Often referred to as non-price factors, these problems can be accommodated within a pricing framework by noting that, in effect, they raise the shadow price of fertilizers to farmers.

Although the features of the African fertilizer economy that lead to high prices are often intertwined with those that constrain availability, policy makers have often focused solely on the one effect (high prices) rather than on availability, and ignored the underlying causes completely. The next section outlines in greater detail some reasons why the actual and shadow prices of fertilizer are high in Africa; it also describes some of the policies affecting prices and availability. In the following section, we consider the effects of present policy and discuss policy options.

Supply Constraints to Fertilizer Use and Policy Responses

Procurement and Distribution

In most sub-Saharan African countries, small present and potential fertilizer markets make importing fertilizer generally more economical than producing it locally (Vlek 1990; Appendix B).[19] Nonetheless, the differences between world f.o.b. prices and landed cost

[18] Maize production during minor rainy seasons in bimodal systems is also riskier.

[19] Exploitation of local rock phosphate deposits might be an exception.

tend to be twice as high in many sub-Saharan countries as compared to Asian countries. (Shepherd and Coster 1987). Bumb (1988) states that this large difference is the result of the small fertilizer volumes most African countries import. Small volumes increase transportation costs and weaken the nations' position in negotiating for lower prices.

In 1990, almost one-third of all sub-Saharan fertilizer imports were financed by aid. In fact, for 21 countries with small markets, all fertilizer was financed through donor programs. Donors impose conditions (such as limitations on origin, transporters, and fertilizer type) that can lead to excessive marketing costs and margins, which ultimately translate into higher fertilizer prices (Gerner and Harris 1993).

High distribution costs are another reason for relatively high fertilizer prices in sub-Saharan Africa. First, land-locked countries such as Malawi face additional high transport costs from seaport to port of entry. Second, internal distribution costs tend to be considerably higher than in other developing countries (Bumb 1988), as a result of high transportation costs and other factors, such as the small volume to be distributed. In turn, high transportation costs are the result of poor physical infrastructure. Sub-Saharan Africa lags far behind India and China in km of roads per 100 km^2 (Vlek 1990; Spencer 1994). Other important infrastructural issues include maintaining roads and establishing a balance between rural/feeder and trunk roads (Mwangi 1995).

Substantial credit requirements throughout the fertilizer marketing channel commonly cause late delivery, thus raising the shadow price to farmers. Finally, lack of competition in fertilizer distribution systems, often as a result of public-sector operation, can also contribute to inefficiencies and higher marketing margins (Pinstrup-Andersen 1993).

Direct Subsidies

Many sub-Saharan countries have tried to promote fertilizer use through price and/or credit subsidies, even though many other factors are important to the growth of fertilizer consumption. Much of the policy literature on developing-country fertilizer consumption has focused on subsidies, perhaps because their effects on government agricultural budgets are relatively easy to observe. Table 8 provides a brief history of explicit fertilizer subsidies in some major maize-producing countries of sub-Saharan Africa.[20] The table also indicates that, in recent years, fertilizer subsidies have tended to be reduced or eliminated, often as the result of pressure from the World Bank, the International Monetary Fund, or other donors.

Indirect Policy Effects

Numerous indirect pricing effects can be caused by variations in the timing, financing, and institutional management of fertilizer procurement and distribution. Losses by public-sector organizations in trading fertilizer are often made good by the government or offset by profits in commodity trading. Wastage, costs of capital, or costs of extending credit to

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[20] This table focuses on explicit subsidies. The combined effects of pricing, accounting, and inventory practices, as well as other macroeconomic influences such as exchange rate overvaluation, are often quite difficult to unravel (HIID/EPD 1994).

farmers are often underestimated (HIID/EPD 1994; Shepherd 1989). Perhaps the most universal indirect effects in sub-Saharan Africa, however, are pan-territorial pricing[21] and exchange rate overvaluation.

When pan-territorial pricing combines with public-sector fertilizer distribution, marketing organizations are often unaware of the true marketing costs. In effect, these practices offer higher implicit subsidies to farmers in regions with higher transport costs. Even when other aspects of the market are liberalized and subsidies are reduced or eliminated (as in Ghana), pan-territorial pricing may persist (Bumb et al. 1994). One intermediate step toward removing this practice is to control prices up to a country's regional distribution centers, but not beyond them (Shepherd 1989).

Exchange rate overvaluation has been a common feature of macroeconomic management in nearly all sub-Saharan countries (Ghura and Grennes 1991), although it is much less evident today than in the past. In the long run, such overvaluation tends to discriminate against the agricultural sector, and it will therefore work against increased fertilizer use. In the short run, however, imported fertilizers, as a tradable input, will be subsidized implicitly by overvaluation.

Fertilizer Policy: Issues and Options

Worsening food-production deficits and concern about soil nutrient depletion suggest to many observers that African agricultural development has been in a state of crisis for some

Table 8. Explicit fertilizer subsidies in selected African maize-producing countries.

Country	Explicit Subsidy	Period	Explicit Subsidy (%)	Period
Tanzania	55-75%	1975-1992	0	1995
Nigeria	80-85%	1976-1987		
Kenya	0%			
Malawi	app. 25%	1980-1992	11	1993
Zimbabwe[a]	0%	since 1975		
Zambia	median 40-50%	1971-1991	0?	since 1993?
Cote d'Ivoire[b]	yes	until mid 1980s	0	since mid 1980s
Ghana[c]	40-80%	1979-1987	0	since 1990
Benin	app. 50%?	early 1980s	0?	since late 1980s
Togo	50-85%	1973 to 1986	35?	since late 1980s?
Cameroon	55-65%	1977-1987	0?	since late 1980s?

Sources: Lele, Christiansen, and Kadiresan (1989); Tshibaka and Baanante (1988); Bumb et al. (1994); Howard (1994); Jansen (1988); HIID/EPD (1994).

[a] Price controls on imported urea protect local manufacturers of ammonium nitrate.
[b] Tax on imports to protect local manufacturer; compensatory mechanisms to neutralize effects on farmers.
[c] This table reports explicit subsidies, not additional effects of exchange rate overvaluation which affected all countries in the table. Exchange rate overvaluation was probably greatest in Ghana over the 1970s and early 1980s.

[21] Pan-territorial pricing for an input like fertilizer means the price to farmers throughout a country is the same, despite differences in transportation, storage, and other marketing-related costs.

years. But as soil fertility continues its apparent decline and slow growth in food production becomes slower still, we note two factors that may partially counteract negative trends in economic incentives for fertilizer use: 1) declining soil fertility should mean, in many cases, that agronomic fertilizer responses will increase; 2) increasing reliance on food imports should imply, increasingly, that the appropriate price for determining the social value of fertilizer applications will be the import parity price of a major food crop such as maize (Seckler, Gollin, and Antoine 1991; J. Shaffer, personal communication).

In this section we consider specific policy options for the fertilizer sector. We first look at the demand side, moving from the relatively short-run question of fertilizer subsidies to the longer-run issues of determining and targeting high-potential areas and developing appropriate agricultural research programs. We then discuss the supply side. Again, short-term concerns such as donor aid, credit, and distribution costs in general precede intermediate options such as privatization and long-run considerations such as local production capacity and infrastructure development.

Prescriptions for fertilizer policy in general and maize in particular must be modified to fit national circumstances. At one extreme is Nigeria: high population pressure on the land, large potential fertilizer demand, and internal sources of fertilizer feedstock make it most likely to benefit from an understanding of fertilizer-sector development in many Asian countries. At the other extreme, the many small countries with low current fertilizer demands face very different sorts of problems.

In an excellent approach to fertilizer policy issues, Ahmed, Falcon, and Timmer (1989) state, "some combination of market forces and government interventions is needed, with the market providing allocative signals, the government stabilizing them around a market trend," based in some way on world prices, "and a competitive private sector delivering the goods at low cost." These authors point out that for most Asian and Near Eastern countries, whose fertilizer policies are often seen as "successful" from the African perspective, such a fertilizer strategy has not been achieved.[22] Furthermore, as we have argued, solutions to Africa's fertilizer policy problems must go beyond this framework.

Theoretical and Actual Effects of Fertilizer Subsidies

Though credit subsidies are almost universally regarded as doomed to failure (Byerlee et al. 1994), fertilizer subsidies have received some support from policy analysts. In a world of market and information failures, where policy makers often choose non-efficiency objectives, a subsidy on inputs might be justified (Shalit and Binswanger 1985).[23] If the government's goal is to achieve food self-sufficiency, a subsidy on fertilizer is relatively more efficient, in many cases, than a subsidy on output (Barker and Hayami 1976; Parish and MacLaren 1982; Chambers 1985; Sidhu and Sidhu 1985).[24] Given broader policy

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[22] See for example Tomich, Kilby, and Johnston (1995), Chapter 7.

[23] One example, more relevant for export crops than for a food crop like maize, is compensation for a tax on output.

[24] Martin and Lele (1992) appear to be following this approach when they argue that fertilizer subsidies benefit both producers and consumers in Tanzania. The authors do not appear to consider treasury costs of the subsidy, however, and whether these could be allocated to producers and consumers in more efficient ways.

objectives such as food security or growth with equity, however, a fertilizer subsidy may no longer be the preferred policy instrument (Quizon 1985). For countries whose goal is to develop local fertilizer production capacity, some form of subsidization might also be part of the policy package (Ahmed, Falcon, and Timmer 1989).

Perhaps the most persuasive justification for subsides, with respect to increasing African maize production, is that they might encourage farmers to adopt fertilizer in cases where learning costs and other system bottlenecks tend to slow or halt movement towards a socially optimum level of use (Shalit and Binswanger 1985; Miller and Tolley 1989). Miller and Tolley show that the social benefits from an optimal subsidy policy are expected, theoretically, to be relatively small, although the parameters in their model were derived primarily from Asian, not African or Latin American, experience. In practice, however, reviewers from Dalrymple (1975) to Ndayisenga and Schuh (1995) have concluded that subsidies have not been a particularly efficient means of encouraging fertilizer adoption in Africa.[25] Furthermore, rent-seeking behavior on the part of both public- and private-sector actors can make subsidies difficult to remove.

In sum, the question of whether the social return from fertilizer subsidies exceeds returns from alternate forms of investment—such as agricultural research, extension, or infrastructure development—is an empirical one. A complete analysis is likely to be complicated by the fact that the payoff period for these alternate investments tends to be longer than for fertilizer subsidies. Also, there may be some complementarities between fertilizer subsidies and investments with longer horizons.

During the period of heavy subsidies in many African countries (lasting until about the mid-1980s), growth in fertilizer consumption was not particularly rapid. Massive subsidization can lead to an inadequate appreciation of fertilizer's actual value and a complete neglect of issues like timeliness and availability.[26] The record from individual countries is mixed. For example, in Nigeria, fertilizer has been heavily subsidized in the past, and Smith et al. (1994) argue that despite problems of fertilizer supply, the subsidy undoubtedly assisted in the adoption and expansion of maize seed-fertilizer technology. Nonetheless, Daramola (1989) concludes that chaotic and untimely fertilizer supply was one of the most important reasons for non-adoption. Moreover, the rapid growth in fertilizer consumption in the 1970s appears to have slowed considerably in the last decade or more. Nwosu (1995) argues that continuing the fertilizer subsidy cannot be justified on grounds of efficiency or equity.

In many African countries, both subsidy removal and exchange-rate liberalization have reduced fertilizer consumption, sometimes quite sharply. Ghana and Zambia are examples

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[25] Desai (1991) argues that the effects of fertilizer subsidies on fertilizer adoption in India were negligible; the observable effects of India's subsidy policies were far greater in the development of the domestic fertilizer industry.

[26] At one point in Ghana, for example, the empty plastic bag was worth more on the black market than the fertilizer inside. Fertilizer was thus often discarded at the port and the empty bags were sold (G. Edmeades, personal communication).

of major maize-producing countries where policy changes have played a part in such reductions. Similar reductions may have occurred in other maize producers—such as Tanzania and Malawi[27]— where the most recent FAO data (1993) do not yet show diminished fertilizer use. Aggregate data for sub-Saharan Africa as a whole have not yet shown declining total or per hectare consumption, however, because 1) the policy changes in some countries have been quite recent and 2) until recently, fertilizer consumption in Nigeria obscured the effects of cutbacks in smaller countries (see Table 2).

Targeting High-Potential Areas

Strong arguments have been made that targeting high-potential areas is one of the most effective ways to increase food production. With respect to fertilizer use, such areas are determined by agronomic response and economic potential, the latter being related, in turn, to location and infrastructure (Byerlee et al. 1994). Several considerations should be borne in mind with respect to agronomic response. First, absolute potential yield level is as important as marginal response at zero nutrients.[28] Second, the availability of improved, more-responsive maize varieties is likely to be important.[29] In any case, the need to target high-potential areas has received adequate attention: it is time for proponents to specify where those areas are and spell out the central efficiency, equity, and environmental issues.[30]

Developing, Collating, and Distributing Information Through the Research and Extension Systems

Carefully focused agricultural research is crucial to fertilizer-sector development. The adage about getting the right fertilizer to the right place at the right time assumes that a great deal of information is already available. What, for example, is the right fertilizer? For maize production in sub-Saharan Africa, the following questions are particularly important: What are the major nutrient limitations for current maize production systems? Why aren't response rates to nitrogen higher on supposedly nitrogen-deficient soils (Table 5)? Have responses simply been mismeasured, has the limiting factor been misidentified, or have other means of increasing fertilizer use efficiency been ignored?[31]

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27 Recall that the sharp drop in Malawi's fertilizer consumption in 1993/94 resulted from the collapse of the smallholder credit system, not an abrupt change in the nutrient-grain price ratio faced by farmers.

28 High marginal response to an initial application of fertilizer in an otherwise marginal area with naturally poor soils, where organic matter levels may never support long-term sustainable yield increases, is a much less favorable indicator than high marginal response to fertilizer on relatively good soils and in good growth environments where nutrients have become depleted because of continuous extraction by crops (P.L.G. Vlek, personal communication).

29 This is a different issue from that of improving nutrient use efficiency in high-yielding varieties that are already widely used by farmers.

30 Although the idea of using fertilizer subsidies to counter environmental degradation may be regaining currency, Shalit and Binswanger (1985) argue that such subsidies would only be justified as a special case of the adoption-promotion argument that focuses on higher potential areas. Targeting subsidies is generally difficult, and attempting to combat environmental problems by subsidizing fertilizer use in marginal areas seems particularly ill-advised. The question of income generation for marginal areas is a larger one than can be addressed in this paper.

31 Nitrogen and phosphorous aside, sulfur, zinc, and potassium might be particularly important for large maize-producing areas in Africa. Custom blending fertilizers or adding micronutrients tends to increase price by about US$15-20 per metric ton, so even beyond major nutrients, discovering the "right fertilizer" has economic implications. According to criteria stated by Vlek (1990), only nine countries in sub-Saharan Africa—Cote d'Ivoire, Nigeria, Sudan, Ethiopia, Kenya, Tanzania, Malawi, Zambia, and Zimbabwe—can cut costs economically through local blending at current levels of demand (Appendix B). With the exception of Sudan, all are major maize producers.

Two avenues must be pursued if such questions are to be answered. First, existing soil-fertility information must be collected and analyzed with the express goal of making it relevant to fertilizer policy development. Such efforts must go far beyond the repetitive calculation of value-cost ratios that receive little policy interpretation. New data-management techniques—such as crop modeling and geographic information systems—may assist in this enterprise.[32] Accurate data from on-farm research will be much more valuable than results from experiment stations.

Second, new knowledge must be developed by extending both the spatial and temporal dimensions of soil fertility research. Even in a country like Kenya, with a relatively long and effective history of such research, available information may be inadequate to develop a comprehensive fertilizer policy (P.L.G. Vlek, personal communication). Although there is evidence that greater research attention is being paid to these issues (Waddington and Ransom 1995), declining support for agricultural research threatens such progress. In countries like Zimbabwe, private-sector initiatives may fill part of the gap, but the necessary long-term research strategies will still require substantial public-sector involvement, which in turn will require higher, not lower, investments in agricultural research.

Similarly, the process of developing research recommendations, making them consistent with policy, and turning them into more effective (and often more complicated) extension advice is far from satisfactory in most sub-Saharan countries. Improving that process is crucial to transforming agronomic potential into effective fertilizer demand (Gandhi and Desai 1992).[33]

Short-Run Supply Issues

Major maize-producing and fertilizer-consuming countries that have had significant amounts of donor-financed fertilizer include Tanzania, Kenya, Malawi, Ethiopia, and Ghana (Gerner and Harris 1993). Donors should quickly remove requirements that particular types of fertilizer be purchased from specific sources and instead provide fertilizer aid in cash rather than in kind (Ndayisenga and Schuh 1995); tied requirements often increase prices and encourage the use of inappropriate types of fertilizer.

Other measures to reduce distribution costs include consolidating orders within a country, pooling orders among small neighboring countries, easing the process of obtaining foreign exchange for fertilizer imports, ending public-sector favoritism within the marketing

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[32] Crop modelling may be particularly useful for such topics as risk assessment.

[33] A relatively simple example is provided by Marfo and Tripp (forthcoming). In Ghana, nutrient-grain price ratios in the absence of subsidies are now, at least in part, so high (compare, for example, Ghana with Cote d'Ivoire in Table 6) because Ghana's major nitrogen source has been, until recently, low-analysis ammonium sulfate. On-farm experimentation has shown that higher-analysis urea can be as effective as ammonium sulfate, and at the aggregate level, urea has been substituting for ammonium sulfate. Nonetheless farmers have resisted urea because it needs to be buried rather than broadcast. Farmers have been reluctant to use urea even though merchants, attempting to clear stocks, have discounted its price. Marfo and Tripp conclude that "privatization has effectively decoupled any link between agricultural research and input policy."

channel, and reducing bureaucratic obstacles in general (Ndayisenga and Schuh 1995). Countries that have not moved towards the use of high-analysis fertilizers (such as urea, DAP, and TSP) can reduce fertilizer prices by doing so.[34] As we have noted, research and extension measures must accompany changes in fertilizer type.

Credit problems are rife at all points in the marketing channel. In Ethiopia, for example, international shippers at the Eritrean port of Assob require a guarantee of U.S. $6 million before fertilizer can be unloaded for transshipment to Addis Ababa. Government-guaranteed loans to fertilizer importers, wholesalers, and large traders selected by banks on strict commercial criteria would be one way to overcome this problem (Ndayisenga and Schuh 1995). Government-sponsored credit schemes featuring group lending, trader-extended credit, and effective rural financial intermediation based on small community savings and credit schemes have all been proposed as solutions to small farmers' liquidity problems. Nonetheless, experience with government schemes has been disappointing (Eicher and Kupfuma, forthcoming), and even credit programs meeting all the standard criteria for success, such as Malawi's, have collapsed (HIID/EPD 1994; Smale and Gerrard 1995). To date, however, experience with and analysis of other ways to provide smallholders with credit have been limited.

Privatization of Supply

As an intermediate measure, governments can enhance market efficiency by creating a policy environment that 1) helps develop privately operated businesses in the fertilizer sector and 2) provides basic institutions and infrastructure (Ndayisenga and Schuh 1995; Ahmed, Falcon, and Timmer 1989). Experience with privatization in Africa, however, has been mixed. Private-sector firms are not going to enter a system that proves unprofitable because of larger infrastructural constraints or other factors, such as fixed marketing margins, uneven application of subsidies to different actors in the system, or uneven risk-sharing in the case of large stock accumulation. Inviting the private sector in at the time a market is shrinking is hardly a prescription for success, as, for example, the Ghanaian case shows (Bumb et al. 1994; Kwandwo Asenso-Okyere 1994). Experience from Cameroon, on the other hand, shows that once a market is developed, the private sector can import and deliver inputs at a lower cost, provided that the public sector provides market information and other appropriate support (Truong and Walker 1990).

Caution in the Development of Local Production Capacity

In Africa, only Nigeria and Zimbabwe produce large quantities of nitrogen fertilizer. Twenty-nine African countries possess phosphate reserves, but only three currently use them to produce phosphatic fertilizers (Gerner and Harris 1993). In the foreseeable future, local production is unlikely to contribute substantially to large-scale increases in African fertilizer consumption. Forty years experience with local production capacity elsewhere in the developing world suggests that, for nitrogen at least, most countries, even those with

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[34] In Malawi, which has particularly high external transport costs, a partial transition to high-analysis fertilizers has been effected, and pessimism has been expressed about some of the other short-term measures (HIID/EPD 1994).

substantial feedstocks, would have done better to import fertilizer than to manufacture it locally. Economic evaluations of potential plants have consistently over-estimated finished-product to feedstock price ratios and capacity utilization. The use of local rock phosphate deposits may prove an exception to this rule, but, nonetheless, projects should be subject to more careful *ex ante* economic analyses than has been the case in the construction of nitrogenous fertilizer plants (Tomich, Kilby, and Johnston 1995).[35]

Infrastructural Development

For a bulky input like fertilizer, transportation and storage costs must be reduced if long-run consumption is to approach the social optimum. Since infrastructure affects far more than the fertilizer sector alone, we will not consider it in detail here. However, construction and maintenance of rural/feeder roads, as well as more general attention to maintenance within the transport sector, are likely to play a key role in reducing fertilizer distribution costs. The public provision of legal and social infrastructure may also help to reduce the risks of fertilizer distribution (Ndayisenga and Schuh 1995).

Conclusions

Increased fertilizer use, particularly on maize, is essential to increasing per capita food production in Africa. Although region-wide growth in fertilizer consumption has slowed, fertilizer use on cereals in general, and on maize in particular, has become relatively more important. Nonetheless, although several African countries had achieved relatively high rates of maize fertilization by about 1990, in general the proportion of fertilized maize area has remained lower than for developing countries in Asia and Latin America.

Until recently, policy debates about the fertilizer sector in African countries focused particularly on subsidies and macroeconomic management, giving little attention to the larger issues of research investments or infrastructural development. Institutional details related to policy making were also given rather short shrift.

Without a doubt, subsidies in many countries have been considerably higher than can be justified by any economic rationale.[36] We would suggest that the long-run goal in any country be complete removal of fertilizer subsidies. Countries where fertilizer consumption is limited at present could lift subsidies in relatively short order. In countries where current consumption is higher (say 25,000 nutrient tons per annum on a relatively sustained basis), subsidy withdrawal should be made conditional on the development of a comprehensive

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[35] The current situation in Nigeria and Zimbabwe gives little cause for optimism. The economics of nitrogen fertilizer manufacture in Nigeria is difficult to unravel. Despite an inability to satisfy the market in Nigeria and neighboring countries that import urea from Europe, the NAFCON plant has to export urea, in some cases to Europe, to obtain foreign exchange (Gerner and Harris 1993). The case of Zimbabwe is somewhat simpler. Protected local ammonium nitrate manufacturers probably could not compete with imported urea were trade barriers removed.

[36] Those who argue that Africa is somehow “different” should be challenged to develop formal policy models that clearly specify policy objectives. Good examples are provided by Barker and Hayami (1976), Quizon (1985), and Miller and Tolley (1989). Model parameters could then be changed to reflect empirical African conditions.

agricultural-sector strategy (Lele 1992). As with economic reforms in formerly socialist economies, opinion is divided between advocates of "short, sharp, shock" shifts in policies, and advocates of a slower movement towards a more optimal policy regime. Although phased subsidy withdrawal and similar policies can create opportunities for delay and subversion, our considered opinion is that, given the large possibilities for disequilibrium already present in the fertilizer sector, gradual and carefully planned reforms are likely to give better long-run results than does shock treatment.

At present, policy makers often seem influenced more by donor or lending agencies, or by crisis-management imperatives, than by long-run strategic considerations. In some cases, long-established procurement, distribution, and pricing arrangements are changed drastically and at short notice. The result is all too predictable: highly variable and even conflicting signals are sent to public agencies, private-sector organizations, and farmers. As a prerequisite to developing optimal fertilizer polices, decision makers must move beyond crisis management to crisis avoidance. Whether because of subsidy withdrawal or exchange-rate liberalization, mismanagement of a donor-assisted fertilizer grant (von Braun and Puetz 1987), or collapse of a supporting institution like the credit system (HIID/EPD 1994), sharp fluctuations in fertilizer usage are an all too common feature of African agricultural economies.

For the fertilizer sector to be effective, the government—in consultation with the private sector and donors—must develop what most sub-Saharan countries lack: a detailed national fertilizer-sector policy and plan that is carefully integrated with a comprehensive agricultural strategy. National policies must be broadly consistent with one another, and present and potential actors in the system must understand policy objectives and the means of attaining them. In turn, governments must develop strong internal policy capacities and the ability to communicate forcefully with donors and the private sector (Martin and Lele 1992). Strengthening policy capacity through better public-service incentives will complement private-sector participation (Ndayisenga and Schuh 1995).

Two recommendations follow from these insights. First, over time governments should withdraw from fertilizer procurement, distribution, and pricing; instead they should concentrate on providing information, enhancing legal institutions, and improving infrastructure. Throughout the privatization process, the relationship of government and the private sector must be clearly defined: short- and long-term roles, and how these change as the sector develops, will need to be spelled out if mutual trust and confidence are to develop (Sodhi 1993). Initially, fertilizer distributors may need to be trained. In countries with relatively large markets, a fertilizer industry association can promote dialogue between public and private sectors (Ogola 1987).

Some government functions are likely to remain important after fertilizer marketing has been privatized. These include setting and enforcing standards and quality control; estimating demand, in consultation with the private sector; monitoring and evaluating sector performance; establishing mechanisms for consultations between the private sector and the government; creating an environment conducive to private-sector participation;

and supporting long-term research and extension, as well as infrastructure development (Sodhi 1993). Appropriate representatives from all these areas should be involved in decisions about fertilizer policy.

Second, future studies must devote greater attention to the institutional details of policy making. Any institutional study of reform in the policy-making process should consider how all interested parties can contribute to effective decision making. Government commitment to agricultural development, active collaboration with the private sector, and more thoughtful, coordinated donor action will all be necessary. Comprehensive agricultural strategies, strong government policy capacity, and financially viable private-sector fertilizer distributors are unlikely to come into existence all at once, but institutional understanding should contribute substantially to the design of second-best solutions.

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Appendix A

Fertilizer Use by Crops and Fertilizer Application Rates to Maize, Additional Developing Countries

For comparative purposes, Table A1 presents data on fertilizer consumption by crop (maize and other cereals) for developing countries. Table A2 indicates nutrient application rates to maize for developing countries other than those shown in Table 4 of the main text.

Table A1. Fertilizer use by crops, other developing countries.

Country	Maize area 1990-92 '000 ha	—% Fertilizer (nutrients) applied to— maize	other cereals	Maize area: % of total cereal area	Maize fertilizer as % of fert. to all cereals	Year
Asia						
India	5981	3	61	6	4	1989
Philippines	3600	34	42	52	45	1990
Indonesia	3230	12		24		1981
Thailand	1453	14	55	13	20	1990
Pakistan	860	4	56	7	7	1989
Nepal	747	8	37	26	17	1989
Vietnam	437	7	85	6	8	1990
Latin America						
Mexico	7212	37	29	71	56	1990
Colombia	785	4	31	49	10	1991
Guatemala	646	55	4	88	94	1987
Ecuador	454	20	20	55	50	1991
Venezuela	452	34	27	56	56	1991
Honduras	410	10	11	82	49	1990
Paraguay	343	26	22	59	18	1991
Peru	312	26	22	45	54	1991
Bolivia	256	4	4	43	50	1991
Nicaragua	205	19	12	69	60	1991
Commercialized Maize Producers						
China	21405	11	57	23	16	1990
Brazil	12644	15	14	64	52	1989
South Africa	3318	34	21	60	61	1990
Argentina	1970	1	47	24	3	1987

Sources: IFA/IFDC/FAO (1992); Timmer (1987); Martinez (1990).

Table A2. Fertilizer application rates to maize, additional developing countries.[a]

Country	% maize area receiving NPK	kg NPK/ha on area receiving fertilizer	kg NPK/ha total maize area
Asia			
Pakistan[b]	100	88	88
Nepal	40	17	7
Vietnam	na	na	32
Latin America			
Colombia	20	133	27
Ecuador[c]	50	230	115
Venezuela	90	260	234
Honduras	10	231	23
Paraguay	10	37	4
Peru	51	173	88
Nicaragua	52	122	64

Source: IFA/IFDC/FAO (1992).

[a]Data from countries where relatively high application rates are reported on a relatively small proportion of total maize area should probably be treated with particular caution.

[b]Although fertilizer use on maize in Pakistan might be somewhat lower than reported by IFA/IFDC/FAO, it is still relatively high, probably covering at least 90% of maize area (Asghar and Longmire 1989).

[c]These application rates appear quite high in view of the reported low yields of maize in Ecuador.

Appendix B

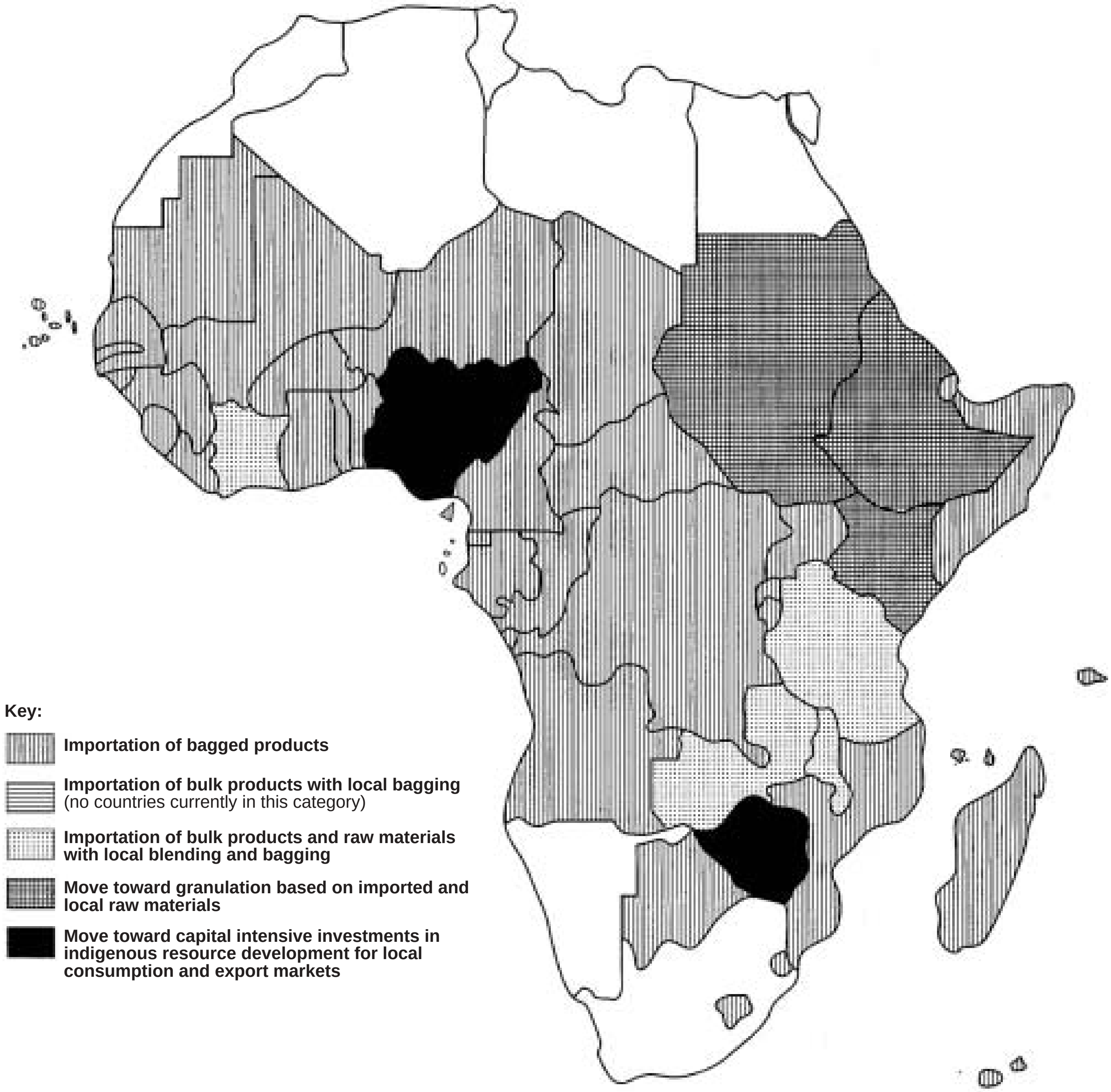

Figure B1. Optimal means of assuring fertilizer supply at current (1993) consumption levels, sub-Saharan Africa (single country option).

Note: Criteria proposed by Vlek (1990). Vlek's criteria for fertilizer consumption thresholds (in total product tons) are applied to FAO data for 1993. Note that apart from Nigeria and Cote d'Ivoire, all sub-Saharan African countries for which investment in some local capacity (e.g. bagging, blending, or granulation) may be justified lie in eastern and southern Africa, in a belt stretching from Sudan to Zimbabwe. Note as well that Tomich, Kilby, and Johnston (1995—see main text) would argue that capital intensive investment in developing indigenous resources might not even be justified for Nigeria and Zimbabwe.

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