



Green Revolutions for Sub-Saharan Africa?

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Africa Programme | January 2011 | AFP BP 2011/01

Summary points

- In most of sub-Saharan Africa, faster growth in agriculture is a precondition for sustainable economic growth and poverty reduction. This will require technical progress tailored to Africa's varied agro-ecologies, notably improved seeds, more fertilizer and water management. Models of how to do this are available from Asia's Green Revolution and from some recent African success stories.
- Africa is short of capital and increasingly land-scarce. It also has many underemployed poor people. Asian experience shows that in such conditions employment-intensive, small-scale farming is usually both more efficient and more pro-poor than available alternatives.
- Current foreign land acquisitions in Africa will serve its interests only if they underpin the development of scientific, labour-absorbing and usually small-scale farming. In some former 'settler economies', progress will require careful land reform.
- Other requirements are improvements in infrastructure and institutions – transport, marketing facilities, credit and insurance – tailored to the needs of small- and medium-scale farming. Markets and states need one another.
- Recent progress – through increased shares of public resources devoted to agriculture, donor pledges, some improved output trends and better access for sub-Saharan farm products to world markets – is real but overstated; much more needs to be done.

Introduction

Between 1966–68 and 2006–08, farm output per person in sub-Saharan Africa (SSA) fell by a quarter, while it doubled in South Asia and tripled in East Asia.¹ This ‘Green Revolution’ – driven by improved varieties of staple crops, water control and fertilizers – transformed agricultural growth, mostly from small farms, slashed poverty and improved efficiency. This briefing paper asks whether sub-Saharan Africa can achieve its own green revolutions.

The problem

In the last 60 years the population of sub-Saharan Africa almost quadrupled and the area cultivated rose by a quarter. Between 1961–63 and 2007–09, average cereal yields crawled up from 0.8 to 1.5 tonnes per hectare (t/ha), while South Asia raised yields from 1 to 2.6t/ha, and East Asia from 1.5 to 5.4t/ha. Uniquely in the world, the region’s cereals and crop output per person fell substantially. And, while food imports increased sixfold between 1967 and 2005, malnutrition rates stayed stubbornly high.

Progress was slow because many farmers felt that investment was often unaffordable, unprofitable and risky, partly because of low supportive public expenditure and amounts of aid. Between 1980 and 2005, while the development community ‘prioritized’ Africa and poverty reduction, aid to SSA agriculture collapsed. Governments typically spent only 5% of outlays on agriculture, compared with 20–25% in Asia before the Green Revolution. Yet in sub-Saharan Africa six out of ten people (and eight out of ten poor people) live mainly from farming.

There are signs of change. Under the African Union’s Comprehensive Africa Agriculture Development Programme (CAADP), 22 states have pledged to raise agriculture’s share of their national budget to 10%. The Alliance for a Green Revolution in Africa (AGRA) has begun to expand research support. Aid to African agriculture has picked up. Foreign private companies and governments are also seeking to stimulate farm production, sometimes taking control of land in the process.

Will this suffice to generate green revolutions in sub-Saharan Africa? Resource depletion across the region makes this harder. Decades of slow yield growth, alongside rapid growth of population, forced farmers to expand crops into marginal lands, with soil mining, shortening fallows and deforestation (thrice as fast as the global average). By 2002–03, 40% of farmland was losing over 60 kg/ha of main plant nutrients each year. Yet, per hectare cropped, fertilizers added only 10 kg of main soil nutrients in 2008, as against 134 kg in South Asia. More fertilizer is needed just to stem soil depletion, let alone permit sustainable green revolutions. For this to happen, extra fertilizer use must pay the farmer. That requires fertilizer-responsive seeds, water control and cheaper transport. This last is impeded by long distances from farm to market: road density in sub-Saharan Africa approaches that of India 60 years ago.

Fertilizer use can be risky or unprofitable in areas of low, unpredictable rainfall. By 2008 over 40% of Asia’s cropland was prepared for irrigation, compared with 2.6% in sub-Saharan Africa. CAADP envisages major expansion. Some countries and areas (Nigeria, Ethiopia, South Africa’s Eastern Cape province) have potential from surface water, but in others topography and river systems offer less scope than in much of Asia. Groundwater irrigation is promising in several areas, but sometimes prohibitively costly. Green revolutions require expansion of irrigated farmland, but most land will remain un-irrigated. On such land, water control requires improved water harvesting, conservation or drainage, and faster-maturing (drought-evading) or drought-tolerant seeds.

The very absence of a widespread African Green Revolution suggests that – if lessons can be learned from past successes – there are good prospects for raising food output as public commitment to agriculture recovers. Already in the past decade, according to (usually extremely weak) official data, farm output growth has accelerated, in some countries to over 4%. However, the highest rates reflect a one-off recovery from conflict situations. Much recent growth has come

¹ The data compiled are three-year averages, in order to reduce the impact of chance weather fluctuations. Agricultural data here and elsewhere in the paper from FAOSTAT, at <http://faostat.fao.org/>. Full details of sources are available in the longer programme paper at [http://www.chathamhouse.org.uk/hunt_0111/].

from high-value export crops; if small-scale farmers rely solely on selling these to buy staples, they add 'price risks' to pervasive natural hazards. With low income, few assets and no insurance, few smallholders will commit most of their land to cash-cropping. Data for smallholder food production remain very weak, but those on food consumption, trade and nutrition are better; they suggest few significant gains in staples yields.

With a labour force growing yearly at 2–3%, many African households cannot generate corresponding income growth from self- and waged employment. Are there alternatives to agriculture? *Oil and minerals* expansion has typically generated little employment, and has often brought the well-known effects of a 'resource curse'.² Growth in *manufacturing* costs less per workplace than minerals – though more than farming. Despite islands of success, in the medium term sub-Saharan African manufacturing is seldom competitive with Asia: skilled labour costs more and main markets are further away. Usually, in the early stages of development, the main source of extra employment with low, and therefore affordable, capital cost per workplace – and hence of income growth and poverty reduction – is through extra production of farm output, including staples. Only later does this fuel rapid growth in non-farm and urban employment.

Strategies to stimulate African green revolutions

Technical progress

Asia's Green Revolution focused mainly on irrigated wheat and rice. The main staples of sub-Saharan Africa are unirrigated maize, cassava, millets, sorghum, yams, sweet potatoes, plantains and rice. Green revolutions must be adapted to diverse staple crops, agro-ecological zones and rain-fed farms. As in Asia, African diversity raises issues of priority, between high- and low-potential areas, and between putting the emphasis on seeds, fertilizers and irrigation and focusing on land and water management, together with increased attention, in crop-breeding and

selection, to drought-tolerant varieties and crops. Semi-arid regions have special research needs: plants, varieties and rotations with higher drought tolerance; soil moisture conservation and management.

Despite falling resources, significant investments in plant breeding in Africa have included the Rockefeller Foundation-supported development of drought-tolerant maize, 'new rice for Africa' (NERICA), and IITA (International Institute for Tropical Agriculture) and other pest-resistant cassava varieties. However, despite claims of widespread adoption, NERICA has had slow uptake, and the claims about cassava rest on problematic data. Further yield-enhancing innovations are needed. National breeding programmes continue in many countries, but are under-resourced.

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As for access to improved seed and fertilizer, by early 2009 \$84 million, or over a quarter of AGRA receipts, had been granted to 13 countries to address identified deficits in delivering improved varieties and inputs. CAADP has more resources and covers more countries. It has wider aims too: to extend sustainable land management (including through irrigation), to improve infrastructure for market access, to increase food security, but also to promote research

² Such as overvalued exchange rates, corruption, depletion of the exploited minerals; see Paul Collier, *The Bottom Billion: Why the Poorest Countries are Failing and What Can Be Done About It* (Oxford University Press, 2007).

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Modern crop-breeding or organic/low-external-input agriculture?

Africa's rising populations face fixed land endowments, increasingly claimed and used. Output growth requires rising land productivity. Labour productivity too must rise if returns to workers, including farmers themselves, are to be attractive. But land productivity must rise *faster*, for farm employment to rise.

Strategies to raise yield may emphasize high external inputs (HEI) – modern plant-breeding and inorganic inputs – or low external inputs (LEI), sometimes with organic farming (OF). Today, the high costs of modern inputs compel many African farmers to use low-productivity versions of OF and LEI by default, as most have done for centuries. Once, such methods were well adapted to land abundance and labour scarcity. Now, however, population expansion and land scarcity require faster innovation to raise yields.

Improved LEI/OF are advocated both on sustainability grounds and as the way to improve incomes for poor, remote farmers, especially in dry or high-risk environments. Can LEI accelerate farm growth and eliminate food shortages? Two African overviews from 2006–07 reported 60–100% yield gains from recommended LEI methods.³ If that is attainable, why are such cases the exception? First, LEI/OF sometimes require too much land or peak-season labour to attract farmers. Second, methodological weaknesses underlie some yield claims. Controls and experimental layouts are often under-specified. Organic humus, including manure, is recommended, ignoring the need for additional green matter or animals – and hence land. Non-chemical pest control may need crop rotation to 'clean' the land. Grass-roots NGOs may be needed to supply new knowledge: is this hidden cost sustainable? Some studies fail to ask whether insecure land rights inhibit recommended investment in trees, or in soil and water conservation. Others extrapolate from trials to

general adoption of small-scale off-take from rivers or wells to tap ground water, although both are often sustainable *only* if not too many farmers use the water.

The most striking successes of organic farming involve high-priced horticulture for niche 'green' markets. For staples, rapid yield gain entails a more eclectic approach, drawing also on the scope for a seed-cum-fertilizer revolution, especially in more favoured rain-fed, and irrigated, areas, but recognizing the risks of some forms of HEI innovation.

Mainstream breeding and genetic modification

By 2009, sub-Saharan Africa's average cereal yield was 1.8 times its level in 1961, but in China 4.5 times. Apart from irrigation, and (from 1977) land reform and better incentives, China's performance is based on better seed *quality* and seed research and distribution *methods*. Most SSA farmers still sow seeds from the previous year's harvest, sometimes with quality loss. The expertise to improve seed with non-genetically modified (GM) breeding (over 90% of high-yielding varieties in Asia, over 99% in Africa) has long been present in several African countries; the use of hybrid maize has expanded to many smallholdings, although most hybrid or GM seeds require new purchase each season, and hence reliable, affordable delivery systems. However, there is huge unrealized potential, including for other food staples, certainly for conventional plant-breeding and probably for GM, although more knowledge of impacts is needed.

In South Africa, GM maize has added herbicide resistance, sometimes permitting moisture-conserving no-till agriculture. As with bollworm-resistant GM cotton, the gains have spread to many smallholders, with yields and margins well above those of non-GM varieties. In West Africa, on the other hand, a transgenic cowpea resistant to pod-borer is available but illegal. Some HEI technologies require precautions. Farmers in South Africa's KwaZulu-Natal province experienced health problems from incorrectly applying chemicals to GM herbicide-ready maize. Weeds and pests develop resist-

³ See C. Badgley et al., 'Organic Agriculture and the Global Food Supply', *Renewable Agriculture and Food Systems* 22(2), 2007: 86–108; and J. N. Pretty et al., 'Resource Conserving Agriculture Increases Yields in Developing Countries', *Environmental Science & Technology*, 40(4), 2006: 1114–19.

ance to herbicides and pesticides, requiring ‘maintenance breeding’. Moreover, before supporting packages that encourage herbicide use, policy-makers should ensure that the resultant reduced hire of weeding labour is likely to be compensated, for the poor, by employment gains (e.g. in harvesting), higher yield or cheaper food in local markets.

Complex, well-informed and tested LEI/OF farm systems⁴ are, of course, sometimes sustainable and productive, whereas industrialized agriculture has sometimes dangerously over-used fertilizers, irrigation or pesticides. However, much of agriculture in sub-Saharan Africa has minimal external inputs, low productivity and growth, as well as unsustainable water or plant-nutrient use. In Africa’s better-watered, humid and sub-humid areas, increased external inputs are often essential for major improvement: few sub-Saharan African smallholders can much improve productivity (or sustainability) with the current tiny intakes of inorganic fertilizer.

However, farmers in semi-arid, rain-fed environments sometimes want crop improvements aimed not mainly at response to high fertilizer intakes (which risk crop burn in seasons of poor rainfall), but at drought tolerance or avoidance, plus improved water and soil management. This also needs plant breeders, to identify and develop appropriate varieties, even species. However, equally important is improved farm management. Control of water and soil run-off, and better humus retention and replacement, help soils to retain moisture and absorb inorganic fertilizer; but they require more labour input. This pays better if scientifically developed and tested seeds offer higher yields: appropriate LEI, conservation and modern technology can be complementary.

Institutional change: markets

Institutions are ‘the rules of the game’ – formal and informal regulations and norms that govern human interaction. The key institutions for diffusing innovation involve farm input and output markets and land rights.

As for markets, the debate is not just over market vs state, or free market vs subsidies. Apart from providing public goods, the state has a market- and safety-regulating role. Privatization without regulation can adversely affect farm performance and farmer welfare. In the 1990s improved maize seed production in Kenya was largely privatized. Complaints about quality multiplied, as with private production of NERICA rice seed, particularly where one firm had a national monopoly. Isolated, low-income farmers often lack redress if a distant source supplies, say, dormant seeds, or all-male day-old chicks. Meanwhile, for most African farmers innovations with regard to varieties or inputs remain inaccessible, unaffordable, risky or otherwise unsuitable. Input costs are raised by poor rural infrastructure, low population densities in areas of lower potential, dispersed residence patterns or sparse trading networks.

Appropriate policy and institutions for better market performance vary with local conditions. In Malawi, state-subsidized farm inputs were reorganized in 2005 to reach target beneficiaries and minimize leakage while stimulating private provision of inputs and credit. In Kenya, from the mid-1990s, the liberalization of the fertilizer market as well as increased state investment in market infrastructure (rural transport) led to increased supplier competition, smaller margins on fertilizers leading to lower costs for farmers, and denser input distribution networks. This increased fertilizer use, maize productivity and maize consumption. However, such reforms, and their impacts, are fragile: in 2008–09 political violence, drought and soaring world fertilizer prices threatened this success story. Political stability and further public investment (ports, rail maintenance) are needed to sustain input distribution margins and contain price increases.

Governments can sometimes work with seed companies to improve smallholder access to improved seed. The slow diffusion of NERICA rice (released in 2000) contrasts with the rapid uptake of a rust-resistant millet hybrid (HHB67) which was released in southern India in 2007 and aggressively marketed by seed companies from the outset. The small size of African markets hampers seed companies;

⁴ These are systems where agricultural extension workers and researchers themselves have done tests or have seen reliable tests, and can successfully communicate information to farmers.

regionally harmonized seed regulation would enable them to market seeds approved for several countries. India also benefits from a denser rural infrastructure than most of Africa. In Kenya, where the main maize surplus areas have a relatively good infrastructure, big seed companies have been involved since 2007 in spreading a striga-resistant hybrid.⁵ This response to a tough, largely African problem involved international and national research stations, local seed companies, NGOs and farmers. That is less likely where growing conditions or market access are less favourable: in these areas, initial effort must be largely made by the public sector.

Kick-starting or supplementing input delivery often requires public action beyond road-building. The difficulties of the poor in obtaining credit and taking risks suggest state-managed support for market-based distribution of new, yield-enhancing farm inputs, as in Malawi, where subsidized fertilizer and maize-seed vouchers by 2007 were worth a total of \$60 million. Partly as a result, Malawi went from food deficit to a 1.3m-ton surplus in 2006–07. One warning for Africa from Asia's Green Revolution is that such policies, even good ones, can become path-dependent. Fertilizer and irrigation subsidies speeded India's Green Revolution, but created a powerful farmer-supplier lobby. Subsidies now induce overuse of water and agrochemicals, and divert state funds from needed investment (e.g. in irrigation maintenance).

Linking technical advice to seasonal credit through private crop traders – if corruption and local monopoly are avoided – has good prospects. But this is less the case in low-income, high-risk farm areas, where higher crop yields may require *prior* improved land and water management practices. For small farms, this usually requires the public sector to disseminate knowledge, and to improve seeds and roads to market, so that using such knowledge pays dividends.

Since 2000, several countries have reported the failure of local markets to clear bumper harvests resulting from better planting materials and weather. In 2001–02, the combination of good weather and high levels of adoption of improved seed and fertilizer among Ethiopia's maize

farmers led to a bumper harvest. This was followed by an 80% drop in the maize price: 300,000 tonnes of grain rotted in farmers' fields. In Nigeria, improved cassava yields from new high-yielding planting material led to market gluts and a decline in uptake. Promising public-sector initiatives to absorb such surpluses include the UN World Food Programme's 'Purchase for Progress', linking food distribution to local procurement from surplus areas, and (despite failures in Asia) CAADP's experiments with local food sourcing for schools. Farmers' service cooperatives can bulk up produce, cutting the transport and storage costs of market access. However, cooperatives do better if most members are literate, and bigger service cooperatives usually perform worse: small-group cohesiveness and oversight outweigh economies of scale.

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Risk impedes innovation and cash-cropping. Can insurance or micro-finance help? In much of sub-Saharan Africa, climatic risk and high monitoring costs mean that it is usually prohibitively expensive to provide formal insurance to smallholders. There is scope for local pilot schemes learning from India's Comprehensive Crop Insurance Scheme, whereby payouts for key crops are triggered by local rainfall failure (which is carefully measured). As for finance, despite local examples of good uptake and repay-

⁵ Striga, a parasitic plant, affects 3.6 million hectares in Kenya and can lead to yield losses of over 30%. It is difficult to control, especially on poor soils.

ment, few small-scale farmers have formal credit. Even a specialized rural development bank (in Uganda) and a land bank (in South Africa) found loans to smallholders too challenging. However, there are alternatives to formal credit and insurance. Informal rotating savings and loan institutions can undertake some farm finance, as in Ghana and Kenya, but are less adapted to financing seasonal inputs (when all members need credit at the same time). Improved inputs can also be divided into smaller packages (cutting risk and price): such repackaging is characteristic of both Kenya's liberalized fertilizer market and Malawi's seed-fertilizer subsidies.

Institutional change: land rights

What is a 'good' farm size and land distribution in low-income economies? How does land access affect the prospects for a green revolution?

Efficiency, equity and farm size

In developing economies, small and large farms face strikingly different costs for labour and capital. Small farms using mainly family labour have lower labour recruitment and supervision costs. Larger farms face lower costs in borrowing, buying and operating equipment (tractors, tubewells, etc.). In low-income, labour-abundant economies, where capital is scarce, there is an efficiency case for supporting small-scale farms, since they use this large available labour resource intensively. They also tend to manage other resources more intensively: management time has a low opportunity cost, smaller areas are easier to oversee, and farmers often know their hired workers; meanwhile family labour is better motivated and needs less oversight. Small farms' low labour costs in slack seasons also often increase investment in types of farm capital that can be constructed and managed labour-intensively (terracing, storage, etc.). Consequently there is an *inverse relationship* in developing economies between farm area and both labour per hectare and output per hectare.

The efficiency and equity advantages of small family farms suggest a win-win case for land reform, especially where land is very unequal. However, new technologies entail costs and start-up risks. Are small farms badly placed

to incur these? There is evidence, including from Asia's Green Revolution, that they come to use yield-enhancing inputs and practices – if profitable and accessible – *more* intensively and successfully than large farms. Medium-scale farmers are often pioneers in innovation, because they get more agricultural research and farm support, and can more readily carry risk and access credit. Yet a uniformly small farm sector supported by an appropriate infrastructure – as in post-war Japan, South Korea and Taiwan, and in the 1980s in China and parts of South Asia and Indonesia – can achieve rapid diffusion of innovative technologies and high land productivity. In Africa too, small-scale farmers have innovated over large areas, as with cocoa in Ghana, cotton and coffee in Uganda, high-value horticulture in Eastern Africa, and irrigated farming in Iringa (Tanzania), Mwea (Kenya) and the Niger basin.

Despite these advantages for small farms, there is concern for their post-harvest prospects. Yet recent evidence (e.g. in China, Indonesia and Kenya) shows that such farms can match the economies of scale of large farms in storage, transport and processing, and can competitively supply domestic supermarkets and export outlets. Such supply usually requires intermediation between small farms and large buyers for processing, bulking up or supervision of grades and standards. Such intermediation can be successfully supplied by buyers themselves, large farms, specialist processing firms or groups of small farmers. This last has sometimes worked well, but difficulties in group organization mean that sometimes large farms are better at guaranteeing regular throughput, especially for new products. This may enable them to pioneer innovations, especially for export. For cash-crops, measures used in Africa to combine the labour-cost advantages of small family farms with the post-harvest advantages of some large units include tenancy, contract farming and 'outgrower' schemes (in which core large farms and surrounding small farms deliver to a single processor). However, there is little evidence that small farms need such links to market surplus food staples.

Recent large-scale farmland acquisitions

There has been a recent acceleration in large-scale acquisitions of land in Africa, usually by foreign investors, but

many of these large holdings do not catalyse the development of small farms. In Ethiopia, Ghana, Madagascar and Mali, allocations totalling some 2 million hectares in plots of over 1,000 ha have been approved since 2004. This is a small proportion of land, but high-potential land is targeted, most of it previously used or claimed. So far there has been little development of the transferred land. As in Tanzania and Mozambique, action to safeguard, or even consult, local interests has been scanty. Acquisitions were facilitated by host governments through bilateral investment treaties, revised investment codes, and ‘one-stop-shops’ to help investors negotiate local regulations.

Owing to widespread tenure insecurity and limited records of land rights, local livelihoods are often undermined by such acquisitions. Little good potential land remains truly unclaimed, and investors acquire land informally claimed by small-scale farmers. Laws to protect local rights have been undermined when they are perceived to hinder foreign investment: Mozambique’s 1997 Land Act was intended to protect community land rights, but interpretative practice and a 2007 amendment weakened such protection. Transparency is often lacking in contract negotiations, and there is little external scrutiny. Since land registration is often inaccessible to local users, compensation has been confined to land improvements, with none for loss of basic land rights. Most African economies also lack robust mechanisms to enforce compliance with investment commitments made by buyers.

Given the rising global demand for food and biofuels, demand for land by large-scale investors will continue. But such investments can be structured so that the value is shared with smallholders. Institutional options include tenancy, contract farming, joint ventures, community leases and management contracts. All exist in Africa and elsewhere. The criteria for commitment to value-sharing in projects proposed by purchasers include:

- distribution of ownership of key assets (e.g. land, processing facilities);
- voice (who takes/influences business decisions);

- risk (how supply, production, market and other risks are shared); and
- reward (how costs and benefits are shared).

Possible actions to make outsider investment in land development more likely to benefit local small farmers include:

- development by potential investors of business models to share value added with local producers;
- closer scrutiny of investment proposals by host governments;
- negotiation and enforcement of deals that maximize local benefits;
- scrutiny of contract negotiations by civil society; and
- action by local farmers and NGOs to protect local land rights and achieve better deals.

An international code of conduct for investment in land (similar to the Minerals Transparency Initiative) has also been proposed.

Land reform

Improved design of large-scale land investment does not address the already very unequal land distribution in parts of Africa, often the legacy of colonization and European settlement. Such inequality, alongside high under-employment, harms the poor, reduces farm output and probably lowers GDP growth.

Land reform is ‘legislation intended and likely to directly redistribute ownership of, claims on, or rights to farmland – and thus to benefit the poor by raising their absolute and relative status, power, and income, compared to likely situations without the legislation’.⁶ Such reform can contribute to ensuring that a green revolution will not only raise land productivity but cut poverty.

Redistribution of rights from large farms (private, state or collective) to small-scale farmers, and sometimes to the landless, normally meets this definition of land reform, because it is *incentive-compatible* whereas other putative land reforms often are not (‘avoidance’ – measures such as

⁶ Michael Lipton, *Land Reform in Developing Countries: Property Rights and Property Wrongs* (London: Routledge, 2009).

selling or renting by large-scale farmers to avoid ceilings imposed on landholdings – also tends to get land to smaller-scale farmers). Collectivization harms the poor because it encourages remote management, provides incentives to the state to extract surpluses, and (usually) leads to farms that are over-large. Although some types of tenancy reform and *de*-collectivization strengthen the land rights of the poor, others harm the poor. Restricting leasing may reduce their access to land. *De*-collectivizing into large holdings tends to leave land in mechanized units with low employment levels. These reforms are anyway less relevant in Africa than redistribution of ownership rights. However, in Africa as elsewhere, collectivist and large-farm biases (including the assumptions that large farms are more efficient, that increased mechanization is good even where labour is abundant, and that land should not be subdivided even where ownership is) can and do derail land reform.

‘As for infrastructure, Africa’s agricultural renaissance requires more, better and more diversified transport, storage and crop-processing capacity. Thin transport networks raise the cost of accessing farm inputs’

Since 1970, the proportion of farmland cultivated in smaller farms has risen (and typical farm size has fallen) in almost all developing countries with comparable data. This is not simply because of subdivision at inheritance: such farms would be combined, unless smaller farms were preferred to larger ones. However, small-farm advantage, based largely on lower labour costs and more effective labour supervision, dwindles during the later stages of development. Employment and wage rates rise, and financial and physical capital become increasingly attractive as a substitute for labour. The cost advantage of small family farms in labour transactions is gradually eroded by that of large farms in capital transactions. Governments that

promote small-scale farming need to adjust as larger farms become appropriate, but this is far in the future for most of Africa.

Should African governments formalize titles for those farmers – the majority – who hold land under customary tenure? Recent initiatives have demonstrated scope for land adjudication costs to be significantly lowered, but better organizational arrangements and institutions are needed to maintain land registers. However, simply formalizing the status quo may ‘freeze’ the inequities of customary law, which often subordinates women’s rights. Though frequently the main food producers, women often depend on male kin for tenure of and access to the land that they cultivate, and have no veto over its sale, lease, loan or mortgage. Formal veto rights may increase women’s security as farmers, and formal recognition and registration of women’s rights to own land, and to transact in the land market, could also enhance their role as farm entrepreneurs. In any case, issue of title deeds does not substitute for redistribution to poor farm households.

Research and development and physical infrastructure

Farm innovation – the adoption by farmers of earlier inventions, such as new seeds, improved plant varieties or fertilizers, that raise profit or reduce risk – is the main driver of agricultural growth. Institutional change can induce farm innovation only alongside (a) a process to invent, adapt and deliver locally appropriate farm techniques, and to maintain their usefulness against new threats (such as plant diseases affecting improved plant varieties); and (b) adequate physical infrastructure to deliver techniques and inputs and to market outputs. Innovation requires an effective, reliably resourced research and development (R&D) programme, involving international and national research agencies, and taking into account the programmes of relevant multinationals. Planners and implementers of research – from breeding methodology to species and varietal trials and regional sub-station testing of farm management practices – should consult farmers; local trials need to be designed partly in response to farmers’ priorities, and the results fed both to national centres and to farmers themselves. Farmers’ groups can also participate in the final testing of innovations before release.

As for infrastructure, Africa's agricultural renaissance requires more, better and more diversified transport, storage and crop-processing capacity. Thin transport networks raise the cost of accessing farm inputs. Inadequate local storage and processing capacity, plus high transport costs, lower the returns to farmers from food surpluses, reducing incentives to innovate. R&D for small- to medium-scale crop processing can cut unsold surpluses, lower transport costs and increase product storability. Kenya's Rural Feeder Roads Programme illustrates how local labour and hand-held tools can improve the construction and maintenance of rural transport infrastructure, thereby limiting budgetary pressures; but the main rural transport arteries often require central government to increase resource commitments, especially in more remote areas.

Conclusion

The last 50 years have seen much slower development of agriculture in Africa than in Asia or Latin America. Slow output growth has been accompanied by soil loss and tighter constraints on water availability. Output per head has fallen; food imports have risen. Yet there have been crop-breeding successes, and instances of significantly increased yields in response to fertilizer use, successful irrigation management and institutional reform. Modern plant breeding, including biotechnology, can help raise crop yields but should be complemented by better physical and institutional infrastructure and increased emphasis on water and soil management, to enhance yields sustainably while reducing farmers' exposure to climatically generated risk.

If the food supply shortfall is to be eliminated, a pragmatic approach is required to identify and diffuse viable yield-enhancing innovations for the diverse agro-ecolo-

gies of sub-Saharan Africa. Key components of such an approach include:

- investments to reduce erosion, restore land fertility, irrigate and drain as appropriate, and control and harvest water;
- research on appropriate yield-increasing technologies, including varieties for both well-watered and semi-arid rain-fed environments;
- rigorous estimation of returns in farmers' fields to LEI/OF methods;
- use of smart subsidies, small-scale credit and extension to kick-start new inputs and methods;
- infrastructure investments to improve market access and cut costs; and liberalization of input markets where input use has become established;
- protection and promotion of smallholder land rights, by appropriate conditions on land acquisitions, and sometimes by land reform.

Widespread development and poverty reduction in Africa normally require much faster, and more widely shared, agricultural growth than countries have achieved since independence. This can be achieved by strengthening the knowledge, institutions and infrastructure to support scientific farming, mainly by smallholders. African governments, and civil-society organizations, increasingly recognize this verbally, and in many cases in their actions. At a minimum, governments need to progress towards the CAADP target of a 10% budget commitment to agriculture, and to complete their national contributions to CAADP's associated regional investment plans, as Rwanda has done. Donors should translate their pledges at the G8 summit in L'Aquila in 2009 into cash for African governments that commit significant, sustained resources to agriculture and food security.

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Registered charity no: 208223

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