



Improving African Food Security

**An
International
Center for
Soil Fertility
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by

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IMPROVING AFRICAN FOOD SECURITY

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One of Africa's most urgent issues today is food security—food production is not keeping pace with population growth, leading to continued declines in its already low food production per capita. In fact, the Green Revolution, which combined improved seeds, inorganic fertilizers, and plant protection products, has bypassed Africa. This problem is rooted in Africa's poor agricultural resource base, which makes the use of external inputs such as inorganic fertilizers unprofitable. The socioeconomic and policy environments create further obstacles. Exceptions to the general trend at the country, region, and crop level underline the importance of the factors causing stagnation elsewhere and help to identify technologies and strategies for change. Integrated soil fertility management can improve African food security. The synergism of locally available soil amendments, such as animal manures and crop residues, can make inorganic fertilizer use more economically attractive. Combining technology with an enabling environment for farmers to invest in their soils and for the private sector to invest in agricultural input and output market development further improves the economic feasibility of using fertilizer. Strategies that support farmers' organizations and private sector associations, and their effective cooperation with the public sector, can help create this enabling environment.

Food security is one of the most urgent issues facing Africa today. The African agricultural sector is stagnant, and food production, which is mainly subsistence oriented, lags behind the already low growth of agriculture in general. Sub-Saharan Africa has the lowest land and labor productivity rates in the world,¹ with annual growth in the cereal yield averaging only 10 kilograms per hectare per year (kg/ha/yr)—about 1%. Counting growth in area harvested as well, total food production increases annually at about 2%—less than the population growth rate of 3%. Annual per capita food production, which is already more than 50 kg below the es-

timated minimum per capita requirement of 200 kg/ha, is declining, seriously threatening African food security.

As long as agricultural growth in sub-Saharan Africa remains below 3%, food security is wishful thinking. If Africa seeks to rely on agriculture for economic development, 4%-7% annual growth is required,² amounting to average annual cereal yield increases three to six times the current 10 kg/ha level. Worldwide, the so-called Green Revolution—in which the use of external inputs, such as inorganic fertilizers, improved crop varieties, and plant protection products,

intensifies agricultural production—has shown average annual yield increases of 75 kg/ha. United Nations Food and Agriculture Organization (FAO) statistics suggest that food-secure countries spend more than \$5 per capita on inorganic fertilizers; only two sub-Saharan countries reach this level, and most spend much less than \$1 per capita.³ Structural adjustment programs, implemented with the aim of improving African economies, have even had adverse effects, increasing the possibility of food shortages.

This paper explains why the Green Revolution that boosted food output elsewhere several decades ago bypassed Africa. It argues that Africa is at a comparative disadvantage vis-à-vis other continents due to its poor natural resource base for agriculture, and that unfavorable socio-economic conditions further exacerbate this problem. It then analyzes the exceptions that prove the rule, exceptions that point to a strategy of agricultural intensification to combat food insecurity and increase agricultural productivity. Through such a strategy, the exceptions can become the rule.

The African Agricultural Context: The Population Paradox

Average annual growth of cereal production, compared with yield growth across various countries or continents, illustrates the arrears of African agriculture. Agriculture without the use of external inputs, also called extensive agriculture, shows an average cereal yield increase of less than 10 kg/ha/yr. In contrast, intensive Green Revolution agriculture yields growth of about 75 kg/ha/yr. (A similar differential holds true worldwide.⁴) The growth rate improvement in Western Europe and the United States took place in the 1950s. In South America and Asia, the adoption of Green Revolution tools and the concomitant increase in yield growth began in the 1970s. But cereal yields in Africa are still increasing by only 10 kg/ha/yr.⁵

The Green Revolution that helped boost yields on other continents never reached Africa. Con-

sider the level of external inputs used in African agriculture as compared with India and China.⁶ In 1960, differences in fertilizer use were limited: 5 kg/ha in Africa against 10 kg/ha in India and China. By 1995, fertilizer use had increased by only 60% in Africa, while it had increased 1,100% and 2,300% respectively in India and China. The number of tractors and the acreage under irrigation followed similar trends, showing rapid growth in the two Asian countries and extremely limited growth in Africa.

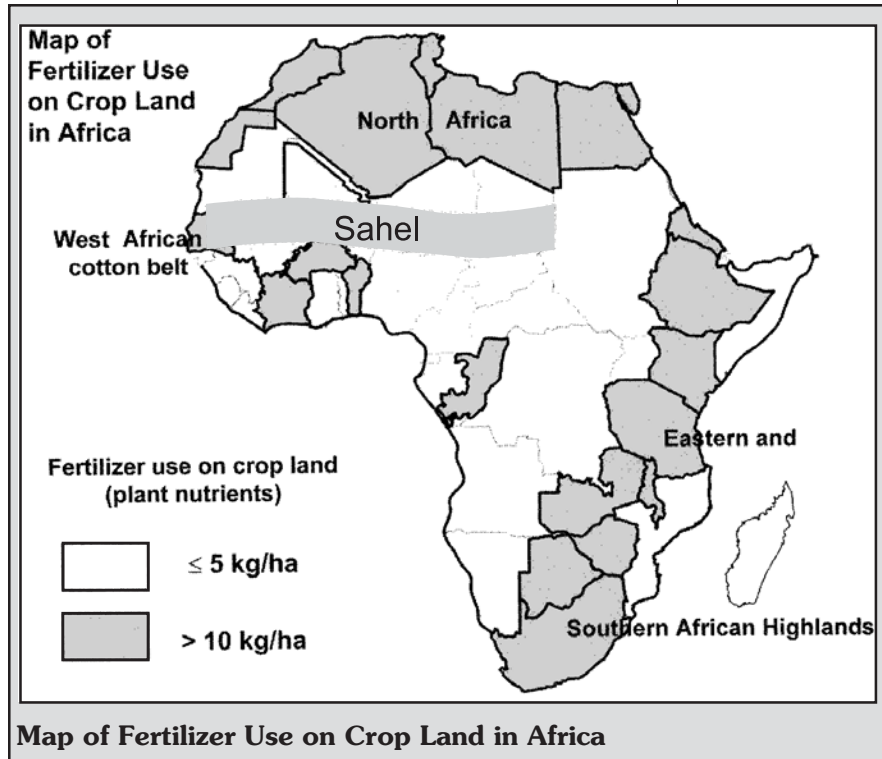
A similar comparison between Africa and Asia as a whole shows large differences in per capita cereal production and fertilizer use. In Asia, cereal production increased from 231 to 274 kg per capita between 1970 and 1995, and total fertilizer use, from all crops taken together, from 0.005 to 0.019 kg per capita. During the same period, African cereal production per capita decreased from 166 to 137 kg, while total fertilizer use remained negligible at less than 0.005 kg per capita.⁷

Agro-Ecological Conditions

The soils of sub-Saharan Africa formed from old, weathered rocks that are low in nitrogen and phosphorus, the two most important nutrients for healthy plant growth. In addition, the characteristics of the dominant clay minerals in African soils are such that the nutrient storage capacity of the soils is limited. Not only are the soils poor, but the climate is also extreme, rainfall being either low, irregular and erratic, or too high and intense.⁸ The annual water balance, measured as precipitation minus evaporation, is so low that perennial plants do not contribute as much organic matter to the soil as in other parts of the world.⁹ Low organic matter content contributes to the lack of nutrient storage capacity and to a low water retention capacity that makes the soil prone to erosion. The poor quality of African soils is the most important limiting factor for African agriculture. This is true even in regions like the drought-prone Sahel, the semi-arid transition zone from the Sahara Desert to

the West and Central African savannah (see map). Africa's poor quality soils limit agriculture even more than its difficult socioeconomic conditions.¹⁰

only Patagonia and Australia's Northern Territory have levels as low. However, while those areas are almost unpopulated, with only one to two inhabitants per square kilometer (km²), West Africa is home to almost 100 people per km².¹²



Overexploitation of natural resources, the main cause of the negative balance of plant nutrients, aggravates the problem of a poor resource base. This overexploitation stems from overpopulation in countries or regions that rely on agriculture based almost exclusively on natural resources. Overpopulation as such is not necessarily a problem; it can also be part of the solution.¹³ However, the resource base of West Africa and other African regions is so poor that overpopulation occurs at low absolute population density.

Nutrient mining of soils aggravates the situation. Harvesting, grazing, and wood cutting remove more nutrients from the soil than are returned by natural processes, fertilizer use, and other farm practices such as the use of manure, nitrogen-fixing leguminous species, and agroforestry. Average use of inorganic fertilizer in Africa is less than 10 kg/ha of nutrients, only one-tenth of the world average. As well as having the lowest yields, Africa therefore has the highest nutrient-depletion figures, with a negative nutrient balance of about 60 kg/ha.¹¹ The situation in West Africa may be the worst of all. As in East and Central Africa, average annual rates of nutrient depletion are between 50 and 100 kg/ha of nitrogen, phosphorus, and potassium, but the soil's inherent quality is poorer. For example, the annual sustainable availability of nitrogen in West Africa is less than 20 kg/ha;

Intensification of agriculture and the increased use of external inputs are required at a moment when most production is still subsistence oriented, and infrastructure, distribution, and transport systems development is limited; road density in Africa, for example, is only one-tenth of that in Southeast Asia during its Green Revolution in the 1980s. The costs of farm-level inputs are therefore high, and the prices of agricultural products quite low. Making matters worse is a low efficiency of inputs (limited yield increase per unit of input) caused by the same unfavorable agro-ecological conditions described above, slow development of domestic markets and purchasing power, and limited employment outside of agriculture. Thus, the extremely low use of external inputs and the slow transformation from self-sufficiency to market-oriented production are explained by the low efficiency of agricultural inputs, the high price of inputs at the farm gate,

and the low price of agricultural products, all linked to the poor natural resource base for agriculture. In order to stop soil depletion, improve the resource base, and increase output through more intensive agriculture, the use of fertilizers and other external inputs is an absolute necessity. Doing so implies developing a market-oriented agriculture; however, Africa's low population density makes such development difficult. Average African population density is less than 30 people per km², compared to several hundred in Southeast Asia. The paradox of African agriculture is that agricultural development is inhibited at once by overexploitation of the land because of "overpopulation" and by poor market development because of "underpopulation."

The Socioeconomic Context

The socioeconomic context, both internal and external, continues to undermine efforts to intensify agriculture and make it more sustainable. External factors include globalization and the World Trade Organization agreements, which have forced open developing country agricultural markets while developed countries continue to implement highly protectionist agricultural policies.¹⁴ Internal factors include the legacy of incomplete and ill-conceived market reform—inadequate, inappropriate, and sometimes inconsistent agricultural policies that do not provide the much-needed environment for private sector participation and favor consumers over producers. Urban consumers, who spend up to 80% of their income on food, constitute a powerful lobby that pressures governments to maintain low food prices. Dispersed rural producers tend not to be organized and therefore are not effective in pressuring policymakers to maintain reasonable prices for their products.

Prior to the structural adjustment programs implemented in the 1980s, governments all over the continent were responsible for procuring and distributing fertilizer and other external agricultural inputs. Reforms in the agricultural sector focused on input market privatization and liber-

alization, and were implemented abruptly, without a transition period to allow for private sector development. In particular, these reforms did not contain regulations to guide privatization or clear roles for government in the newly privatized input market. Privatization, therefore, occurred in an unpredictable environment for private sector participation. The basic elements of market reforms in the agricultural subsector were:

- Government withdrawal from fertilizer procurement and distribution.
- Input and product market and price liberalization.
- Removal of subsidies and guaranteed prices.
- Elimination of territorial and seasonal prices.
- Abolition of parastatal marketing boards.

Import liberalization and the state's withdrawal from the market created an immediate and natural opportunity for the private sector, which initially responded well. As privatization progressed, importers and distributors of agricultural inputs proliferated. The parastatal companies and plantations (e.g., cotton, rubber, oil palm, banana, pineapple, cocoa, etc.), which had imported fertilizer and other inputs directly for their producers, began using international tenders for the private sector to supply inputs, worth several millions of dollars annually per country. However, because of stringent bank requirements for credit (usually a 100% guarantee to establish letters of credit), only a few suppliers with deep pockets or connections to the manufacturers won the tenders. Parallel markets emerged for subsidized fertilizer procured and distributed by NGOs, for example, or in commodity subsectors like cotton and cocoa in which the old parastatal agencies procured and distributed inputs to their members under different credit conditions. Governments also misused (and continue to misuse) donor aid by selling foreign fertilizer received as aid at less than the market price. At the same time, the private sector imported fertilizer commercially and had to sell it at full cost. This misuse of donor aid continues to distort the market and increase market uncertainty; since the timing and

quantity of donor aid are uncertain or irregular, it is impossible for the private sector to identify the market size at any given time to determine how much to import. Privatization and market liberalization without a regulatory system also gave rise to the proliferation of poor quality fertilizer.¹⁵ The reform process, in other words, has only been partial, creating a risky situation that inhibits market development by scaring off potential private investors and entrepreneurs.

The combination of reform policies that cut input subsidies, dissolved parastatal distribution and extension services, restricted agricultural credit, and liberalized output markets has made it increasingly difficult for farmers to sustain the use of agricultural inputs they had adopted before the reforms. During the 1990s, inorganic fertilizer use in sub-Saharan Africa decreased from 10 to 8 kg/ha of nutrients. The lack of domestic and international investment, along with the effects of social unrest and wars, has resulted in an even lower use of external inputs today than at the start of structural adjustment.

Success Stories: Exceptions Prove the Rule

Exceptions to the general trend at the country, region, and crop level underline the importance of factors causing stagnation elsewhere and help to identify technologies and strategies for change. Intensification is becoming a reality in some areas and achieving results despite structural, economic, and social difficulties. Intensification based on the use of fertilizers and other external inputs is occurring in places where the natural resource base is relatively good compared to the African average, or where the value-cost ratio (VCR) is favorable enough even without an enabling socioeconomic and policy environment.¹⁶ A good example is peri-urban agriculture, which flourishes all over Africa using relatively high levels of external inputs. Areas near cities produce large amounts of vegetables and fruits, and cereal production is intensifying at even greater distances from cities, driven by con-

centrated urban populations with relatively high and stable incomes. This ready domestic market leads to improved transport and distribution infrastructure and enables soil fertility improvement by converting urban wastes into compost.¹⁷

Steve Wiggins' 1995 study of the evolution of agriculture in 14 West, Central, and East African sites showed that population growth, reduction in transport costs, and market growth lead to intensified agriculture.¹⁸ Internal and regional markets, even more than exported cash crops, appear to be important stimulants for change. However, Wiggins excluded war-torn countries, making the steadily growing farm outputs that he observed in most cases biased. He also overlooked the quality of the resource base. The sites he studied were in regions with relative advantages like comparatively good soils and high water availability that allow efficient use of external inputs and make the VCR of external inputs more attractive. Twelve of his fourteen sites also had a higher rural population density than the country average, the urban population included. His study therefore tends to underline the importance of the natural resource base as a support for intensifying agriculture.

Annual fertilizer consumption patterns reinforce this observation.¹⁹ In three regions, fertilizer use is above the continental average of less than 10 kg/ha of nutrients: North Africa, the West African cotton-producing countries, and a closed band of countries from Eritrea to South Africa. Northern Africa's more temperate climate and the fertile Egyptian Nile valley favor the use of external inputs. The West African cotton belt has reasonable rainfall conditions and relatively good soils. The East and Southern African countries have highlands with a relatively temperate climate, while recent volcanic activity improved the old leached and weathered soils. Even in these three regions, average fertilizer consumption is still low, generally less than 20 kg/ha of nutrients. Egypt is the exception with

more than 300 kg/ha, while South Africa and Zimbabwe use about 50 kg/ha, and Morocco, Libya, and Malawi about 30 kg/ha. Average figures can hide crucial differences within countries. While large commercial farmers in South Africa and Zimbabwe use most of these countries' fertilizers, smallholders also use several times more than the African average.

Important differences also exist in input use among crops. In Mali and Burkina Faso, cotton receives more than 100 kg/ha of nutrients, even though most of the cereal production in these two countries is still completely extensive. Again, the detailed picture is different. Maize production, which is concentrated in the cotton belts of Burkina Faso and Mali, shows a much higher yield increase than sorghum and millet, which is produced mainly outside the cotton belt. In Mali, the figures are 40 kg/ha/yr for maize against less than 10 kg/ha/yr for sorghum and millet.

West African rice provides yet another example of differences across crops.²⁰ From 1984 to 1999, rain-fed upland rice production increased by 27%, exclusively through area extension, while rain-fed lowland and irrigated rice production grew 200% and 170%, respectively, partly as a result of intensification. In 1984, the yield without external inputs was 1 ton per hectare (t/ha) for upland rice and 1.4 t/ha for rain-fed and irrigated lowland rice, reflecting the more favorable soil and water conditions of the lowland production systems. Only lowland rice production has intensified since then, producing yields in 1999 of 1.8 and 2.1 t/ha respectively for the rain-fed and irrigated systems.

Finally, the Malian case of the "Office du Niger" underscores the ability of improved socioeconomic conditions to stimulate intensification of food production. After independence, this parastatal organization became responsible for the exploitation of a large irrigation scheme, and transformed colonial cotton production into rice production. It controlled agriculture in detail:

water management, extension, procurement and distribution of external inputs, rice thrashing, and commercialization. Important investment projects, supported by the Dutch, the French, and the World Bank, and channeled through the Office du Niger in the 1970s, did not succeed in increasing the productivity of the irrigated rice; yields remained at about 1.5 t/ha, the average since Malian independence. But privatization and liberalization of input and output markets in the 1980s triggered change; farmers had an incentive to invest in inputs and in more labor-intensive technologies. In a period of 10 years, yields increased to 5.0 t/ha.

These examples show that intensification in food production has tended to occur under some combination of the following conditions:

- Relatively favorable climate.
- Relatively good soils (e.g., good storage capacity for nutrients and water).
- Existence of irrigation systems.
- High population pressure and urbanization.
- Relatively good transport and distribution systems.
- Adequate economic and agricultural policies.
- Access to local, regional, or international markets.

The first three make agricultural inputs efficient to use, while the last four help create favorable input and output prices.

Exceptions and the Challenge of Change

Understanding the African agro-ecological context, and how the socioeconomic and policy environment reinforces it, is essential in formulating effective strategies for change. The intermediate goal of such strategies should be to improve the VCRs for using external inputs. The agronomic components of the strategy have to ensure more efficient use of external inputs, while the socioeconomic and policy components should provide incentives for farmers to adopt new technologies and encourage competitive pricing.

Fertile Ground: Growth Through Soil Management

To increase the efficiency of external inputs and make them an attractive option for African farmers first requires improving the African agricultural resource base. This can be achieved by increasing either nutrient availability or water availability. In principle, the latter option is attractive, but Africa is not well endowed with irrigation potential, and even small-scale irrigation systems are still expensive—usually between \$4,000 and \$8,000 per irrigated hectare. While irrigation has clear benefits, the rate of return for irrigation infrastructure is quite low. Still, governments and donors have continued to focus on such projects while neglecting investment in soil fertility improvement.²¹

As indicated above, low soil fertility, even in the semi-arid Sahel, limits food production even more than water availability. As one moves in West Africa from the central Sahel, with rainfall of 400 mm/yr, to the southern part of the cotton belt, with 1,200 mm/yr, cereal production increases from about 0.5 to 0.8 t/ha. A three-fold increase in water availability results in only a 60% yield increase. Irrigation in the 400-mm/yr zone leads to rice yields of 1.4 t/ha; with fertilizer use, 8 t/ha would be possible. Fertilizer use alone at 400 mm/yr increases the fodder production of natural rangelands from 1.6 to between 4.8 and 8 t/ha, depending on soil texture.²² Despite such evidence, the assumption that water is the most limiting factor in African agriculture seems almost ineradicable.

The better solution for intensifying agriculture is soil improvement combined with fertilizer use.²³ Chemical fertilizer has a low efficiency when the agricultural resource base is as poor as in most of Africa. Introducing amendments, such as manure or crop residues, to the soil can improve its organic matter content and quality, phosphorus availability, and pH, thereby increasing the efficiency of chemical fertilizer. This change often requires chemical fertilizer to pro-

duce enough organic matter of the desirable quality. The integrated use of chemical fertilizer and locally available soil amendments is therefore the best approach for achieving higher fertilizer use efficiency—in other words, making it more economically feasible. In this context, soil improvement is both a tool for and a goal of agriculture intensification based on more sustainable production systems.²⁴

Dutch-Malian research cooperation led to the development of the integrated soil fertility management approach between 1976 and 1996; IFDC²⁵ and partners have since developed the method further by creating a whole menu of integrated soil fertility management options that take into account farmers' interests, agro-ecological conditions, and the socioeconomic conditions in West Africa.²⁶ This plan calls for combining inorganic fertilizers with amendments like crop residues, manure, compost, and phosphate rock, or using the fertilizers as elements of complex systems like agroforestry, crop-livestock integration, cereal-legume rotation, and crop-pasture rotation. The medium-term results are encouraging. IFDC has observed fertilizer use efficiency up to twice as high as the regional average. Yields of maize, sorghum, and millet are typically twice or even three times higher than average levels. Returns to invested capital exceed 100%, with VCRs well above two, and returns to family labor two to six times higher than the average wage prevalent in the region.²⁷ The attractive aspect of integrated soil fertility management is its comparative advantage for smallholders and marginal land because labor and the adaptation of production systems to the particularities of the land partially replace capital.

The investment required for soil improvement is considerably less than for irrigation and is spread out over a period of time during which the soil organic matter and related benefits build up. One estimate of the investment necessary to double fertilizer use efficiency for the West African cotton belt found the cost to be quite

reasonable.²⁸ The investment included organic amendments (straw or manure) and erosion controls necessary to start improvement of degraded loamy soils.²⁹ Only the investments for erosion controls required immediate full payment; the rest could be spread over periods of 4-7 years. Estimated costs totaled up to \$550/ha for a system using straw and \$730/ha for one using manure, only a fraction of the investment costs for small-scale irrigation, which run between \$4,000 and \$8,000/ha. The benefits of soil fertility improvement build slowly and peak after at least 4 years; while yields increase from the beginning, VCRs improve gradually over time. The internal rate of return is between 11% and 15%, higher than the typical 10% or less realized through irrigation investments.³⁰

In spite of the low investment costs and favorable VCRs of these technologies, their adoption rate is low. Bottlenecks include lack of capital, the long period of time required to realize the direct benefits, and poor access to input and output markets. Because of these constraints, farmers continue to deplete the soil in the short term because it is a more efficient way to maintain revenues than attempting to change the production system.³¹

Practical Policy Steps

Support from governments, donors, and international financial institutions is key to promoting the transformation of farmers' practices. Socioeconomic and policy environments must be altered to enable farmers to invest in their soils and spur the private sector to invest in input and output market development.³² Direct investments by governments and donor agencies in soil fertility improvement should be part of the solution. Improving the availability and accessibility of sources of organic matter is an option for Africa as a whole. More specific investments will depend on regional characteristics, such as phosphorus deficiency or soil acidity, the availability and quality of phosphate rock and lime, and the costs of transport and distri-

bution.³³ For example, programs that encourage the use of phosphate rock are a good option for regions near phosphate rock reserves like Minjingu in Tanzania and Tilemsi in Mali.

Policy measures that should accompany efforts to improve soil fertility include addressing credit problems and land rights; improving and extending rural infrastructure, marketing, and distribution networks; increasing the effectiveness of extension services; and shifting government emphasis from consumer support to producer support. Specific attention should be given to the availability and accessibility of external inputs.

Most importantly, governments must become facilitators instead of actors. This has been one of the most obvious conclusions of IFDC's analysis of the failing agricultural input sector in sub-Saharan Africa.³⁴ Governments have an important role to play in input quality control, input and output market information systems, tax reforms, and regional cooperation where markets are too small to attract private investments. When these services are missing, the private sector cannot grow to its potential.³⁵ Too often, however, government procedures for ensuring input accessibility are neither transparent nor consistent. For example, subsidies are reinstalled after being abandoned, donor aid inputs are sold below full market prices, and liberalization and privatization are not fully carried out because such reforms threaten the interests of some policymakers. Those policymakers who indirectly benefit from fertilizer procurement and distribution may be reluctant to support complete government withdrawal. This is one of the reasons why structural adjustment programs do not seem to have been effective, and why the accessibility of agricultural inputs is declining in Africa as a whole.

Government use of subsidies to intervene in the input market relates to growth patterns in fertilizer use. Since the 1980s, fertilizer consump-

tion in almost half of all African countries has continued to grow by more than 1% annually, while consumption in others has stagnated or declined. Comparing the evolution of chemical fertilizer consumption over the last 10 years with the World Bank's analysis of structural adjustment successes shows a positive correlation between fertilizer consumption and the degree of structural adjustment reform.³⁶ The twelve countries in the World Bank study in which fertilizer prices are subsidized or under government price control show an average fertilizer consumption growth rate of only 1%, against 6% for the 17 countries without any control on prices or marketing. Worldwide, an impressive list of cases demonstrates that input accessibility and use is best served by creating an enabling environment for the private sector to invest in market development, one element of which is the elimination of direct government intervention.

During the transition period in which governments change from being actors to facilitators, farmers and private sector input dealers must organize themselves better, and policymakers should encourage and support such efforts. These types of organizations have at least three key functions: creation of economies of scale in input procurement, access to credit, and advocacy. The dialogue among farmers' organizations, private sector associations, and the public sector becomes an indispensable element for agricultural development as governments retreat. To be effective, the strength of the individual stakeholder groups has to be more or less equal.³⁷

Aggregate data on fertilizer consumption trends in many countries have shown sharp declines following agricultural sector reforms because of abrupt government withdrawal before the private sector was prepared to take over. No consistent effort was made to improve the tech-

nical and business knowledge of the new private sector input dealers. In addition, access to credit facilities, which is critical for procurement and distribution, was difficult, inhibiting the ability of the private sector to function efficiently. To restore fertilizer consumption to previous levels, some have advocated using direct subsidies as a tool for moving to more sustainable systems.³⁸ However, because of the market-distorting nature of subsidies, indirect support to farmers through increased access to soil amendments is a preferable solution for long-term market health. Where direct subsidies for fertilizers seem indispensable (for example, to re-establish a country's agriculture after a war or natural disaster), they should be distributed in a voucher system that does not distort the market. Vouchers can also be useful tools in introducing farmers to fertilizer use in the early stages of agricultural development and for smallholders on marginal land.³⁹

Conclusion

African food security is worsening by the year. Africa is at a comparative disadvantage vis-à-vis other continents because of its poor natural resource base and unfavorable socioeconomic conditions. Nevertheless, addressing these twin problems simultaneously can ensure food security. First, governments and international donors should make and encourage investment in soil improvement and in input and output market development, correcting the bias towards expensive irrigation projects that have been the traditional approach to improving soil fertility. Second, governments must move from direct intervention through market-distorting tools such as subsidies to market facilitation, and shift emphasis from consumer support to producer support. In conjunction with government action, strong farmers organizations and private sector associations also play an essential role in creating and supporting efficient and profitable agricultural markets.

Notes

1. Ph. Pardey et al., "Agricultural Research in Africa: Three Decades of Development," Briefing Paper 19, 1995. The Hague: International Service for National Agricultural Research (ISNAR).
2. The World Bank and the African Development Bank respectively suggest a 4% and 7% growth requirement. Refer to O. Kabbaj, "The Challenge of Development and Poverty Reduction in Africa" (Sir John Crawford Memorial Lecture, Washington, DC, CGIAR, 1998).
3. This figure assumes \$400 per ton of fertilizer nutrients. See K.G. Soh, "Agriculture and Fertilizer Use in the 90's: A Decade of Significant Transformation," Proceedings of the *International Fertilizer Association Regional Conference for Africa*, Maputo, Mozambique, June 1998 (Paris: IFA, 1998).
4. See comparisons of growth rates in different parts of the world by C.T. de Wit in the Introduction to H. van Keulen and J. Wolf, eds., *Modeling of Agricultural Production: Weather, Soils and Crops* (Wageningen, the Netherlands: Centre for Agricultural Publishing and Documentation [PUDOC]), 3-10.
5. See Henk Breman, "Soil Fertility Improvement in Africa: A Tool for or a Byproduct of Sustainable Production?" Special Issue on Soil Fertility, *African Fertilizer Market Bulletin* 11, No. 5 (1998): 2-10.
6. CGIAR, "Views of Leaders of African NARS on Chartering CGIAR's Future," *ICW paper 00/07-6*, 2000. Washington, DC: CGIAR-World Bank.
7. Soh, "Agriculture and Fertilizer Use in the 90's."
8. Henk Breman, "No Sustainability Without External Inputs," in *Beyond Adjustment; Africa Seminar*, Maastricht, the Netherlands. Ministry of Foreign Affairs, Den Haag, 1990, 124-133.
9. See S. K. Debrah, "Strategies to improve soil fertility in African farming" (paper presented at the Agricultural Workshop of the African-American Summit held in Accra, Ghana, May 17-19, 1999).
10. F.W.T. Penning de Vries and M.A. Djitéye, eds., "La productivité des pâturages sahéliens: Une étude des sols, des végétations et de l'exploitation de cette ressource naturelle," Agricultural Research Reports 918, PUDOC, Wageningen, the Netherlands, 1982.
11. See J. Henao and C. Baanante, *Estimating Rates of Nutrient Depletion in Soils of Agricultural Lands of Africa*, IFDC, Muscle Shoals, AL, 1999.
12. See Breman, "No Sustainability Without External Inputs," and Penning de Vries & Djitéye, "La productivité des pâturages sahéliens."
13. High population density leads to economic development and employment outside agriculture, creating markets for agricultural products. For examples from East Africa, see M. Tiffen et al., *More People, Less Erosion: Environmental Recovery in Kenya* (Chichester, England: John Wiley, 1994); for Central Africa, see J. M. Cour and S. Snrech, "Preparing for the Future: A Vision of West Africa in the Year 2020," *West Africa Long-Term Perspective Study*, 1998. Paris: OCDE/Club du Sahel.
14. Examples are the dumping of meat by the EU and the present protection of cotton farmers in the United States, EU, and China. On meat dumping, see R. Ruben et al., "Les subventions d'exportations européennes sur la viande bovine," *International Spectator* 48, No. 12 (1994): 599-600; on cotton subsidies, see, for example, F. Bérourd, "La production de coton en Afrique zone franc" in *Revue du Comité Consultatif International du Coton*, March-April 2002. Washington, DC: International Cotton Advisory Council.
15. For more details, see S.K. Debrah, "From State Monopoly to Private Sector Oligopoly: African Agricultural Input Markets in Crisis?" in Proceedings of the SADAOC

- Round-Table Conference on Agricultural Inputs*, Ouagadougou, Burkina Faso, September 2000 (Ouagadougou: Sécurité Alimentaire Durable en Afrique de l'Ouest/Centrale [SADAOC], 2000).
16. The value-cost ratio (VCR) is a measure of the profitability of fertilizer use, defined as the ratio of the value of additional crop output (yield increase) due to fertilizer use to the cost of fertilizer used in producing the additional output. The criterion for profitability is a ratio greater than two.
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