POLICY FORUM: ECOLOGY

Soil Fertility and Hunger in Africa

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Africa south of the Sahara is the only remaining region of the world where per capita food production has remained stagnant over the past 40 years. About 180 million Africans—up 100% since 1970—do not have access to sufficient food to lead healthy and productive lives, making them more susceptible to the ravages of malaria, HIV-AIDS, and tuberculosis. Absolute poverty—characterized by incomes of less than U.S. $1 per person per day is coupled with an increasingly damaged natural resource base (*1*).

Efforts focused on child survival, coping with HIV-AIDS, improving governance, increasing foreign investment, breaking trade barriers, and providing debt relief are all necessary, but they are insufficient because they do not directly address agriculture, the economic sector that engages 70% of all Africans. Africa's food insecurity is directly related to insufficient total food production, in contrast to South Asia and other regions where food insecurity is primarily due to poor distribution and lack of purchasing power. African agriculture has performed dismally, in sharp contrast to Asia and Latin America, regions that benefited from the Green Revolution (*1*). Some African states and developed countries are now considering restoring high priority to agricultural development in Africa (*2*). Policy-makers must get the strategy right.

Depletion of soil fertility, along with the concomitant problems of weeds, pests, and diseases, is a major biophysical cause of low per capita food production in Africa. This is the result of the breakdown of traditional practices and the low priority given by governments to the rural sector (*3*). Over decades, small-scale farmers have removed large quantities of nutrients from their soils without using sufficient quantities of manure or fertilizer to replenish the soil. This has resulted in a very high average annual depletion rate—22 kg of nitrogen (N), 2.5 kg of phosphorus (P), and 15 kg of potassium (K) per hectare of cultivated land over the last 30 years in 37 African countries—an annual loss equivalent to U.S. $4 billion in fertilizer (*3*, *4*). The potential of genetically improved crops cannot be realized when soils are depleted of plant nutrients. A recent study shows that while the rates of adoption of improved crop varieties have been similar in Asia, Latin America, the Middle East, and Sub-Saharan Africa during the last 38 years, such varieties are responsible for 66 to 88% of the crop yield increases in the first three regions, but only 28% in Africa (*5*).

The traditional way to overcome nutrient depletion is the use of mineral fertilizers. But fertilizers in Africa cost two to six times as much as those in Europe, North America, or Asia. Spot checks indicate that a metric ton of urea costs about U.S. $90 FOB (free on board) in Europe, $120 delivered in the ports of Mombasa, Kenya, or Beira, Mozambique, $400 in Western Kenya (700 km away from Mombasa), $500 across the border in Eastern Uganda, and $770 in Malawi (transported from Beira).

Depleted maize (left) **and improved harvest** (right). Maize suffering from fertility depletion is improved by alternate nutrient-accumulating plantings. Left, Campetha, Zambia; right, farmer Monica Oketch, Nyanza Province in Kenya.

A soil fertility replenishment approach has been developed during the last 10 years by researchers from the International Center for Research in Agroforestry and national and international partners working with farmers, using resources naturally available in Africa. Participatory research trials were conducted in farmer fields, where researchers and farmers tested practices together. This step was followed by farmer-designed trials in which farmers tested and adapted new practices as they wished. The results consist of three components that can be used in combination or separately: (i) nitrogen-fixing leguminous tree fallows, (ii) indigenous rock phosphates in phosphorus-deficient soils, and (iii) biomass transfer of leaves of nutrient-accumulating shrubs (*6*).

Leguminous trees of the genera *Sesbania*, *Tephrosia*, *Crotalaria*, *Glyricidia*, and *Cajanus* are interplanted into a young maize crop and allowed to grow as fallows during dry seasons, accumulating 100 to 200 kg N ha^{-1} over the period from 6 months to 2 years in subhumid tropical regions of East and Southern Africa. The quantities of nitrogen captured are similar to those applied as fertilizers by commercial farmers to grow maize in developed countries. After harvesting the wood from the tree fallows, nitrogen-rich leaves, pods, and green branches are hoed into the soil before planting maize at the start of a subsequent rainy season. This aboveground litter decomposes with the tree roots, releasing nitrogen and other nutrients to the soil. Yields of maize, the staple food in this region, increase two- to fourfold as nitrogen deficiency is overcome. Farmers are now establishing rotations of 1 year of trees followed by one crop of maize in bimodal rainfall areas of East Africa, and 2 years of trees followed by two to three maize crops in unimodal rainfall areas of Southern Africa. These fallows are economically and ecologically sound and fit well with farmer customs and work calendars, which comes as no surprise because the technology was developed with farmers.

Phosphorus deficiency is widespread in East Africa and the Sahel. In Western Kenya, 80% of the land held by small-scale owners that is used for maize is extremely deficient in phosphorus Using indigenous rock phosphate deposits provides an alternative to imported superphosphates. The mild acidity (pH 5 to 6) of most of the soils in these African regions helps dissolve high-quality rock phosphates at a rate that can supply

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phosphorus to crops for several years. Under such conditions, their direct application doubles or triples maize yields, 90% as efficiently as superphosphates, over a 5-year period.

Transfer of leaf biomass of the nutrient-accumulating shrub *Tithonia diversifolia* from roadsides and hedges into cropped fields adds nutrients and routinely doubles maize yields at rates used by farmers, without fertilizer additions. This organic source of nutrients is more effective than urea when applied at the same nitrogen rate because tithonia also adds other plant nutrients, particularly potassium and micronutrients. Because of high labor requirements for cutting and carrying the biomass to fields, the use of tithonia as a nutrient source is profitable with high-value crops such as vegetables but not with relatively low-valued maize. *T. diversifolia* grows spontaneously on roadsides of subhumid tropical Africa.

This soil fertility replenishment approach has several limitations. Improved tree fallows, although they perform well, are not attractive to farmers at the margins of humid tropical forests of the Congo Basin because they have better land-use alternatives owing to population pressure. Improved fallows have yet to prove their worth in the semiarid tropics of Africa because the much longer dry season limits their growth and nitrogen fixation potential. Fallows also do not perform well in shallow soils, poorly drained ones, or frost-prone areas. The availability of high reactivity rock phosphate is limited by insufficient market development, but demand is growing. Many of the rock phosphate deposits in Africa are of low reactivity and have limited potential for direct application. A nutrient-accumulating analog of *T. diversifolia* is yet to be found for the semiarid tropics. In spite of the above limitations, this approach can be used in the most widespread "red" soils of the subhumid tropics, where the bulk of people in rural Africa live.

After the soil's fertility is replenished, high-yielding crop varieties, integrated pest management, conservation tillage, high-value trees, vegetable crops, and dairy cattle should come into play. Such land-use change also has positive environmental effects. Most tropical soils used for agriculture are depleted of soluble carbon that microorganisms use as their energy source. Organic inputs enhance nutrient cycling, mineralization rates, and the transformation of inorganic forms of phosphorus into more available organic ones. Such agroforestry systems also can sequester large quantities of carbon in the tree biomass and soils, 5 to 10 times as much as that realized per year in most other agricultural practices (*7*).

The on-farm production of firewood reduces encroachment onto nearby forests and woodlands, helping preserve their remaining biodiversity. The diversity of plant species grown in these farms mitigates the effects of pest attacks and market price fluctuations. These agroforestry systems are also robust, suffering less of a decrease in crop production when droughts hit because the soils are more porous and hold water better.

Tens of thousands of farm families in Kenya, Uganda, Tanzania, Malawi, Zambia, Zimbabwe, and Mozambique use various combinations of fallows, phosphorus, and biomass transfers with good and consistent results. Many farmers make their own combinations of the three components and add some of their own.

Adoption of this approach is taking place by the transfer of knowledge from farmer to farmer and village to village, by community-based organizations and by a multitude of national research and extension institutes, universities, nongovernmental organizations, and development projects. The challenge, now, is to accelerate the adoption rate to reach tens of millions of farm families. The main obstacles are the insufficient supply of high-quality seeds and seedlings, lack of rock phosphate, and insufficient awareness and knowledge of the technology components.

The approach reported here is effective and more appropriate to current African conditions than those used during the Green Revolution. These "low-tech" but knowledge-intensive technologies should precede the promise of genetic engineering and other "high-tech" approaches, because without available nitrogen and phosphorus in the soil African farmers have no chance of succeeding.

Large and sustained investments are necessary to capitalize and extend these promising leads. Specifically:

• Implement development projects to scale-up fertility replenishment practices from tens of thousands to tens of millions of African farm families. A total additional cost of U.S. $100 million a year for the next 10 years is a reasonable estimate. It represents 10% of the annual investment suggested for overcoming hunger and malnutrition in Africa (*8*).

• Development projects should focus on key bottlenecks such as the supply of quality tree germplasm grown by community-based nurseries, access to rock phosphate and the awareness and knowledge of the three technology components.

• Develop policies that reduce the disparity between world market and the prices paid by African farmers for mineral fertilizers. This can be done by identifying constraints and improving transport infrastructure. The solutions presented here will eventually lead to a larger demand for mineral fertilizers to be used in combination with organic inputs.

• Implement, in some form, the clean development mechanism proposed in the climate change debates to help alleviate the poverty of those tropical farmers that can remove large quantities of carbon from the atmosphere though tree-based soil fertility replenishment technologies.

• Invest in community-based development projects that integrate the agriculture, education, and health sectors, because such approaches have a greater chance of success than those that focus on a single sector because the problems are interrelated.

One way forward is to bring the Africa Soil Fertility Initiative sponsored by the World Bank and the Food and Agriculture Organization of the United Nations into full implementation and make soil fertility replenishment a key action item at the forthcoming World Summit on Sustainable Development in the Johannesburg, and similar fora. But most importantly is for African governments to attain the political will to act decisively.

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