Agricultural Productivity in Changing Rural Worlds

A Report of the CSIS Task Force on Food Security

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Changing Rural Worlds

In a village near Sheikhupura, Pakistan, Shahid Zia and other elders discuss strategies for coping with steadily declining water levels in the tube wells long used to irrigate their rice crop. They bemoan the rising costs of renting combines to harvest their wheat, made necessary to reduce post-harvest losses from the monsoon that now arrives earlier. Their soils are tired, and their crop yields stagnant. Farmers whose fathers once led the Green Revolution on the moist, rich soils of Pakistan's Punjab, they must now rehabilitate their soils, restore groundwater, and diversify crops to remain commercially competitive.[1] The harvest laborers whose livelihoods these well-educated landowners supported now eke out a living in the slums of Lahore.

Asia's Green Revolution was, in many respects, a development economist's dream come true. Initially targeted to the irrigated areas, public investments in short-strawed, fertilizer-responsive varieties, irrigation, and infrastructure dramatically boosted crop productivity during the 1960s and 1970s. High-yielding varieties diffused more gradually across rainfed environments, and the benefits of increased demand for labor and lower food prices were broadly transmitted by markets through the rural and urban economies. Governments consolidated research activities into centralized, national research organizations, backed by publicly funded international research institutes[2] with a mandate to promote food production in poor countries. In Southeast Asia especially, the Green Revolution was small farmer–based.[3] High-yielding rice varieties were diffused largely from farmer to farmer, though state-driven, private traders were also instrumental to the transformation.

Soon, however, evidence had accumulated in Asia that the impacts of the Green Revolution were uneven across agroecologies, and the poor outside irrigated areas had remained poor. By the 1990s, better-off farmers in the irrigated areas were beset by stagnating yields,[4] the adverse

1. Based on the experiences of Dr. Shahid Zia, formerly with the Pakistan Agricultural Research Council from the 1980s and now a farmer leader and agricultural adviser with Oxfam Great Britain. Dr. Zia reports that three to five years after applying ecological approaches to farming, soils began to improve and yields rose again.

2. In India, at that time, these were the International Rice Research Institute and the Centro Internacional de Maiz y Trigo (CIMMYT, the International Maize and Wheat Improvement Center).

3. Goran Djurfeldt, Hans Holmén, Magnus Jirström, and Rolf Larsson, "African Food Crisis—The Relevance of Asian Experiences," in G. Djurfeldt, H. Holmén, M. Jirström, and R. Larsson, eds., *The African Food Crisis: Lessons from the Asian Green Revolution* (Wallingford, UK: CABI Publishing, 2005).

4. Prabhu Pingali, M. Hossain, and R.V. Gerpacio, *Asian Rice Bowls: The Returning Crisis?* (Wallingford, UK: CAB International, 2007). Roderick M. Rejesus, Paul W. Heisey, and Melinda Smale, *Sources of Productivity Growth in Wheat: A Review of Recent Performance and Medium- to Long-Term Prospects,* Economics Working Paper 99-05 (Mexico, D.F.: CIMMYT, 1999).

effects of unsafe chemical use on human health,[5] and environmental problems such as salinity and waterlogging.[6]

Thousands of miles away from Shahid's village, on the border of the Sahara in Burkina Faso, Yacouba Savadogo convenes a market day around the theme of local tree species, conferring with farmers about the methods they have used to rehabilitate barren, windswept land and re-create agroforestry parklands following the devastating drought of 1972–1973. Men exchange seed, tools, and experiences, noting higher sorghum yields, a change in the local micro-climate, and describing how groundwater levels at some local wells are rising. Women discuss how they will spend the cash earned from sales of baobab leaves and fodder collected from trees in their family's fields. Others remark that their sons are more often staying at home now in the dry season, harvesting and selling fuelwood, rather than trying their luck at menial jobs in Ouagadougou.[7]

Just across the border, cotton growers in Sikasso, Mali, are vexed by the rising prices of fertilizer and the falling prices of cotton. Despite a dense network of local markets, higher rainfall than other zones of Mali, powerful farmers' associations, and ample public provision of services such as training in literacy and numeracy, the competitiveness of these farmers has eroded in the face of U.S. farm subsidies. The "paradox of Sikasso," the foremost cotton-producing zone in Mali, is that malnourishment and illiteracy persist despite other signs of wealth. In the 2008 season, caught in a "price scissors," some Malian farmers diversified to organic cotton or out of cotton altogether, growing cereals to which they apply less fertilizer. Fanta Sinayogo, however, has found her niche. Having grown organic cotton for four years on half a hectare, along with groundnuts, a high-value local cereal called fonio, organic sesame, and organic karité (to make shea butter), she is pleased by her profits and increasing financial independence—which she needs to pay the school fees and to feed her nine children. During the 2008 food price crisis, she was able to buy food for her children from her savings. In her local coop, she claims proudly, women's voices and rights are now respected by men.[8]

All three of these farmers face a lingering food price crisis, spurred in part by rising energy prices that raise fertilizer costs even more than product prices, and now a global economic recession. Each seeks to adapt to a warming earth, shifting seasons, and water that flows in unexpected times and amounts as the climate changes.

Because they do not have the same access to resources, however, today's challenges affect them in different ways. Consider land quality and access to markets—the fundamentals of productive agriculture. Only about 34 percent of the farmers in low- and middle-income countries have both.[9] An estimated 20 percent of farmers in these countries live in areas that are too dry or rough

5. John Antle and Prabhu Pingali, "Pesticides, Productivity, and Farmer Health: A Philippine Case Study," *American Journal of Agricultural Economics* 76, no. 3 (1994): 418–430.

6. Mubarik Ali and Derek Byerlee, "Productivity growth and resource degradation in Pakistan's Punjab," in *Response to Land Degradation,* ed. E.M. Bridges et al. (Enfield, N.H.: Science Publishers, 2001), 186–199.

7. Based on the experience of Yacouba Savadogo, a farmer-innovator and leader. See Chris Reij, Gray Tappan, and Melinda Smale, *Agroenvironmental Transformation in the Sahel: Another Kind of Green Revolution,* Discussion Paper 00914 (Washington, D.C.: International Food Policy Research Institute, November 2009).

8. This anecdote is based on an interview conducted by Chris Hufstader, senior writer at Oxfam America.

9. Based on the World Bank classification.

in terrain to be favored for agriculture and do not have good access to market infrastructure.[10] Diversified livelihood strategies are needed for these farmers; agriculture alone will probably offer few sustainable pathways out of poverty. Another 10 percent farm land of poor quality but are well-served by markets. These will probably choose to leave farming but remain in rural areas if there are better opportunities offered by higher rural wages or nonfarm enterprise. The remaining third are isolated from markets, but farm land of good quality. Adequate public investments in market infrastructure, and the institutions that enable them to effectively participate in markets, could boost their productivity and offer a pathway out of poverty relatively soon.

Recognizing that this picture is static, however, is crucial to the perspective taken here. The farmers of Punjab are relatively privileged by fertile soils, well-developed infrastructure, and supporting institutions. Yet today, in the aftermath of the Green Revolution, these farming systems, which used water, land, and energy-intensive inputs intensively, are threatened by environmental degradation. Faced with a human and environmental crisis of enormous magnitude during the 1970s, many Sahelian farmers have already undertaken the type of improvements in soil and water management that are needed to use improved seeds and mineral fertilizers efficiently. Driven by economic necessity, some farmers in Mali's cotton belt are also adopting more restorative, diversified crops and practices.

In today's changing rural worlds,[11] efforts to raise the productivity of small-scale farmers will not be sustainable without attending to the natural resource base, whether in areas relatively favored for agriculture or not. This report emphasizes three ways that the United States can contribute to raising agricultural productivity in poor countries. The first is to invest in agricultural productivity from a longer-term, resource-based, farmer-centered perspective. The central role of smallholder farmers (women and men) as not only producers of food but rural citizens and

10. Kate Sebastian, "Mapping favorability for agriculture in low and middle income countries: technical report, maps and statistical tables," Oxfam America Research Unit, Washington, D.C., 2009. The market accessibility data measure in hours the amount of time to the nearest market town. A cost-distance function was used to measure the "cost" of reaching the nearest market in minutes/hours based on a number of input variables (roads, markets/towns, elevation, slope, boundaries, and landcover). We classified poor market access as an estimated time to market of 2–4 hours by car as compared with high access. This is a generous definition, but in many instances motorized transport is not available. For farmers to make the most of market opportunities, high access is needed. See Melinda Smale and Emily Alpert, "Making Investments in Poor Farmers 'Pay': A Review of Evidence and Sample of Options for Marginal Areas," Background Paper, Oxfam America Research Unit, Washington, D.C., 2009, for a summary of related literature by Peter Hazell, John Pender, and colleagues.

11. The rural worlds typology is another way to understand the diversity of rural conditions and the unevenness of rural poverty in order to identify appropriate investments for raising productivity. Rural world 1 is composed of large-scale commercial agricultural households and enterprises. Some farmers in the Indian Punjab, and very few farmers in Sub-Saharan Africa, would meet this classification. Rural world 2 refers to smaller-scale agricultural households and enterprises that are not internationally competitive, such as today's cotton farmer in Mali. Rural world 3 is composed of subsistence agricultural households like those in Yacouba's village. Landless laborers are classified in rural world 4. Their livelihoods depend very much on agricultural productivity growth and the development of nonfarm rural enterprise. Rural world 5, the chronically poor, will need safety net approaches if they are to accumulate the capacity and assets to become productive. See Organization for Economic and Cooperative Development (OECD), *Promoting Pro-Poor Growth: Agriculture,* DAC Guidelines and Reference Series, DAC Reference Document (Paris: OECD, 2006). This paper focuses on the first three worlds, but particularly on worlds 2 and 3.

custodians of global public goods should be revalidated.[12] Doing so requires investment in human, social, and political capital of farming communities and rebuilding rural institutions from "the bottom up." A second is to revamp the way that technology is developed and diffused in order to better diagnose and solve the practical problems of rural people. Rigid models in which scientists develop technologies and state extension services deliver them to farmers should be replaced with those that foster partnerships among the multiple actors who can best finance and provide the services (including farmer associations, community-based organizations, private companies, nongovernmental organizations or NGOs, national and international research institutions). The third is to complement investments in the "hard" infrastructure of markets (roads, rural electrification) with investments in "soft" infrastructure, including rules, regulations, policies, financial and market information systems that kick-start private sector investments. The next three sections explain these approaches and provide some examples from the field, and the report concludes with recommendations.

1. Managing Natural Resources for Agricultural Productivity

Agricultural productivity will not increase without intensification,[13] but in many regions of the world, intensification will not be possible without restoring soil and water resources. Where intensification has already occurred to sustain productivity growth, more attention will need to be paid to natural resource management. A standardized package of inputs or practices will not have widespread impact.

Sustaining Productivity in Input-intensive Systems

Over the last 50 years, with the expansion of irrigated land and widespread adoption of new seed varieties and fertilizers in both rich and poor countries, agricultural productivity outstripped world population growth and global food prices declined. The Green Revolution, centered on

12. It is generally argued that poor farmers contribute to environmental degradation because they do not have the wealth to be able to take risks and forgo short-term for long-term gains. Some researchers have provided empirical evidence to the contrary. For example, Scott Swinton and Roberto Quiroz found that fallowing was practiced by poor farmers, and rotational grazing, which reduces overgrazing, is neutral to farm size in the impoverished Peruvian altiplano. They conclude that relative improvements can be made in natural resource stewardship even among the very poor: "Awareness of sustainability problems and low-cost steps to address them, combined with closely knit community structures are the key factors that support good stewardship in such a setting" ("Is poverty to blame for soil, pasture and forest degradation in Peru's altiplano?" *World Development* 31, no. 11 [2003]: 1903–1919). William G. Moseley presents evidence from food security and famine early warning systems that rather than sacrificing the future for the present, during periods of food shortage, poor households in many African contexts often undertake extreme measures, such as depriving the family of needed calories, in order to preserve productive capital (a plow, oxen, or seed) for the future ("African Evidence on the Relation of Poverty, Time Preference and the Environment, *Ecological Economics* 38 (2001): 317–326.

13. Intensification of agriculture in the broadest sense means only that more is produced per unit of land, through greater application of inputs, including purchased inputs such as seed, fertilizer, or machinery or on-farm inputs such as labor, knowledge, and managerial skills. Examples of intensified systems include not only high-yielding specialized cropping systems that rely heavily on purchased inputs and capital, but mixed crop and livestock systems, complex agroforestry and multicropping systems, labor, manure, knowledge, and managerial skills.

the major food staples of rice and wheat, raised yields per hectare through more intensive use of purchased inputs (seeds, fertilizers, and pesticides). Similar approaches, including new livestock breeds, associated veterinary drugs, and blended feeds with nutrient additives, hold great potential in farming systems with reliable moisture, relatively uniform agroecological resources (such as areas with large-scale irrigation), dependable input suppliers, and markets.

Some experts argue that many of the opportunities for intensifying input-based production have already been exploited. To create new technical opportunities, cutting-edge science in advanced research institutions will need to be redirected toward the practical problems of poor farming communities.[14] More attention to the environmental and health consequences of unsafe use of mineral fertilizers and pesticides will also be necessary. Because pathogens evolve continually, continual investments in breeding for genetic tolerance to biotic stress[15] (in genetically modified seed, hybrid seed, or improved varieties) offers a high social rate of return.[16] Biotic stress is great in intensive irrigated systems where staple foods are extensively monocropped. Broad-based genetic tolerance (as compared to single gene resistance) to biotic stress can reduce reliance on toxic chemicals over time. Diversification of crop varieties and species in the landscape, including tree crops, is an investment option that can also reduce biotic stress while generating economic benefits in local farming communities well linked to a nexus of village markets.

New opportunities are also made possible not only through plant breeding but through changing farming practices, with the added benefit that this process of change also involves more learning and experimentation by farming communities than does adopting seed alone. Integrated pest management (IPM) approaches, for example, seek to reduce unsafe use of synthetic insecticides, curb yield losses due to pests, and lengthen the time until pests develop resistance to control. Farmers learn principles and develop adaptive responses to pest pressures that suit their own farming system. The benefits from IPM are often visible in a single season, providing an important incentive for farmers to invest their time and resources. IPM practices are thought to have their greatest potential in irrigated environments where agricultural production is highly intensive and the returns to adoption are correspondingly high.[17]

The System of Rice Intensification (SRI) is one of the most promising examples of a resource-conserving, but intensified set of practices designed for well-watered environments (box 1). Called the "The Root Revolution," SRI uses low-cost, simple techniques that change the way plants, soil, water, and nutrients are managed. Evidence of SRI's benefits is now available across a wide range of ecosystems throughout the major rice-producing areas of Asia and in coastal West Africa and the Niger Delta. SRI produces higher returns to land, labor, capital, and water with varieties currently used by farmers and does not depend on variety introductions.[18] Recent reports suggest that SRI crops are able to withstand considerable water and temperature stress, are more resistant to storm

14. Personal communication, Dr. Gebisa Ejeta, Purdue University, to CSIS 2009 Task Force on Global Food Security, June 4, 2009.

15. Stress from living factors (evolving pests and diseases) as compared with abiotic stress, which is the impact of nonliving factors in the environment (heat, too little or too much water).

16. H. Jesse Dubin and John P. Brennan, "Fighting the 'Shifty Enemy': The International Colllaboration to Contain Wheat Rusts," in David J. Spielman and Rajul Pandya-Lorch, *Millions Fed: Proven Successes in Agricultural Development* (Washington, D.C.: International Food Policy Research Group, 2009).

17. John Pender, *Agricultural Technology Choices for Poor Farmers in Less-favored Areas of South and East Asia,* Occasional Papers 5 (Rome: International Fund for Agricultural Development, 2008).

18. SRI is now being extended to rainfed rice production in India, Cambodia, and Myanmar, with yields averaging as much as 7 tons per hectare, and to other crops like wheat, finger millet, and sugar cane.

Box 1. The System of Rice Intensification in Cambodia

More than 70 percent of Cambodia's workforce depends on agriculture to make a living, most of them small farmers that grow rice to feed their families. To help them grow more rice, Oxfam America and its partner, the Center for Study and Development of Cambodian Agriculture (CEDAC), supported the introduction of a set of practices called System of Rice Intensification, or SRI.

Changing Minds, Not Just Practices

Rort Kea rolls up his pants and steps down into the rice paddy. Walking backward through the mud, he takes the biggest seedlings from his nursery and plants them in a row. Trained in the System of Rice Intensification (SRI), Kea knows that by dividing the clump of seedlings and planting them farther apart, he can give the healthiest plants their best chance to thrive. But accustomed to using speed to carry out the task, he moves too quickly and winds up planting the seedlings too close together.

Standing on the dirt road above the paddy, Luy Pisey Rith watches the farmer as he works. A program officer in Oxfam America's East Asia office, he is skilled at observing a situation and determining the appropriate response. Rather than lecture Kea on the drawbacks of how Cambodian farmers have planted for generations, Rith simply walks around the perimeter, gathering scraps of wood. Crouching near the ground, he lashes the wood together, creating a grid. Then he demonstrates how to use the grid to mark off parallel lines for planting. Kea laughs as he watches him. But soon he's accepted the homemade tool, carrying it with him as he moves. This is the reality of changing minds, not just practices, in Cambodia.

Mey Som's Legacy

Created in the 1980s by a Jesuit priest in Madagascar, SRI is flourishing in places—like China and Bangladesh—where rice is the staple of every meal and farming is the main occupation. Having learned of its success, CEDAC brought the method to Cambodia in 2000, choosing a farmer named Mey Som as the first trainee. Back then, Som told me that he had seen big changes with SRI just halfway through the first season; he had noticed that his seedlings were growing bigger and stronger. The same plants that had once grown up to his knees were now growing past his head. Som was so encouraged by the results that he began traveling around the country with CEDAC, talking to other farmers about his experiences, explaining how a technique that requires less water and fewer seeds could actually produce more rice. It's all about the roots getting the right amount of water, sunlight, and nutrients, he told the farmers.

When Som, 68, farmed using conventional methods, he barely grew enough to feed his family. He still depended on his daughters' incomes; they were working at a garment factory in Phnom Penh, a two-hour drive from their village. Now, Som's farm is so productive that his daughters quit the factory to run the day-to-day operations. Their father no longer depends on their incomes; instead, he's teaching them SRI. One of Som's daughters, Sophal, who is 37, said that following SRI meant putting more thought into the process. But that translated into less energy in the fields. When she plants fewer seedlings, she can cover the same area in half as much time. "We used to carry the seedlings by ox cart. Now we carry them by hand," she says. "Before, I used to hire labor from the village. Now just my relatives help."

damage, and have greater resistance to pests and diseases.[19] The healthier root systems established when using SRI methods appear to contribute to these benefits.

In Cambodia, more than 80,000 families use SRI practices. An Oxfam evaluation of the experiences of Cambodian farmers using SRI methods for three consecutive years found that not only did their rice yields double during this period but that with the adoption of the new SRI methods, their use of chemical fertilizer declined by 42 percent and the use of other agrochemicals by 80 percent. As a consequence, farm profits increased by almost 300 percent. On August 21, 2009, Cambodia's minister of agriculture directed that SRI become a mainstay of the agricultural development program: provincial departments are to ensure that their teams deliver quality SRI extension while universities and agricultural schools are to focus research and curricula on SRI. The minister equated SRI to poverty reduction, saying it helps farmers "think and decide for themselves."[20]

Another successful example of a resource-conserving, but intensified practice that has emerged in the geographical heart of the Asian Green Revolution is zero-till cultivation. During the late 1990s, small-scale farmers in the Indo-Gangetic plain—a vast region that encompasses parts of Northern India, Nepal, Pakistan, and Bangladesh—began experimenting with zero-tillage cultivation, a crop management technique in which farmers plant seeds in unplowed fields to conserve soil fertility, economize on scarce water, reduce land degradation, and lower production costs. An estimated 620,000 wheat farmers have adopted some form of zero-tillage cultivation over 1.76 million hectares of land, with average income gains amounting to $180–$340 per household.[21]

Africa's Natural Capital

Only 2.6 percent of the rural population in Africa, as compared to 55 percent of the rural population in Asia, lives in irrigated areas. More than half (54 percent) of agricultural land, where slightly under half (46 percent) of the rural population resides in Africa, is not favored for agriculture.[22] Farming systems in sub-Saharan Africa are remarkably varied, reflecting both an impressive array of agroecological conditions and socioeconomic diversity. Consequently, "one-size-fits-all" standardized technical packages like those of Asia's Green Revolution have found only scattered success in sub-Saharan Africa.[23]

Because of the continent's weathered soils and the predominance of rainfed agriculture, the InterAcademy Council (IAC)[24] has recommended a production ecological approach to diagnose problems and find solutions in even the four most promising farming systems of Africa. The four

19. N. Uphoff and A. Kassam, *Case Study: The System of Rice Intensification* (IP/A/STOA/FWC/2005-28/SC42), Annex 3 in European Parliament: Science and Technology Options Assessment (STOA), June 2009.

20. Brian Lund, East Asia Regional Office, personal communication, August 21, 2009. See also http://khmerforkhmer.blogspot.com/2009/08/cambodian-officials-urge-rice.html, Saturday, August 22, 2009.

21. Olaf Erenstein, "Leaving the plow behind: Zero-tillage cultivation in the Indo-Gangetic Plains," in David J. Spielman and Rajul Pandya-Lorch, *Millions Fed: Proven Successes in Agricultural Development* (Washington, D.C.: International Food Policy Research Group, 2009).

22. Sebastian, "Mapping favorability for agriculture."

23. Melinda Smale and Thomas S. Jayne, "Breeding an 'Amaizing' Crop: Improved Maize in Kenya, Malawi, Zambia, and Zimbabwe," in David J. Spielman and Rajul Pandya-Lorch, *Millions Fed: Proven Successes in Agricultural Development*, forthcoming.

24. InterAcademy Council (IAC), *Realizing the Promise and Potential of African Agriculture: Science and Technology Strategies for Improving Agricultural Productivity and Food Security in Africa* (Amsterdam: IAC Secretariat, June 2004).

farming systems that show greatest potential for increasing African food security include (1) the maize-mixed system, including cotton, cattle, goats, poultry, and off-farm work; (2) the cereal/root crop-mixed system, based on maize, sorghum, millet, cassava, yams, legumes, and cattle; (3) the irrigated system, based primarily on rice, cotton, vegetables, rainfed crops, cattle, and poultry, and (4) the tree crop system, based primarily on cocoa, coffee, oil palm, rubber, yams, maize, and off-farm work.

Africa's Nutrient Deficit[25]

Fertilizer use is much more extensive in other regions of the developing world than in Africa. In 2002, the average intensity of fertilizer use in Africa was only 8 kilograms per hectare of cultivated land.[26]

High cost, combined with low agronomic efficiency, makes the use of inorganic fertilizers unprofitable for many farmers. Low agronomic efficiency results from poor soil and moisture conditions, which can be remedied by adding organic sources of nitrogen. Numerous studies have shown that fertilizers do not increase yields if soils are too degraded.[27] Experts recommend greater emphasis on integrating organic matter, such as manure from livestock or post-harvest crop waste, to raise soil carbon levels and make nutrients from fertilizers more available to plants. Improving soil fertility in Africa requires a long-term commitment to restoring the soil and water resource base so that crops respond better to fertilizer.

Improving the agronomic efficiency of fertilizer use involves not only long-term investments in restoring soils but long-term investments in people. For example, a recent study[28] shows that despite the fact that maize growers in Zambia have long experience applying fertilizer, labor shortages, timely access to oxen, and farmer knowledge continue to dampen the yield gain per unit of nutrient applied.

Weather shocks aggravate this situation. Rainfed agriculture dominates in Africa. Statistical indicators of yield variability and risk are substantially higher than those measured in Asia for major cereals grown by farmers for food and sales (rice, maize, millet, and sorghum). Year-to-year

25. This section is principally drawn from Michael Morris, Valerie A. Kelly, Ron J. Kopicki, and Derek Byerlee, *Fertilizer Use in African Agriculture: Lessons Learned and Good Practice Guidelines* (Washington, D.C., World Bank, 2007); Paul W. Heisey and George W. Norton, "Fertilizers and Other Farm Chemicals," *Handbook of Agricultural Economics* 3, edited by Robert Evenson and Prabhu Pingali (Amsterdam: Elsevier, 2007).

26. According to Michael Morris et al., economic analysis reveals that the nitrogen to product price ratios are generally higher than in other regions and often more than twice as high. The number of units of output relative to nutrient input is only in the profitable range for maize and rice. Looking at the value to cost ratio (including the technical and price relationships), fertilizer application is even unprofitable for maize and rice in some years. Application on sorghum and millet is only marginally profitable, and use of fertilizer on cash crops such as groundnuts, cotton, and tea is often, but not always, profitable. Furthermore, an overall downward trend in fertilizer profitability is "fairly conclusive." In a review of experience in Cote d'Ivoire, Ghana, Nigeria, and Kenya from about 1971 to 2001, Heisey and Norton found that nitrogen prices were below the world price for much of the early part of the period in all four countries and then moved to about double the world price in the late part of the period.

27. Recently, Paswel P. Marenya, Christopher B. Barrett," Soil quality and fertilizer use rates among smallholder farmers in western Kenya," *Agricultural Economics* 40 (2009): 561–572; Paswel P. Marenya and Christopher B. Barrett, "State-conditional fertilizer yield response on western Kenyan farms," *American Journal of Agricultural Economics* 91(2009): 991–1006).

28. Zhiying Xu, Zhengfei Guan, T.S. Jayne, and Roy Black, "Factors influencing the profitability of fertilizer use on maize in Zambia," *Agricultural Economics* 40, no. 4 (July 2009): 437–446.

yield variability is compounded by price volatility caused by either poor performance in local markets (particularly for food crops) or shifting world market conditions (for energy-intensive inputs and export crops like cotton), or both. Given that economically optimal rates of fertilizer application fall sharply when credit is relatively expensive and also when production is risky, the decision of many African farmers to apply little fertilizer makes economic sense.

Intensifying African Agriculture

Better farming practices or ecosystem management techniques are part of the solution. Often referred to as "agroecological farming practices,"[29] these varied techniques aim to reduce reliance on costly inputs while (1) enhancing soil fertility (manures, composts, agroforestry); (2) protecting soils against water erosion (water harvesting, agroforestry, conservation tillage, mulches, cover crops); and (3) controlling weeds and pests (integrated pest management, intercropping). They can also "fix" atmospheric carbon in soil or trees, helping poor farmers adapt and mitigate changing climate conditions. Over the past two decades, evidence has accumulated that a number of these approaches can bring both economic and environmental benefits to farmers in either remote areas with harsh or complex growing environments or those located in already intensified systems where farmers use high rates of purchased inputs.[30]

The story of farmer-managed, agroenvironmental change in parts of the West African Sahel stands out in this regard.[31] Since the human and environmental catastrophe of the Sahelian droughts during the early 1970s and 1980s, farmers have improved and replicated traditional soil, water, and agroforestry management practices across a vast expanse. On the Central Plateau of Burkina Faso, using primarily their own labor, farmers rehabilitated 200,000 hectares of degraded land through constructing stone contour bunds[32] and digging planting pits (*zai*). Their efforts enabled them to develop agroforestry systems and intensify cereal production on land that had been made barren by drought and overexploitation. Local groundwater levels were recharged. In south-central Niger, farmers have managed a process of natural regeneration using improved, traditional agroforestry practices over an estimated 5 million hectares. This large-scale effort reduced the wind speed and soil erosion and increased the production of crops, fodder, firewood, fruit, and other products. In both cases, income opportunities were created, reducing incentives for

29. There are many definitions of "agroecology." Wikipedia notes that the OECD defines agroecology as the study of the relationship of agriculture to soil health, water quality, air quality, meso- and micro-fauna, surrounding flora, environmental toxins, and other environmental contexts. In the global south, the approach is considered to embody political goals of social and economic justice. In the global north, agroecology is more often viewed as a scientific discipline with less specific social goals. FAO defines agroecology as "the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems."

30. Peter Hazell et al., "Development Strategies for Less-Favored Areas," in *Development Economics between Markets and Institutions: Incentives for Growth, Food Security and Sustainable Use of the Environment,* ed. Erwin Bulte and Ruerd Ruben (The Netherlands: Wageningen Academic Publishers, 2008); John Pender, *Agricultural Technology Choices for Poor Farmers in Less-Favoured Areas of South and East Asia* (Rome: International Fund for Agricultural Development, 2008); Niels Röling and Jules N. Pretty, "Extension's Role in Sustainable Agricultural Development," in *Improving Agricultural Extension: A Reference Manual,* ed. Burton E. Swanson et al. (Rome: Food and Agriculture Organization of the United Nations, 1997); Ruerd Ruben et al., "Sustainable Poverty Reduction in Less-favoured Areas: Problems, Options and Strategies," in *Sustainable Poverty Reduction in Less-Favoured Areas,* ed. Ruerd Ruben et al. (Wallingford, UK: CAB International, 2007); and Robert Tripp, *Self-Sufficient Agriculture: Labour and Knowledge in Small-Scale Farming* (London: Earthscan/Overseas Development Institute, 2006).

31. Reij, Tappan, and Smale, *Agroenvironmental Transformation in the Sahel.*

32. Project or public funds were required only to transport stones.

migration. Women benefited from improved supply of water, fuelwood, and other tree products. Human, social, and political capital was strengthened in a process of farmer-driven change. Fluid coalitions of actors, including charismatic local leaders, local and international NGOs, and an array of donors, expanded the scale of the transformation.

Similar successes have occurred in Eastern Zambia and Western Kenya, where farmers manage a fallow system using leguminous shrubs. Often, these systems were initiated by farmers, formalized by agricultural researchers and refined through extensive on-farm trials conducted in collaboration with farmers and nonprofit agencies.[33]

Restorative approaches such as those described above were locally developed and refined through farmer interaction with technicians rather than supplied by research and extension programs as a standardized, recommended package. As in the case of SRI, farmers follow a "menu" of options and principles, rather than a "recipe." Participatory research is needed to communicate farmers' demands to those providing research and extension services. Farmers must help evaluate, refine, and disseminate locally adapted techniques, which is costly to them. In support of their involvement, new types of research, extension, and educational systems must be crafted and staff trained in new ways. Often, successful cases rely on strong community-based organizations as well as local facilitators or *animateurs,* such as NGO staff, to link communities with sources of research products and advice. In part because of political expediency, public policy has not often been supportive of these approaches because their impacts are gradual and diffuse. By contrast, the impacts of emergency programs to distribute improved seeds and fertilizers are visible during an election period. Like the standardized technical packages of the Green Revolution, however, agroecological practices have met scattered and periodic success in Africa—though for different reasons. Examples of ways to address this problem are discussed next.

2. Innovation Systems to Support Agricultural Productivity

Top-down, supply-driven technology transfer approaches have not been sufficiently responsive or flexible to meet the needs of Africa's diverse small-scale farmers. Although more challenging to design and implement, an agricultural innovation systems approach involving farmer advisory services provided by a range of actors could scale-up technical innovations more effectively. The "best fit" combination of actors depends on the context.

Past Models

Institutional as compared to technical factors have limited the scale and longevity of most of the many successes in African agricultural development that have been documented over the past few decades.[34] The cost and complexity of meeting the needs of dispersed smallholders in differentiated farming systems and economic contexts add to the challenges of building strong institution.

33. Steve Haggblade and Peter Hazell, ed., *Successes in African Agriculture: Lessons for the Future* (Baltimore, Md.: Johns Hopkins University Press, 2009).

34. In addition to the two books already cited (Spielman and Pandya-Lorch, *Millions Fed*; Haggblade and Hazell, *Successes in African Agriculture*), other examples include Derek Byerlee and Carl Eicher, eds., *Africa's Emerging Maize Revolution* (Boulder, Colo.: Lynne Rienner, 1997), and Arthur J. Dommen, *Innovations in African Agriculture* (Boulder, Colo.: Westview Press, 1988).

Since African nations achieved independence, "technology transfer" was the most common model used to support agricultural intensification for productivity growth. In this model, an innovator (who is a scientist) supplies technical packages of seed, fertilizer, and recommended agronomic practices through the research pipeline to extension agents who convey them to farmers. The model was linear and top-down—connecting a centralized research system to smallholders, who were viewed as either "progressive" (early adopters) or "laggards" (late adopters). Consistent with this model, donors sought to strengthen research supply during the 1980s by financing infrastructure, capacity, and policy support to publicly funded national agricultural research systems (NARS).

Universal application of this approach was fraught with problems. For example, though many donor specialists and academics encouraged African nations to build up the "three pillars" of agricultural research, education, and extension, most donor agencies, unwilling or unable to do so because of how they are organized, have funded only one or the other.[35] Investments were thus fragmented.

Although practitioners soon began to recognize the importance of farmer engagement in diagnosing problems and finding solutions, many agents were equipped with a "supply-push" mentality—keen to deliver messages rather than advise farmers based on farmers' demands. Narrow training left many agents with technical backgrounds that lacked knowledge in complementary fields such as marketing, economics, resource management, and participatory approaches. Gender bias of state research and extension systems in African agriculture has been well documented.

The fiscal burdens of this model were probably the foremost reason why African governments scaled back. Funding constraints could be overcome through effective partnerships or contracts with research institutions, agricultural universities, NGOs, civil society organizations, and community-level organizations, but each actor has typically pursued its objectives in relative isolation.[36] Lack of interaction weakens innovative capacity and reflects deep-rooted habits and practices in both public and private sector organizations.[37] Infusing resources will not be enough to solve today's problems, and practitioners widely acknowledge that the model itself is in need of reform.

Emerging Models

A number of factors drive change in funding, provision, and format of agricultural advisory services. Today's economic and political context demands a less fiscally burdensome, more effective public extension service. The innovation systems model[38] has been recommended to over-

35. Carl Eicher, "Africa's Unfinished Business: Building Sustainable Agricultural Research Systems," Staff Paper No. 2001-10, Department of Agricultural Economics, Michigan State University, East Lansing, May 8, 2001.

36. InterAction, Food Security and Agriculture Working Group, *Revitalizing Agricultural Extension,* Working Paper (Washington, D.C.: InterAction, July 2, 2009).

37. Andy Hall, *Challenges to Strengthening Agricultural Innovation Systems: Where Do We Go from Here?* United Nations University, UNU-MERIT, Working Paper Series 2007-38 (2007), http://arno.unimaas.nl/show.cgi?fid=9401.

38. David Spielman defines an innovation system as "a network of agents, along with the institutions, organizations, and policies that condition their behavior and performance with respect to generating, exchanging, and utilizing knowledge" in "A Critique of Innovation Systems Perspectives on Agricultural Research in Developing Countries," *Innovation Strategy Today* 2, no. 1 (2006), http://www.biodevelopments.org/innovation/index.htm, p. 46. The New Partnership for Africa's Development (NEPAD) has endorsed this

come some of the limitations of the state-driven technology transfer model. Drawn from industry experience in Organization for Economic Development (OECD) countries, the approach has been applied only recently to developing agriculture. Operational aspects have not been fully explored or evaluated.

In this model, the source of technical change in agriculture is farmer innovation, but the supply of new knowledge by scientists does not necessarily lead to farmer innovation. An innovation system spans the totality of both private and public actors involved in raising agricultural productivity in addition to farmers and scientists. In so doing, systemic constraints are more easily identified. If the major impediment to farmer adoption is another actor or component of the system, strengthening the agricultural research and extension system may not be the best way to improve its impacts. For example, a major impediment to farmer innovation could be the credit system, the communications system, or government pricing policy.[39]

"Pluralistic advisory services" (services involving combinations of actors) have been recommended as part of this model. Recognition that private service delivery is more efficient, even where public financing of extension is justified, in serving clients has led to strategies that delink the funding source from service delivery, such as contracting of extension services. The state may continue to play a mediating or facilitating role even when not involved in service provision. Table 1 shows workable options for combining public sector, private sector (farmers, companies), and third sector (NGOs and farmer-based associations) by source of finance and provider of service.

Governance structures for advisory services in francophone Africa have some distinctive characteristics compared with those of anglophone Africa, in part as a reflection of the organization of the colonial and postcolonial economies. For a brief period, the concept of *Animation Rurale* (AR) gained importance in a number of francophone African countries. One way of dealing with the shortcomings of large extension systems was to localize extension and utilize the self-help potential of groups already active in rural communities. Since the advent of structural adjustment in a number of francophone West African countries, farmers' associations and federations have gradually taken over much of the responsibility for providing services to food crop growers. Farmers' associations are often powerful players in vertically integrated export crop industries such as cotton.[40] Community-based organizations and local NGOs have also played an important role in agricultural service provision, as in the Sahelian success story noted above.

As there is no "one-size-fits-all" in agricultural technology, there is no single means of funding and providing agricultural advisory services. For example, comparative case studies in Ghana, India, and Ethiopia have shown that the opportunities and challenges of making rural service

approach. See also Regina Birner et al., *From Best Practice to Best Fit: A Framework for Designing Pluralistic Agricultural Advisory Services Worldwide,* Working Paper No. 37 (Washington, D.C.: International Food Policy Research Institute, Development Strategy and Governance Division, August 2006); William M. Rivera, Gary Alex, *Extension Reform for Rural Development,* vols. 1–5: *Case Studies of International Initiatives* (Washington, D.C., World Bank and USAID, 2005); Jock Anderson and Gershon Feder, "Agricultural Extension," in vol. 3, Part II, *Human Resources and Technology Transfer,* in Robert E. Evenson, Prabhu Pingali, and Theodore P. Schultz, eds., *Handbook of Agricultural Economics, Agricultural Development: Farmers, Farm Production and Farm Markets* (Amsterdam: North-Holland, 2006); World Bank, *Enhancing Agricultural Innovation: How to Go beyond Strengthening Research Systems* (Washington, D.C.: World Bank, 2006).

39. Regina Birner and David Spielman, personal communication, August 5, 2009.

40. James Bingen, "Agricultural development policy and grassroots democracy in Mali," *African Rural and Urban Studies* 1, no. 1 (1994): 57–72.

Table 1. Options for Providing and Financing Pluralistic Agricultural Advisory Services

	Source of Finance				
		Private sector		Third sector	
Provider	Public sector	Farmers	Companies	NGOs	Farmer-based associations
Public sector	Advisory services with different degree of decentralization	Fee-based public sector advisory services	Companies contract staff from public sector advisory services	NGOs contract staff from public sector advisory services	FBOs contract staff from public sector advisory services
Companies	Publicly funded contracts to private service providers	Companies provide fee-based advisory services	Companies provide information with input sale of marketing or produce	NGOs contract staff from private service providers	FBOs contract staff from private service providers
NGOs	Publicly funded contracts to NGO providers	Advisory services agents hired by NGO, farmers pay	Companies contract NGO staff to provide advisory services	NGOs hire own advisory staff and provide free services	—
Farmer-based Associations	Publicly funded contracts to FBOs	Advisory service staff hired by FBO, farmers pay	—	NGOs fund advisory service staff who are employed by FBO	FBOs hire own advisory staff and provide services free to members

Source: Birner et al., *From Best Practice to Best Fit.*
Note: FBOs = farmer-based organizations.

provision more responsive to the needs of women differ considerably across countries and across services, depending on the political system, the system of local governance, the way in which a particular service is organized, and the role of women with respect to the service.[41]

Formats for Delivering Messages

The combination of actors involved in financing and providing advisory services will influence the format for delivering messages. Numerous formats have been tested, and each has pros and cons.[42] The Training and Visit System (T&V), developed by the World Bank and promoted by national governments until the mid-1990s, had a hierarchical organization, and consisted of a biweekly

41. World Bank, *Gender and Governance in Rural Services: Insights from India, Ghana, and Ethiopia,* Report funded by Bank Netherlands Partnership Program (BNPP) with additional support from Ethiopia Strategy Support Program (ESSP) and Ghana Strategy Support Program (GSSP), International Food Policy Research Institute (Washington, D.C.: World Bank, 2010).

42. See Birner et al., *From Best Practice to Best Fit;* World Bank, *Enhancing Agricultural Innovation;* and Anderson and Feder, "Agricultural Extension."

visits by contact farmers to other farmers. These systems were gradually dismantled because of bias in the selection of contact farmers, difficulties in demonstrating long-term impact, disinterest of farmers, and financial burden. Farmers didn't necessarily want such frequent visits.

Some of the most promising developments in extension format have occurred where the agenda is equity or the environment. For example, in the fee-for-service format, farmers or farmer groups directly contract advisory services. The advantage of this approach is better accountability and reduced fiscal burden. The quality of service is expected to be higher. The obvious disadvantage is that poor farmers, and especially women, are often underrepresented because they cannot pay for the service. This problem can be resolved through matching public funds, such as targeting vouchers to excluded groups. Targeting, of course, has its own difficulties in communities where all farmers are below the poverty line. Groups are also excluded precisely because they are politically disfavored.

The Farmer Field School format became well known when the Food and Agriculture Organization (FAO) promoted them widely in Asia as a means of diffusing IPM to combat the environmental problems associated with unsafe pesticide use. Typically, groups of 20 to 25 farmers are taught how to solve their practical problems, set priorities, and conduct experimental research through facilitated hands-on sessions in fields they allocate for that purpose. This format is amenable to "menus" rather than "recipes" and fosters social learning (learning from one's colleagues rather than through formal schooling). Practitioners hope that farmers will feel empowered by learning leadership, communications, and management skills, although the evidence on this point is so far limited.[43] Needless to say, this format has a high cost per farmer. Data on the extent of diffusion from farmer to farmer is scant, and there is some debate among experts concerning the scale of impacts.

An example of another decentralized format for disseminating technology and information is the Agricultural Technology Management Agency (AMTA) undertaken in India and Kenya. ATMAs are registered, autonomous societies designed to coordinate the interests of research and extension stakeholders at district and subdistrict levels. They promote farmer interest groups around specific crop and livestock activities, such as farmer-to-farmer exchange of information and learning, and develop partnerships with private sector stakeholders. ATMAs can receive and expend project funds, enter into contracts and agreements, and maintain revolving funds that can be used to collect fees and recover operating costs.[44] In India, for example, an explicit aim is to "create suitable mechanisms to ensure location-specific adaptive, indigenous, knowledge-based research."[45]

Are there cases where farmer innovation occurs on a large-scale with minimal external support? Certain attributes of innovations contribute to rapid, low–cost, and widespread diffusion. These include: (1) rapidly accruing benefits; (2) highly visible benefits; (3) simplicity; (4) low start-up costs; (5) ability to leverage existing farmer practices; (6) the importance of agricultural constraints they address; and (7) the potential for adoption in parts or pieces rather than the whole, making them less risky and costly.[46]

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43. Robert Tripp, *Self-Sufficient Farming: Labour and Knowledge in Small-Scale Farming* (London: Earthscan, 2006).

44. World Bank, *World Development Report 2008: Agriculture for Development* (Washington, D.C.: World Bank, 2007), p. 174.

45. From http://www.manage.gov.in/natp/atma.htm, November 7, 2009.

46. Andrew Sargent, "Summary of Research Findings," unpublished manuscript prepared for Oxfam America, May 2009; see also Derek Byerlee and Edith Hesse de Polanco, "Farmers Stepwise Adoption of

External policies can create disincentives to adoption and diffusion of agricultural innovations; they can also nullify the potential benefits of a new practice or innovation. Innovations and practices spread via (1) structured replication, where NGOs, governments, and other organizations intentionally encouraged replication, and (2) spontaneous replication, where farmers spread innovations to others both within and outside of their own communities without the direct support, encouragement, or assistance of external organizations.[47] These mechanisms are complementary, and both may contribute to large-scale impacts of farmer innovation. Farmer exchange programs and farmer-to-farmer training programs are examples of structured replication. Spontaneous replication results from the characteristics of innovations, but also from a sense of obligation to share or a sense of self-esteem or social prestige from sharing knowledge, as in the Sahelian case mentioned above. Public recognition of farmers as principal players in agricultural innovation and the stewardship of local and globally important natural resources can enhance diffusion of promising technologies.

A final cautionary note concerns the role of governance.[48] Crafting the "best fit" structure for pluralistic advisory services will not guarantee success unless it is backed by sound incentives. Incentives are generated by public service provision, rules, regulations, and legal frameworks, such as those that create security of tenure, fair pricing, and access to information for both suppliers and purchasers. New roles for advisory service actors will require investment in training, equipment (e.g., bicycles and computers), recruitment, compensation, and monitoring of staff performance; qualifying skills for advisory service agents need to reflect the importance of areas such as financial management of small enterprises, management of saving and loan programs, marketing services, basic nutrition, home garden production, and postharvest processing. Not only will women and excluded groups need to be hired, but their roles and careers made legitimate.[49]

3. "Soft" Market Infrastructure to Catalyze Agricultural Productivity

Africa's gap in power, road, and water supply depresses economic growth and business development, but will be costly to close. Less behind, Africa's information communication technology (ICT) provides an immediate opportunity to broaden market participation, provide financial services, strengthen the performance of value chains, and target particular groups, such as women's associations. Development of both "hard" and "soft" infrastructure must be supported by states committed to establishing rules, regulations, and frameworks that promote private enterprise and maintain a level playing field.

Africa's Infrastructure Deficit

Physical access to markets is far more restricted among farmers in Africa than among farmers in other regions of the developing rural world. Only a quarter of African farmers are within two hours of markets by motorized transport as compared to nearly half of farmers in Asia and the

Technological Practices: Evidence from the Mexican Altiplano," *American Journal of Agricultural Economics* 68, no. 3 (August 1986), pp. 519–527.

47. Sargent, "Summary."
48. Regina Birner and David Spielman, personal communication, August 5, 2009.
49. InterAction, *Revitalizing Agricultural Extension*.

Pacific and 43 percent for the developing rural world. An estimated 75 percent of African farmers are located more than four hours to the nearest market by motorized transport, as compared to 45 percent in Asia and the Pacific.[50] Of course, most rural people in Africa have no access to motorized transport, so these figures understate the magnitude of the problem.

In addition to relatively poor road density, power consumption in Africa is one tenth of that found elsewhere in the developing world (table 2). Firms, particularly in the informal sector, lose sales as a consequence of frequent power outages. Moreover, much of the existing water supply and storage potential is underutilized. Although a negligible percentage of agricultural area, irrigated land contributes substantially to the value of agricultural production. Most of today's large-scale schemes are in need of rehabilitation, suggesting little institutional capacity to maintain them. Not only is access to infrastructure limited, but the prices of services in Africa are "exceptionally high" by global standards. The rates paid are several times those reported in the rest of the developing world, reflecting in some cases higher costs, and in others, higher profits.[51]

Public infrastructure investments can do much to reduce the risk exposure of rural households. Rural feeder roads can do much to integrate market economies, reducing some market price volatility as well as diversifying market opportunities for the rural poor. Shorter transportation times can reduce the risk of deterioration in perishable crops. Similarly, investments in electrification also reduce the risk associated with the production of perishable crops, which are also often higher-value crops. Public investment in local-level grain storage banks can benefit small-scale producers who lack the economies of scale to make it worthwhile to invest at the individual level. They can be particularly important for women who often grow crops for their household food security and lack effective means to store their production without losses.

Globally speaking, rural populations are more educated, less isolated, and more aware of their situation vis-à-vis other citizens, nationally and globally. The location-specificity of many new technologies and practices requires different agricultural information systems. ICT, provided by a combination of public and private actors, has become an essential tool. Interestingly, with respect to ICT, the gap between Africa and other developing regions is narrower (table 2). In less than a decade from 1999 to 2006, the estimated percentage of Africa's population living within range of a GSM (Global System for Mobile Communications) signal rose from 5 to more than 50 percent.[52] Household access to mobile telephone services exceeds that of piped water in some countries. Internet use lags behind, however.

Africa's Market Infrastructure and Agricultural Productivity

A recent study by FAO and the World Bank underscores the fact that weak markets, supporting institutions, and policies leave much of Africa's agricultural productivity untapped.[53] The study

50. Sebastian, "Mapping favorability for agriculture."

51. These points are drawn from Vivien Foster, *Overhauling the Engine of Growth: Infrastructure in Africa*, African Infrastructure Country Diagnostic, Executive Summary (Washington, D.C.: World Bank, 2008).

52. Ibid.

53. This is also why genetically modified crops, while they may be a promising technology, are not a priority investment for Africa (Richard Paarlberg, personal communication, CSIS Task Force on Global Food Security, June 23, 2009). Drought-tolerant maize is an example of a biotech crop with enormous potential private and social payoffs. Genetic tolerance to abiotic stresses, such as tolerance to drought, embeds "crop insurance" in the seed, reducing yield variability. Drought tolerant maize can also mitigate losses associated with the shift, due to climate change, of increasing risk on rainfed lands. Many poor people in

Table 2. Africa's Infrastructure Deficit

	Low-Income Countries in Sub-Saharan Africa	Other Low-Income Countries
Paved road density	31	134
Total road density	137	211
Mainline density	10	78
Mobile density	55	76
Internet density	2	3
Generation capacity	37	326
Electricity coverage	16	41
Improved water	60	72
Improved sanitation	34	51

Source: Vivien Foster, *Overhauling the Engine of Growth: Infrastructure in Africa, African Infrastructure Country Diagnostic,* Executive Summary (Washington, D.C.: World Bank, 2008).

Note: Road density is in kilometers per kilometer squared; telephone density is in lines per thousand population; generation capacity is in megawatts per million population; electricity, water, and sanitation coverage are in percentage of population.

examines the productivity potential of the Guinea Savannah, spanning some 600 million hectares, of which about 400 million can be used for agriculture. Less than 10 percent of this area is currently cropped. Using value-chain analysis of six commodities well-suited to the Guinea Savannah (cassava, cotton, maize, rice, soybeans, and sugar), the study found that (1) farm production costs are competitive in Africa; (2) Africa's producers are competitive in domestic markets with respect to imports, but (3) they are not competitive on the international market. The same high costs that protect them from import competition (resulting from deficiencies in transport, processing, and storage) reduce their export competitiveness. The study concluded that smallholder farms were

Africa will live on land with high risk of drought. Since achieving drought tolerance has posed a scientific challenge, the problem has been tackled with both conventional and transgenic means. Genti Kostandini, Bradford F. Mill, Steven Were Omamo, and Stanley Wood ("Ex ante analysis of the benefits of transgenic drought tolerance research on cereal crops in low-income countries," *Agricultural Economics* 40, no. 4 [2009]: 459–476) have estimated the ex ante benefits to transgenic as compared to conventional breeding for drought tolerance in cereals in Bangladesh, India, the Philippines, Indonesia, Kenya, Nigeria, Ethiopia, and South Africa. The authors find that private sector research on transgenic drought tolerance in the eight low-income countries (annual estimated benefits of $178 million) may yield slightly more benefits than public conventional breeding in maize and wheat, but not in rice. The differences are small, however, and based on the assumption that (1) intellectual property rights can be strictly enforced, (2) commercial seed systems are strong, and (3) farmers have good access to markets. These three conditions simply do not hold in most of Africa outside South Africa. Investing in market access and seed system constraints will have more far-ranging, immediate impacts than investing in biotechnology research and are a precondition for its successful adoption, as shown in the studies edited by Robert Tripp, ed., *Biotechnology and Agricultural Development: Transgenic Cotton, Rural Institutions and Resource-Poor Farmers* (London: Routledge, 2009).

more competitive except in three special cases: (1) growing plantation crops, (2) meeting stringent quality requirements in overseas markets, and (3) developing relatively fertile land areas with few people. The main opportunities for private domestic and foreign investors therefore remain in seed development, input supply, marketing, and processing. The authors of the report concluded that capitalizing on these opportunities will depend not only on more investment, but on getting policies right and strengthening institutions.[54]

Intensifying African agriculture thus depends in a very crucial way on developing markets and related institutions. Market problems for smallholders include weak information, poor contract enforcement, risks of various types, and high costs of negotiating transactions to protect buyers and sellers against risk.[55] Transactions are often based on trust—which is no way to run an efficient market. Search costs are high because there are no printed catalogs or listings; most transactions are small with highly personalized credit arrangements. Quality is uneven, and with few government standards available and no personal identification systems, the transparency problem applies to both sellers and buyers.[56] In many cases, there is an utter absence of markets because of low purchasing power. Production and sales cycles are long by standards of small businesses, and there is a need for seasonal financing. Large shares of output are destined for subsistence, which does not generate cash to cover purchased inputs and labor.

As a consequence of these features, the market-related efficiencies achieved in fast-growing economies do not materialize in Africa. Instead, undeveloped market demand for outputs discourages producers from producing more, while the consequent failure of incomes to rise in rural areas deters agricultural enterprises from entering and doing business. In the absence of functioning markets, rural areas remain trapped in subsistence-oriented economies in which neither the agricultural production sector nor the wider rural economy (both of which generate off-farm employment opportunities) can grow.

Public Investments to Enable Private Investment in Markets

At independence, African governments were acutely aware of agriculture's importance to their economies and society, but because they did not trust the private sector, they vested tremendous responsibility in the public sector. Many governments tried to address market failures in rural areas by creating state-managed organizations, such as marketing boards. Most of these interventions proved to be fiscally unsustainable, contributing to a major shift during the late 1980s that reduced the strength and scope of public activities and encouraged private sector development. There is now widespread recognition that the process of structural adjustment and market liberalization also had mixed results. Where the public sector stepped back, the nascent private sector often failed to step up.

Both the public and the private sector are needed to develop markets in Africa. The public sector has a key role to play by investing in local market infrastructure; the literacy, numeracy and problem-solving skills of actors in agricultural value chains; and overcoming market failures

54. Michael Morris et al., *Awakening Africa's Sleeping Giant: Prospects for Commercial Agriculture in the Guinea Savannah Zone and Beyond* (Rome and Washington, D.C.: Food and Agriculture Organization and the World Bank, 2009).

55. Colin Poulton, Andrew Dorward, and Jonathan Kydd, "Overcoming Market Constraints to Pro-Poor Agricultural Growth in Sub-Saharan Africa," *Development Policy Review* 24, no. 3 (2006): 243–277.

56. Marcel Fafchamps, *Market Institutions in Sub-Saharan Africa: Theory and Evidence* (Cambridge, Mass.: MIT Press, January 2004).

through, for example, information provision. In Asia's Green Revolution, national leaders needed to meet the goal of national food self-sufficiency or lose power. African governments need this accountability in order to ensure that there are incentives for farmers to adopt, advisory services to function properly, and traders to operate efficiently. Public institutions need to develop an appropriate blend of policies, regulatory frameworks, and investments to relaunch the agricultural sector. Some basic requirements include reforming the property system to ensure secure titles to land and other assets owned by smallholders, strengthening the capacity of agricultural households and their associations to voice their needs in decisionmaking for agriculture, and broadening access to finance. A series of briefs produced by USAID under the Business Climate Legal and Institutional Reform project details lessons learned concerning the range of rules, regulations, and policies to enable agribusiness development in Africa; topics include dealing with licenses, employing workers, enforcing contracts, obtaining credit, paying taxes, registering property, trading across borders, and starting and closing a business (www.BizClir.com).

Rural and Agricultural Financial Services

Publicly funded, specialized credit institutions ensured that priority sectors gained access to financial services, and particularly credit, during much of the Green Revolution era in Asia. The main function of these institutions was to stimulate adoption of new technologies in a sector that is not financially attractive to private investors because it is risky and profitability is low. Equally important, social goals for these institutions were a commitment to food security and poverty alleviation. For these reasons, loans were often provided at subsidized rates, intended for specified beneficiaries, and targeted at specified agricultural commodities. In the 1990s, when governments and donors tightened fiscal belts and retracted subsidies on agricultural finance, policymakers assumed that for-profit financial institutions would emerge to service the agricultural sector and address the same social goals.

Not surprisingly, as was generally the case in agriculture, this assumption proved to be untenable. Smallholder farmers make narrow profit margins even in good years, always face risk of a poor year, and do not possess much collateral. The transactions costs of servicing numerous, dispersed smallholder farmers are high. The low loan repayment history associated with government-run credit schemes was daunting.

Some success was achieved with nonbank financial institutions (NBFIs), such as credit cooperatives, credit unions, and village banks. Their advantages often included the capacity to cut administrative costs, better assess the credit risk of potential borrowers, and draw upon peer pressure to help ensure loan repayment. Many also required subsidization during the initial stages of operation.

After becoming established with nonagricultural lending, some microfinance projects started lending to the agriculture sector, realizing that this can diversify their portfolio and expand lending volume. Microfinance lending rates are much higher than interest rates at banks because the transactions costs of microfinance institutions are much higher.

In agricultural finance, as in other agricultural markets, issues such as deficiencies in the legal and regulatory environment must be addressed first (or simultaneously) to ensure that credit delivery generates expected results. Corrective measures in legal and regulatory reform can be undertaken immediately. Such measures include reforming laws governing secured transactions, improving land titling and registration, promoting credit scoring and registering, and deregulating lending and deposit service provisions.

Ongoing Innovations in "Soft" Market Infrastructure

Warehouse Receipts

Efforts to gain a foothold in the underserved areas of the global rural south today have led to a number of innovations, such as a grain-specific form of rural lending that is based on warehouse receipts. To access this credit, a farmer delivers grain to a warehousing facility that produces a receipt to document the quantity of grain delivered. The farmer pays a monthly storage fee but can sell grain during favorable market conditions or as is needed to meet expenditures. Warehouses often have minimum requirements for amounts stored. Smallholder farmers not able to meet the requirement independently may be able to affiliate with a cooperative or farmer association.

Warehouse receipts are considered the "currency of agriculture" in the United States and other developed economies. With a receipt in hand, farmers may negotiate the sale of their crop and transfer title with ease and confidence. Likewise, purchasers of the commodity have the one document they need to guarantee that the facility storing the agricultural commodity must turn it over to them. In countries like India, however, most warehouses are flimsy structures, and receipts for storage are almost unknown.

In addition to providing a storage mechanism for grains, the warehouse receipt may be used as collateral by the farmer to obtain a loan from a financial institution. For a financial institution, lending against warehouse receipts reduces the need to assess repayment capacity. The success of using warehouse receipts as collateral depends on (1) sound warehouse management facilities that will preserve the quality and condition of the stored good (pest control monitoring, humidity control, air movement, bacteria control); and (2) reliable futures prices of grain for assessment of the value of the warehouse receipt.

Warehouse receipt systems vary in size and complexity. In Ghana, for instance, Technoserve's successful experience with warehouses

Box 2. Warehouse Receipts in Uganda

Like other small-scale commercial farmers around Kapchorwa in eastern Uganda's corn belt, Sam Arapsatya found it impossible to get ahead financially. Although his 20 acres of rented land had good yields, Arapsatya struggled to support his large extended family and keep the farm running from one harvest to the next. Bills piled up during the growing season, and when harvest time arrived, he and his neighbors sold their corn immediately to village traders to get cash for school fees and food and to pay farm laborers and buy inputs for the next crop. The flood of maize lowered prices, but the farmers had no other choice. They needed money, and because Uganda's financial sector traditionally has viewed farmers as too risky to deal with, especially renters like Arapsatya who have no land for collateral, borrowing from a bank or other financial institution was not an option.

Today, however, Arapsatya is a welcome customer at the local branch of Stanbic Bank, thanks to USAID's Rural Saving Promotion and Enhancement of Enterprise Development (Rural SPEED) innovative warehouse receipts system which lets him store his crop, use it as collateral for a loan worth 80 percent of the current grain value, and sell later at a higher price when prices increase. The system is helping Ugandan farmers overcome two challenges—the cyclical nature of farm income and lack of access to credit—that kept many of them operating not far above subsistence level. "This system rescues us," says Arapsatya. "With it, I was able to get a loan using my grain as security. With the money, I bought more seeds and fertilizer. Now I can develop my farm."

Source: http://www.microlinks.org/ev_en.php?ID=11423_201&ID2=DO_TOPIC

serving from 40 to 50 farmers encouraged the Agriculture Development Bank there to introduce a large-scale warehouse system whose main benefits are more related to reducing interseasonal price fluctuations than proving inventory credit.[57] Box 2 provides an example from Uganda.

Repos

Other forms of collateral-financing schemes include repurchase agreements ("repos"). Repos are simple forms of commodity finance: the bank, rather than taking a pledge over the goods being stored or shipped, buys goods and simultaneously signs a contract for resale at a certain point in time at a price that reflects the cost of funds from the original time of sale to the resale. Repurchase agreements have spread to over a dozen countries in recent years and are particularly popular in countries that do not have adequate laws and regulations regarding such things as foreclosure mechanisms.

Trader Credits

Trader credits provide farmers with in-kind advances or cash advances, contingent upon repayment at harvest or an agreed-upon selling price of goods at harvest. Trader credit is not intended for financing long-term investments, such as purchasing equipment or property, expanding operations, improving quality standards or starting new activities.[58] The trader benefits from this extension of credit because it secures a local supply of produce and generates income from the related interest gained from the loan transaction. Although trader credit may help farmers with building relationships and obtaining credit, it is short-term, incurs high transaction costs, and offers little to no transparency.

Crop and Livestock Insurance

Crop and livestock insurance is offered to farmers to protect them against unexpected losses in earnings from production and/or market shocks. Many countries have provided farmers or their financial institutions with multi-peril crop insurance intended to cover income loss caused by shocks in production from natural disasters such as floods or drought. Historically, this product has failed due to expensive administrative costs and high losses. The losses stem from asymmetries in information, where the client purchases insurance with better information about the likelihood of production shock than the insurance company.[59] Once the insurance is purchased, the insured farmer may see no incentive for careful crop management because the insurance will pay for any losses at the end of the season (moral hazard). A more cost-effective insurance product for smallholder farmers is index insurance.[60] Index insurance addresses information and moral hazard problems by providing insurance based on regional indices, with indemnities based on area yields or weather information. An example of this type of insurance product is insurance for a crop indexed to a certain level of rainfall. In this case, the indemnity paid on the policy is related only to rainfall. Farmers still have incentives to tend their crops to the best of their ability, and information is constant for the insurance company and the farmer. Examples are currently under way for

57. Rural Finance Learning Center, Warehouse receipt finance and collateral management, March 2007.

58. Douglas Pearce, "Buyer and Supplier Credit to Farmers: Do Donors Have a Role to Play?" Prepared for "Paving the Way Forward for Rural Finance: An International Conference on Best Practices," June 2–4, 2003, available at http://www.basis.wisc.edu/live/rfc/cs_15b.pdf.

59. J.R. Skees and B. J. Barnett, "Enhancing Micro Finance Using Index-based Risk Transfer Products," *Agricultural Finance Review* 66 (2006): 235–250.

60. Mark Wenner and Diego Arias, "Agricultural Insurance in Latin America: Where Are We?" prepared for *Paving the Way Forward for Rural Finance: An International Conference on Best Practices*, held June 2–4, 2003.

Box 3. Index Insurance in Adi Ha, Ethiopia

Farmers in the Ethiopian village of Adi Ha have been busy sowing fresh crops of grain in recent weeks, as is customary when their maize crops struggle because of drought. But this year, they have a second backstop against hunger: insurance. In Adi Ha, farmers can pay a one-time fee of US$5 to US$30 to cover their crops of the grain teff, used to produce the flatbread injera. Depending on how much rain falls on this particular swath of the northern highlands in August and September, policies pay out up to five times the premium. The arbiter will be a satellite, marking the first time that scientists have used space-based observations to fashion contracts at the level of individual farmers.

Unlike standard crop insurance, which requires on-the-ground audits, any payments will be distributed automatically according to a set formula, helping villagers to keep food on the table and buy seeds to start over again next year. "Teff is insurance for these farmers, so by insuring teff we are strengthening their insurance," says Daniel Osgood, a researcher who helped develop the policy at Columbia University's International Research Institute for Climate and Society in New York. Oxfam America and the insurance giant Swiss Re are also involved.

Adi Ha is one of dozens of pilot "index insurance" programs that are popping up throughout the developing world as governments, nonprofit groups, and aid agencies look for ways to help poor communities—and in some cases countries—cope with natural disasters.

crop and livestock insurance in a number of countries, but the outcomes have not yet been fully assessed (box 3).

Financial Information Technology

Financial institutions are finding new ways to provide flexible, far-reaching financial service delivery channels more suited to rural areas than traditional banking. There are a number of promising areas where technology, when combined with business activities of extending credit, can provide advantages that traditional banks and other rural credit providers business have not. Technology alone is not the solution, but it enables business innovations. ICT can reduce costs through lower unit costs and higher-volume productivity. For example, by using technology to streamline business processing, an institution could reduce the time required to disburse loans from five to two days. That translates into a 40 percent increase in the number of loans disbursed. Not only is the disbursement cost per dollar of credit lowered, but revenues are increased as loan capital is turned over more quickly.

A second benefit of using technology is indirect improvement of operations through better risk management. Technology enables institutions to collect data in electronic format that can be synthesized and analyzed to identify trends, such as delinquency or yields, and assess individual creditworthiness through payment histories (savings and credit) as well as develop scoring models. The larger the data repositories, the easier it is to spread risk across larger risk groups. For the industry to scale up, it is imperative that risk be assessed across larger and larger pools of individuals. Technology can be used to create local data repositories that can be aggregated through data consortia to form broader data sets and more statistically significant risk mitigation analysis. Examples of some of the most useful technologies and their potential benefits are shown in table 3.

One of the biggest changes taking place is linked to mobile phones. Mobile phones compensate for inadequate infrastructure, allowing information to move more freely and making markets

Table 3. New Financial Technologies and Their Advantages

Technology	Description	Advantages
Personal digital assistants (PDAs)	Small, hand-held digital computers that can run specialized programs and perform financial calculations	Streamline loan office activities, allow loan office to make decisions in the field, reduce trips to remote areas
Smart cards	Wallet-sized plastic card with embedded computer chips that can process information or store data	Store and manage customer account information; allow clients to make loan payments and purchase inputs without cash; reduce need to travel to bank or ATM
Automatic teller machines (ATMs)	Machine that automates deposits, withdrawals, account transfers, balance requests, and, potentially, loan payments	Provide flexible loan access for customers, can serve non-bank locations, reducing cost per transaction; build client sense of ownership
Point-of-sale devices (POS)	Card reader, mobile phone, personal computer, barcode scanner, or any hardware that can identify customers and receive instructions for value transfer	Allow clients to purchase goods from POS-equipped suppliers without cash; reduce frequency with which clients must visit bank branches; reduce opportunities for theft or fraud through electronic confirmation; build sense of client ownership
Internet banking	Web site that allows customers to manage their account online; conduct transfers; check account balances; make loan payments; apply for loans; and correspond with customer service	Reduce the frequency with which clients must visit bank branches and reduce client and financial service provider time spent on routine transactions; provide clients with flexible access to account information and some transactions

more efficient. With phones now so commonplace, mobile money allows cash to travel as quickly as text messages, and mobile banking is far safer than storing wealth in the form of cattle, gold, or by stuffing banknotes into a mattress.

In a growing number of rural communities in the global south, small shops are beginning to perform the functions of bank branches. In too many countries, however, mobile money has been blocked because operators do not have banking licenses and their networks of corner-shop retailers do not meet criteria for formal bank branches. Kenya's success with mobile banking, however, is attracting increasing interest, and the benefits of this new technology are becoming more widely appreciated (box 4). More enlightened regulators are no longer insisting that these services meet the rigid rules for formal banking, and some banks now view mobile money not as a threat but as an opportunity and are teaming up with operators.

Other Farmer Information Services

A 2008 inventory by the Forum for Agricultural Research in Africa (FARA) explored ongoing innovations in information systems for Africa farmers.[61] Most of these projects are in a pilot phase, and their success has not yet been evaluated. Innovations included voice information delivery services, radio, including dial-up and regular radio broadcasts, extension services based on mobile phones and database monitoring, and e-learning for basic skills, agricultural education, and video-based approaches. The study noted that with the widespread use of mobile phones, voice and short message service (SMS) solutions are expected to offer easy access to farmers. SMS carries only a limited amount of information and requires a basic level of literacy. Voice-based solutions are complicated to develop for they require machines to produce natural speech or, in technical terms, good speech synthesis. These do not offer detailed information such as illustrations that Web solutions can provide. The authors conclude that voice solutions are a promising entry point for African farmers because these can be customized for language, are accessible and natural, and entail use of a mobile phone through direct responses to specific questions. Web-based platforms remain essential for provision of more detailed information. Examples of some of the projects inventoried are shown in table 4.

Box 4. Mobile Money in Kenya

By far the most successful example of mobile money is M-PESA, launched in 2007 by Safaricom of Kenya. It now has nearly 7 million users—not bad for a country of 38 million people, 18.3 million of whom have mobile phones. M-PESA first became popular as a way for young, male urban migrants to send money back to their families in the countryside. It is now used to pay for everything from school fees (no need to queue up at the bank every month to hand over a wad of bills) to taxis (drivers like it because they are carrying around less cash). Similar schemes are popular in the Philippines and South Africa.

Source: "The Power of Mobile Money," *Economist,* September 24, 2009.

The authors of the FARA study emphasize that farmers should not be perceived as consumers of generic information. Instead, the agricultural sector requires a well-organized learning community in the form of farmers' associations, cooperatives, and women's groups. Innovative farmer information systems include face-to-face interaction, learning by doing, learning through evaluation and experience, and conversion of generic to location-specific knowledge. An interesting example from India is shown in box 5.

Recommendations

Rural worlds are changing rapidly. Information technology has shortened the distances from remote villages in the South to urban centers in the North, but has also sharpened the contrasts in our ways of life. About two-thirds of farmers in low- and middle-income countries (1.7 billion) have either poor land or poor access to markets, or both—though quality land and strong markets are fundamental ingredients for agricultural productivity. Climate change, water scarcity, a lingering food price crisis, and economic recession exacerbate this challenge and also highlight

61. Mucemi Gakuru, Kristen Winters, and Francois Stepman, *Inventory of Innovative Farmer Advisory Services Using ICTs,* Forum for Agricultural Research in Africa, February 2009, http://www.fara-africa.org/media/uploads/File/NSF2/RAILS/Innovative_Farmer_Advisory_Systems.pdf.

Box 5. India's e-Choupal Model

ITC, one of India's leading private companies, has initiated e-Choupal (*choupal* means gathering place in Hindi) to place computers with Internet access in rural farming villages. Individual e-choupals serve as both a social gathering place for exchange of information and as an e-commerce hub. What began as an effort to reengineer the procurement process for soy, tobacco, wheat, shrimp, and other cropping systems in rural India has also created a highly profitable distribution and product design channel for ITC.

The e-commerce platform ITC developed has catalyzed rural transformation that is helping to alleviate rural isolation, create more transparency for farmers, and improve their productivity and incomes. The e-Choupal system gives farmers more control over their choices, a higher profit margin on their crops, and access to information that improves their productivity. By providing a more transparent process and empowering local people as key nodes in the system, ITC increases trust and fairness. The increased efficiencies and potential for improving crop quality contribute to the competitiveness of Indian agriculture.

ITC plans to partner with larger banks to design products for rural India. Some of the products being designed include noncash loans for farm inputs, loans to sanchalaks, direct loans to farmers based on the village e-choupal recommendations, and insurance and risk management services.

Despite difficulties resulting from undependable phone and electric power infrastructure (this sometimes limits hours of use), the system also links farmers and their families to the increasingly interconnected world. Some local farmer coordinators running the village e-choupal (called sanchalaks) track futures prices on the Chicago Board of Trade as well as local mandi prices, and village children have used the computers for schoolwork and games and for obtaining and printing out their academic test results. The result is a significant step toward rural integration and development.

The e-Choupal model demonstrates that a large corporation can play a major role in recognizing markets and increasing the efficiency of an agricultural system, while doing so in ways that benefit farmers and rural communities as well as its shareholders.

Source: This example is drawn from Kuttayan Annamalai and Sachin Rao, "What Works: ITC's e-Choupal and Profitable Rural Transformation Case Study," World Resources Institute, August 2003, funded by USAID's Microenterprise Development Office through the Practitioner Learning Program of the Small Enterprise Education and Promotion (SEEP) Network.

the discouraging fact that a 20-year decline in agricultural investments has serious repercussions. Ongoing crises affect farmers differently, depending on their rural world. Closing the investment gap is not sufficient to bring about positive change; how funds are invested is more important. Far-reaching, multiple technological and institutional innovations will be needed to raise and sustain farm productivity. Three types of risk must be curbed for smallholder productivity to rise: production risk, price risk, and risk of access to resources. We propose several ways that we believe the United States can contribute positively to changing rural worlds. Our focus is on Sub-Saharan Africa, though we draw on some experiences from Asia.

Postulate 1: Agricultural productivity will not increase without intensification of farming systems,[62] but in many regions of the world, intensification will not be possible without restoring

62. Intensification of agriculture in the broadest sense means only more is produced per unit of land, through more application of inputs, including purchased inputs such as seed, fertilizer, or machinery or on-farm inputs such as labor, knowledge, and managerial skills. Examples of intensified systems include not

Table 4. Illustrative Examples of ICT Projects for Market Information Services in Africa

Project Title and Location	Description
T2M http://t2m.manobi.sn/ Senegal	Manobi developed the T2M, a system that enables producers, exporters, and the public regulatory agency to use a mobile telephone, a PDA (personal digital assistant) or the Internet in order to know in real time both the price and arrival status of their products at the markets and the availability of the same products in the production sites. The price and arrival changes of the products on the markets are collected by Manobi market researchers twice a day on a PDA application. The data, which are sent via the mobile network to the Manobi multi-channel service platform (MCSP) and stocked at a centralized database, are analyzed in real time before being broadcast to users through a multi-channel platform specially developed by Manobi to provide value-added data services at lower cost with the mobile telephony operators' first generation classical vocal networks.
Project Title Esoko (formerly Tradenet) http://www.esoko.com Benin; Burkina Faso; Côte d'Ivoire; Ghana; Madagascar; Mali; Mozambique; Nigeria; Tanzania; Uganda; Cameroon; Afghanistan	Esoko is a rural communication platform that seeks to improve incomes by building healthy markets. Any individual, business, or producer group can set up Esoko to better manage their marketing, distribution, and procurement networks. There are four key services provided by the platform: (1) *Live market feeds*—real-time SMS alerts on market prices and offers automatically delivered to subscribers. Users can submit offers into the system directly using SMS; (2) *direct SMS marketing*—businesses can target specific groups of users and target procurement or extension messages to reduce their travel and communication costs; (3) *scout polling*: enterprises can set up automatic SMS polling for field activities to track inventories, crop activities, etc., to monitor and report on crop cycles and yields; (4) *online profiling and marketing*—any user or business gets a customizable Web space that can advertise their goods and services. This space can be updated using Esoko's mobile2web content management service. Esoko was begun as TradeNet in 2005 as a private initiative. It partnered with USAID's MISTOWA program in West Africa and CIAT's FoodNet program in Uganda. It works with both Web and mobile devices and has a team of 20 in Ghana developing the technology. It is currently licensed by partners in 10 countries throughout Africa. Anyone can license the platform for use in their own country. Esoko provides a complementary partner support program focused on capacity building and financial sustainability, with an emphasis on market data enumeration and business development services.
Agricultural Marketing Systems Development Programme (AMSDP), Government of Tanzania	Vodacom is working with the Ministry of Industry, Trade and Marketing to implement its AMSDP, a seven-year program. Information is provided by the ministry to Vodacom, where farmers and traders can access the data, including the latest commodity prices through SMS sent from their mobile phones. This service enables farmers and traders to negotiate more effectively on the sale of agricultural produce.

ICT for Shea Butter Producers http://www.iicd.org/projects/mali-shea-butter-and-ict Mali	The project aims to promote shea butter while at the same time increasing the turnover of the Zantiébougou Women Shea Butter Producers Cooperative (COPROKAZAN) through the use of NICT (new information communication technology). The project has involved the installation of lighting and computers, training of women in the use of standard software and office automation tools, installation of e-mail, creation of a Web site, and advertising on radio and television. Approximately 350 women benefit from this project.

Source: Drawn from Gakuru et al., *Inventory of Innovative Farmer Advisory Services Using ICTs,* pp. 23–56.

soil and water resources. In areas where intensification has already occurred, more attention paid to natural resource management will help sustain productivity growth. A standardized package of inputs or practices will not have widespread impact.

Corollary: Restorative approaches for natural resource management offer climate change adaptation and mitigation opportunities and embed capacity strengthening for farmers and farming communities.[63]

General Recommendation: Intensification of agriculture in the broadest sense means only that more is produced per unit of land. This can occur through increased application of inputs, including purchased inputs such as seed, fertilizer, or machinery, or through greater use of on-farm inputs such as labor, knowledge, and managerial skills. Examples of intensified systems include not only high-yielding specialized cropping systems that rely heavily on purchased inputs and capital, but mixed crop and livestock systems, complex agroforestry, and multicropping systems, labor, manure, knowledge, and managerial skills. We should view the intensification process needed to raise agricultural productivity from a longer-term, farmer-centered, and resource-based perspective. This will mean more careful husbandry of natural resources. It will also mean that we should revalidate the central role of smallholder farmers as not only producers of food but rural citizens and custodians of global public goods.

Specific Recommendations

- Invest in science to (1) solve the practical problems of soil and water resource management in diverse agroecologies, including the use of crops tolerant to biotic and abiotic stress and soil and water conserving techniques and practices; (2) support productive farming systems that use soil, water, and energy-based inputs less intensively and labor, knowledge and managerial skills more intensively; (3) focus on solutions that incorporate simple, stepwise approaches and short-term, visible benefits for smallholder farmings;
- Invest in youth and adult education approaches, such as school and farmer field schools, to assist farmers in experimenting, learning, and adapting technologies, techniques, and practices

only high-yielding specialized cropping systems that rely heavily on purchased inputs and capital, but mixed crop and livestock systems, complex agroforestry, and multicropping systems, labor, manure, knowledge, and managerial skills.

63. The United States has experience in climate change adaptation. Consider, for example, the Dust Bowl.

to their own conditions. Equip farmers with problem-solving skills, and the capacity to lead others and diffuse approaches themselves.

- Invest in rural citizenship and in the capacity of farming communities to hold their peers, government, and ministries accountable, encouraging good governance.
- Invest in including women and other excluded groups as actors and beneficiaries in technology development and diffusion rather than observers or silent participants. The roles that women and minority groups play, and the type of technology they are involved in developing and diffusing, will depend on the rural world in which they live.

Postulate 2: Top-down, supply-driven, technology-transfer approaches have not been sufficiently responsive or flexible to meet the needs of Africa's diverse small-scale farmers. Though more challenging to design and implement, an agricultural innovation systems approach involving farmer advisory services provided by a range of actors could scale-up technical innovations more effectively. The "best fit" combination of actors depends on the context.

Corollary: These approaches are by definition demand-driven and will involve partnerships and alliances among multiple providers of services and sources of finance.

General Recommendation: Draw on the comparative advantages and skills of a wider range of actors in the food chain to extend technologies, techniques, and practices effectively among farmers. Involve farmers in diagnosing problems and offering solutions.

Specific Recommendations

- Replace centralized, supply-driven, commodity-based state research and extension approaches with pluralistic advisory services in a food system context.
- Recognize that provision and financing of advisory services can be de-linked and that the public sector, NGOs, private companies, farmers, and farmer-based organizations have a potential role to play in either provision or financing. Seek a "best-fit" rather than a "best practice."
- Seek ways to include women and other excluded groups in pluralistic advisory services in ways that do not compete with their other responsibilities. Vouchers for services are one way to include such groups in farmer-financed provision.
- Recall that certain types of agricultural technologies, techniques, and practices, such as natural resource management approaches, are not provided optimally without public sector involvement.
- Invest in coordinating research, extension, and education funding and approaches with other donors.

Postulate 3: Africa's gap in power, road, and water supply depresses economic growth and business development, but will be costly to close. Less behind, Africa's ICT provides an immediate opportunity to broaden market participation, provide financial services, strengthen the performance of value chains, and target particular groups, such as women's associations. Development of both "hard" and "soft" infrastructure must be supported by states committed to establishing rules, regulations, and frameworks that promote private enterprise but also level the playing field.

Corollary: Achieving realistic levels of infrastructure will require substantial increases in public investment. Most bilateral donor agencies such as USAID are able to finance only relatively small parts of a country's total needs. They can make other contributions, though, by selecting local projects that could become replicable models for government investments by providing technical assistance for strengthening sector planning or management and by participating actively in dialogue on reform of government policies in the sector. Donors with limited resources can also focus on less expensive but equally essential "soft" infrastructure.

General Recommendation: Complement investments by other donors in the "hard" infrastructure of markets (roads, rural electrification, water storage, and supply) with investments in "soft" infrastructure, including rules, regulations, policies, rural financial, and market information services that kick-start private sector investments. Accomplishing this depends on the formation of African "development states."

Specific Recommendations

- Support the establishment of policies, rules, and laws that (1) enable local and international private sector investments in agricultural production and marketing; (2) ensure broad-based participation in growth and benefits sharing through establishing and protecting rights, and making information publicly available.
- Invest in rural and agricultural financial services to strengthen support the greater engagement of farmers, traders, rural households and enterprises, such as (1) warehouse receipts, (2) buyer and seller credit, (3) trader credit, and (4) index insurance.
- Mobile money presents an opportunity to start a second wave of mobile-led development across the poor world. Operators, banks, and regulators should seize it.
- Invest in savings and investment instruments designed to meet the needs of rural women.
- Develop, test, and validating new technologies for financial services, such as PDAs, Smart Cards, ATMs, and Internet banking.
- Invest in developing, testing, and validation new ICT technologies for market information services.

Conclusion

Recognizing that more than half of Africa's land is not favored for agriculture and that Africa's soils are weathered, we nevertheless consider that much of the failure of agriculture to reach its productivity potential is institutional. We recommend (1) greater use of natural resource management approaches combined with pluralistic advisory services to reduce the production risk faced by smallholder farmers; (2) expansion of innovative financial and market information services to reduce price risks and transactions costs, and (3) strengthening of public institutions to develop an appropriate blend of policies, regulatory frameworks, and investments to relaunch the agricultural sector and reduce the risk of access to resources. Private sector actors need the legal and financial instruments to engage profitably in agricultural enterprise. Civil society needs the will and capacity to hold its leaders accountable. A necessary but not sufficient condition for the formation of an effective development state is more effective aid.

ABOUT THE AUTHORS

Melinda Smale joined Oxfam America in 2008 as senior researcher, agriculture and trade. She advises Oxfam on agricultural development policy and commissions research on international trade. From 2002, as a senior research fellow at the International Food Policy Research Institute (IFPRI), she led a global research program aimed at promoting the sustainable utilization of crop genetic resources in developing agriculture, initially as a joint program with Bioversity International in Rome, Italy. Research addressed the impacts of biotech crops, agricultural biodiversity, local seed markets, and underutilized crops. From 1989 to 2000 in Malawi and later in Mexico, she analyzed the adoption and impacts of improved wheat and maize seed as an economist for the International Maize and Wheat Improvement Center (CIMMYT). During the 1980s, Smale worked in Pakistan, Somalia, Mauritania, and Niger on short-term assignments for CIMMYT, Chemonics International, Volunteers in Technical Assistance (VITA), and the U.S. Agency for International Development. She earned a Ph.D. in agricultural economics from the University of Maryland, College Park, in 1992, an M.Sc. in agricultural economics from the University of Wisconsin, Madison, in 1983, an M.A. in international studies (Africa area) at the Johns Hopkins School of Advanced International Studies in 1979, and a B.A. in History/French at Duke University in 1977. Smale is an honorary fellow with Bioversity International, serving on the Advisory Committee of the Collaborative Crops Research Program of the McKnight Foundation and on editorial committees of several journals.

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