Enabling infrastructure (public utilities, public works, transportation, and research facilities) is essential for agricultural development. Infrastructure is defined here as facilities, structures, associated equipment, services, and institutional arrangements that facilitate the flow of agricultural goods, services, and ideas. Infrastructure represents a foundational base for applying technical knowledge in sustainable development and relies heavily on civil engineering. This chapter outlines the importance of providing an enabling infrastructure for agricultural development. Modern infrastructure facilities will need to reflect the growing concern over climate change. In this respect, the chapter will focus on ways to design “smart infrastructure” that takes advantage of advances in the engineering sciences as well as ecologically sound systems design. Unlike other regions of the world, Africa’s poor infrastructure represents a unique opportunity to adopt new approaches in the design and implementation of infrastructure facilities.

Infrastructure and Development

Poor infrastructure and inadequate infrastructure services are among the major factors that hinder Africa’s sustainable
development. This view has led to new infrastructure development approaches. Without adequate infrastructure, African countries will not be able to harness the power of science and innovation to meet sustainable development objectives and be competitive in international markets. Roads, for example, are critical for supporting rural development. Emerging evidence suggests that in some cases low-quality roads have a more significant impact on economic development than high-quality roads. In addition, all significant scientific and technical efforts require reliable electric power and efficient logistical networks. In the manufacturing and retail sectors, efficient transportation and logistical networks allow firms to adopt process and organizational innovations, such as the just-in-time approach to supply chain management.

Infrastructure promotes agricultural trade and helps integrate economies into world markets. It is also fundamental to human development, including the delivery of health and education services. Infrastructure investments further represent untapped potential for the creation of productive employment. For example, it has been suggested that increasing the stock of infrastructure by 1% in an emerging country context could add 1% to the level of GDP. But in some cases the impact has been far greater: the Mozal aluminum smelter investment in Mozambique not only doubled the country’s exports and added 7% to its GDP, but it also created new jobs and skills in local firms.

Reducing public investment in infrastructure has been shown to affect agricultural productivity. In the Philippines, for example, reduction in investment in rural infrastructure led to reductions in agricultural productivity. This decline in investment was caused by cutbacks in agricultural investments writ large, as well as by a shift in focus from rural infrastructure and agricultural research to agrarian reform, environment, and natural resource management. Growth in Philippine agriculture in the 1970s was linked to increased investments in
infrastructure, just as declines in the same sector in the 1980s were linked to reduced infrastructure investment (caused by a sustained debt crisis).

Evidence from Uganda suggests that public investment in infrastructure-related projects has contributed significantly to rural development. Uganda’s main exports are coffee and cotton; hence, the country depends heavily on its agricultural economy. Political and economic turmoil in the 1970s and 1980s in Uganda led to the collapse of the economy and agricultural output. Reforms in the late 1980s allowed Uganda to improve its economic growth and income distribution. In spite of economic growth ranging between 5% and 7%, the growth of the agricultural sector has been very low, averaging 1.35% per annum. Even if the Ugandan government has made great strides in welfare improvement, the rural areas still remain relatively poor. In addition, due to the disparity between male and female wages in agriculture, women are more affected by poverty than men.

The Ugandan government has been spending on a wide variety of sectors including agriculture, research and development, roads, education, and health (data in other sectors such as irrigation, telecommunications, and electricity are limited). Previous studies have mostly measured the effectiveness of government spending based on budget implementation.

Government spending on agricultural research and extension improved agricultural production substantially in Uganda. Growth in agricultural labor productivity, rural wages, and nonfarm employment have emerged as important factors in determining rural poverty, so much so that the public expenditure on agriculture outweighs the education and health effect. Investment in agriculture has been shown to increase food production and reduce poverty. Roads linking rural areas to markets also serve to improve agricultural productivity and increase nonfarm employment opportunities and rural wages.
Having a high HIV/AIDS prevalence, a large share of Uganda’s health expenditure goes toward prevention and treatment. Despite the high expenditure in health services, there does not seem to be a high correlation between health expenditure and welfare improvement.

**Infrastructure and Agricultural Development**

**Transportation**

Reliable transportation is absolutely critical for growth and innovation in African agriculture and agribusiness. Sufficient roads, rail, seaports, and airports are essential for regional trade, international exports, and the cross-border investments that make both possible. Innovation in other areas of agriculture such as improved genetic material, better access to capital, and best farming practices will produce results only if farmers and companies have a way to get their products to market and get critical inputs to farms.

Transportation is a key link for food security and agribusiness-based economic growth. Roads are the most obvious and critical element, but modern seaports, airports, and rail networks are also important, particularly for export-led agricultural innovation such as cut flowers or green beans in Kenya, neither of which would be possible without an international airport in Nairobi. To that end, many African countries have reprioritized infrastructure as a key element in their agricultural development strategies. This section will examine the role roads have played in China’s rural development and poverty alleviation, as well as two cases in African transportation investment: Ghana’s rural roads project and Mali’s Bamako-Sénou airport improvement project.

Ghana’s Rural Roads Project “is expected to open new economic opportunities for rural households by lowering transportation costs (including travel times) for both individuals
and cargo to markets and social service delivery points.” The project will include new construction, as well as the “improvement of over 950 kilometers of feeder roads, which, along with the trunk roads, will benefit a total population of more than 120,000 farming households with over 600,000 members. These activities will increase annual farm incomes from cultivation by US$450 to about US$1,000. For many of the poor, the program will represent an increase of one dollar or more in average income per person per day.” In addition to sparking growth in agriculture, the feeder roads will also help “facilitate transportation linkages from rural areas to social service networks (including, for instance, hospitals, clinics, and schools).”

The Airport Improvement Project will expand Mali’s access to markets and trade through improvements in the transportation infrastructure at the airport, as well as better management of the national air transport system. However, Mali is landlocked and heavily dependent on inadequate rail and road networks and port facilities in countries whose recent instability has cost Mali dearly. Before the outbreak of the Ivorian crisis, 70% of Malian exports were leaving via the port of Abidjan. In 2003, this amount dwindled to less than 18%. Mali cannot control overland routes to international and regional markets. Therefore, air traffic has become Mali’s lifeline for transportation of both passengers and export products.

Malian exports are predominantly agriculture based and depend on rural small-scale producers, who will benefit from increased exports in high-value products such as mangoes, green beans, and gum arabic. The Airport Improvement Project is intended to remove constraints to air traffic growth and increase the airport’s efficiency in both passenger and freight handling through airside and landside infrastructure improvements, as well as the establishment of appropriate institutional mechanisms to ensure effective management, security, operation, and maintenance of the airport facilities over the long term.
In response to requirements for safety and security audits by the International Civil Aviation Organization and the United States Federation Aviation Administration, Mali is in the process of restructuring and consolidating its civil aviation institutional framework. One major result has been the establishment of the new civil aviation regulatory and oversight agency in December 2005, which now has financial and administrative independence. The Airport Improvement Project will reinforce the agency by providing technical assistance to establish a new organizational structure, administrative and financial procedures, staffing and training, and provision of equipment and facilities. Additionally, the project will rationalize and reinforce the airport’s management and operations agency by providing technical assistance to establish a model for the management of the airport and the long-term future status and organization of agency.

“Since 1985 the government of China has given high priority to road development, particularly the construction of high-quality roads such as highways” and freeways. While the construction of high-quality roads has taken place at a remarkably rapid pace, the construction of lower-quality and mostly rural roads has been slower. Benefit-cost ratios for lower-quality roads (mostly rural) are about four times larger than those for high-quality roads when the benefits are measured in terms of national GDP.\(^7\)

In terms of welfare improvement, for every yuan invested, lower-quality roads raised far more rural and urban poor people above the poverty line than did high-quality roads. Without these essential public goods, efficient markets, adequate health care, a diversified rural economy, and sustainable economic growth will remain elusive. Effective development strategies require good infrastructure as their backbone. The enormous benefit of rural roads in China likely holds true for other countries as well. Investment in rural roads should be a top priority for reducing poverty,
maximizing the positive effects of other pro-poor investments, and fostering broadly distributed economic growth. Although highways remain critical, lower-cost, often lower-quality rural feeder roads are of equal and in some cases even greater importance.

“As far as agricultural GDP is concerned, in today’s China additional investment in high-quality roads no longer has a statistically significant impact while low-quality roads are not only significant but also generate 1.57 yuan of agricultural GDP for every yuan invested. Investment in low-quality roads also generates high returns in rural nonfarm GDP. Every yuan invested in low-quality roads yields more than 5 yuan of rural nonfarm GDP.” 8 Low-quality roads also raise more poor people out of poverty per yuan invested than high-quality roads, making them a win–win strategy for growth in agriculture and poverty alleviation. In Africa, governments can learn from the Chinese experience and make sure their road programs give adequate priority to lower-quality and rural feeder roads.

Irrigation

Investment in water management is a crucial element of successful agricultural development and can be broken into two principal areas: policy and institutional reforms on the one hand and investment, technology, and management practices on the other. Water is also a critical input beyond agriculture, and successful irrigation policies and programs must take into account the key role of water in energy production, public health, and transportation. For small farmers, low-cost technology is available, and there are cost-efficient technical solutions in even some of Africa’s most difficult and arid regions. Despite the availability of these technologies, Africa has not seen widespread adoption of these techniques and technologies. Part of the problem is the availability of finance and the slow spread
of knowledge, but equally important is the role of government regulations and subsidies.

Successful strategies for improved water management and irrigation must therefore not only focus on new technologies but also on creating policies and regulations that encourage investment in irrigation, not just at the farm but also at the regional level. Access to reliable water supplies has proven a key determinant not just in the enhancement of food security but also in farmers’ ability to climb higher up the value chain toward cash crops and processed foods. Innovative farmers involved in profitable agro-export may represent a new constituency for the stewardship of water resources, as they earn significantly higher incomes per unit of water than conventional irrigators. Our analysis will focus first on innovation in water management practices, technology, and infrastructure (including examples from Mali, Egypt, and India). In the final section of this chapter, we will also address key water policy and institutional reforms necessary to create an environment in which governments, international institutions, NGOs, and private businesses will be encouraged to make investments in irrigation infrastructure.

Begun in 2007, the Alatona Irrigation Project will provide a catalyst for the transformation and commercialization of family farms, supporting Mali’s national development strategy objectives to increase the contribution of the rural sector to economic growth and help achieve national food security. Specifically, it will increase production and productivity, improve land tenure security, modernize irrigated production systems and mitigate the uncertainty from subsistence rain-fed agriculture, thereby increasing farmers’ incomes. The Alatona Irrigation Project will introduce innovative agricultural, land tenure, credit, and water management practices, as well as policy and organizational reforms aimed at realizing the Office du Niger’s potential to serve as an engine of rural growth for Mali. This project seeks to develop 16,000 hectares of newly irrigated lands in the
Alatona production zone of the Office du Niger, representing an almost 20% increase of “drought-proof” cropland.

“Egypt depends almost entirely on 55.5 billion cubic meters per year of water from the Nile River. This allocation represents 95% of the available resource for the country. Approximately 85% of the Nile water is used for irrigation. Demand for water is growing while the options for increasing supply are limited. To respond, the Ministry of Water Resources and Irrigation (MWRI) has been implementing an Integrated Water Resource Management (IWRM) Action Plan. Its key strategy is to improve demand management. [The Integration Irrigation Improvement and Management Project (IIIMP), a part of MWRI, has been implementing the IWRM Action Plan.]

The IIIMP adopted a three-point strategy: (1) proper sizing of the improved infrastructure to optimize capital costs; (2) technical innovations to increase cost savings and functionality; and (3) extension of the improvement package to the whole system (including tertiary and on-farm improvements). . . . The IIIMP Project appraisal document envisaged (a) an average increase in farmers’ annual income of approximately 15%, (b) water savings of approximately 22%, and (c) an overall economic rate of 20.5%.” In the pilot areas where the program was implemented, “yields increased by 12% to 25%. Net incomes per cultivated acre are increasing by 20% to 64% as a result of the combined effects of increased productivity and reduction of the irrigation costs [depreciation and operations and maintenance of pumps].”

Sugarcane cultivation requires significant water resources, but in much of India it has been cultivated using surface irrigation, where water use efficiency is very low (35%–40%), owing to substantial evaporation and distribution losses. A recent study of sugarcane cultivation in Tamil Nadu, India, has shown that using drip irrigation techniques can increase productivity by approximately 54% (30 tons per acre) and cut water use by approximately 58% over flood irrigation. Unlike
surface methods of irrigation, under drip methods, water is supplied directly to the root zone of the crops through a network of pipes, a system that saves enormous amounts of water by reducing evaporation and distribution losses. Since water is supplied only at the root of the crops, weed problems are less severe and thus the cost required for weeding operations is reduced significantly. The system also requires little if any electricity.

Although new and larger studies are necessary, initial analysis suggests that investment in drip irrigation in Indian sugarcane cultivation is economically viable even without subsidy and may also be applicable in Africa where many farmers have no or limited access to electricity-powered irrigation, water resources are increasingly threatened by climate change and environmental degradation, and less than 4% of the arable land is currently irrigated.11

Further, the present net worth indicates that in many cases farmers can recover their entire capital cost of drip irrigation from first-year income without subsidy. Despite these gains, two impediments must be overcome for drip irrigation to be more widely used not just in India, but in much of the developing world. First, too few farmers are aware of the availability and benefits of drip irrigation systems, which should be demonstrated clearly and effectively through a quality extension network. Second, despite the quick returns realized by many farmers using drip irrigation, the systems require significant capital up front. Banks, microcredit institutions, companies, and governments will need to consider providing credit or subsidies for the purchase of drip irrigation.

The total cultivated land area of the Common Market for Eastern and Southern Africa (COMESA) amounts to some 71.36 million hectares. Of this only about 6.48 million hectares are irrigated, representing some 9% of the total cultivated land area. Besides available land area for irrigation, the region possesses enormous water resources and reservoir development
potential to allow for expansion. Of the world’s total of 467 million hectares of annualized irrigated land areas, Asia accounts for 79 percent (370 million hectares), followed by Europe (7%) and North America (7%). Three continents—South America (4%), Africa (2%), and Australia (1%)—have a very low proportion of global irrigation. COMESA could contribute significantly to agricultural food production and poverty alleviation through expanding the land under irrigated agriculture and water management under rain-fed farming to effect all year round crop and livestock production.

COMESA has recently made assessments through the Comprehensive Africa Agriculture Development Programme (CAADP) stocktaking reports involving some representative countries with respect to agriculture production options and concluded that regional economic growth and food security could be accelerated through investment in irrigation and agriculture water management. Agriculture water-managed rain-fed yields are similar to irrigated yields and always higher than rain-fed agriculture yields. This scenario builds a watertight case for promoting or expanding irrigated land in COMESA.

The best solution to poverty and hunger alleviation is to provide people with the means to earn income from the available resources they have. Small-scale irrigation development coupled with access to long-term financing, access to markets, and commercial farming expertise by producers will go a long way in achieving food security and overall economic development. COMESA has created an agency called the Alliance for Commodity Trade in Eastern and Southern Africa (ACTESA) to implement practical investment actions by engaging public private sector partnerships. In the areas of irrigation and agriculture water management, COMESA has begun to implement a number of important activities, described next.

Accelerated adoption of appropriate small-scale irrigation technologies and improved use and management of agriculture
water will facilitate increased agricultural production and family incomes. The rain-fed land area will require agriculture water management strategies such as conservation agriculture, which enhances production. Appropriate investment in field systems for irrigation with modest investments will help smallholder farmers adopt irrigation technology whereas the majority who practice rain-fed agriculture would improve agriculture productivity by managing rainwater through systems such as conservation agriculture technology. COMESA is embarking on reviewing the policy and legal framework in water resources management programs including trans-boundary shared water resources management policies under CAADP. This will include actions toward adaptation by member states of regional water resources management policies.

COMESA is working with regional and international organizations such as Improved Management of Agriculture Water in Eastern and Southern Africa (IMAWESA), East African Community (EAC), Southern African Development Coordination (SADC), Intergovernmental Authority for Development (IGAD), International Water Management Institute (IWMI), and Wetland Action-UK in creating awareness in regional sustainable water resources management by creating and strengthening water dialogue platform and communication strategies. Through ACTESA, COMESA will help develop regional water management information systems observation networks so as to enhance mapping for water harvesting resources and water utilization in COMESA.

To realize the benefits of irrigation and agriculture water management, COMESA is promoting investment in the following areas: reservoir construction for storage of water to command an expansion of land area under irrigation by 30% in five years; inland water resources management of watershed basins in the COMESA region including, policy and legal frameworks in trans-boundary shared water resources
management, harmonizing shared water resources policies to optimize utilization, strengthening regional institutions involved in water resources management, and establishment of a regional water resources management information system; building capacity and awareness for sustainable water resources utilization and management for agricultural food production; rapid expansion of terraces for hilly irrigation in some member states; and promotion and dissemination of appropriate irrigation and agriculture water management technology transfer and adoption. These include smallholder irrigation infrastructure.

Energy

To enhance agricultural development and to make progress in value-added agro-processing, Africa needs better and more consistent sources of energy. Rolling blackouts are routine in much of west, central, and eastern Africa, and much of Africa’s power generation and transmission infrastructure needs repair or replacement. What Africa lacks in adequate deployment, however, it makes up for in potential. Africa is endowed with hydro, oil, natural gas, solar, geothermal, coal and other resources vast enough to meet all its energy needs. Nuclear energy is also an option. The hydro potential of the Democratic Republic of the Congo is itself enough to provide three times as much power as Africa currently consumes.

The first step to improved power generation and transmission is to repair and upgrade Africa’s existing energy infrastructure. Many African countries are operating at less than half their installed potential due to inadequate maintenance and operation. Connecting rural areas to national grids can in some cases be cost prohibitive, so governments must also look for innovative solutions such as wind, solar, biomass, and geothermal to provide power at the small farm level. Finally, while countries will undoubtedly look first within their own
borders for resources, advanced energy planning should also consider that the most affordable and reliable power may be in neighboring states. Large power generation schemes may also require cooperative agreement on resource management and funding from a host of African and international sources. Cross-border energy networks could help create a common market for energy, spur investment and competition, and lead to a more efficient path of enhanced energy infrastructure.

An example of such a regional energy system is the West African Power Pool (WAPP). Under an agreement signed by 14 ECOWAS members in 2000, countries plan to “develop energy production facilities and interconnect their respective electricity grids. According to the agreement, the work would be approached in two phases . . . ECOWAS estimates that 5,600 kilometers of electricity lines connecting segments of national grids will be put in place. About US$11.8 billion will be needed for the necessary power lines and new generating plants. This infrastructure would give the ECOWAS subregion an installed capacity of 10,000 megawatts” and, critically for agro-processing and business investment, dramatically increase not just the amount but also the reliability of electricity in west Africa.12

“The key objectives of the WAPP are to establish a well-functioning, cooperative, power-pooling mechanism among national power utilities of ECOWAS member states, based on a transparent and harmonized legal, policy, regulatory, and commercial framework. This framework would promote cross-border exchange of electricity on a risk-free basis; assure national power utilities of mutual assistance to avoid a regional power system collapse, or rapid restoration of interconnected regional power; reduce collective vulnerability of ECOWAS member states to drought-induced power supply disruptions; [give] ECOWAS member states increased access to more stable and reliable supplies of electricity from lower-cost regional sources of (hydro and gas-fired thermal) power generation; and create clear and transparent pricing
arrangements for cross-border trade to facilitate electricity exchange and trade.”\(^ {13} \)

The WAPP organization has been created to integrate the national power system operations into a unified regional electricity market—with the expectation that such a mechanism would, over the medium to long term, assure the citizens of ECOWAS member states a stable and reliable electricity supply at affordable costs. This will create a level playing field facilitating the balanced development of the diverse energy resources of ECOWAS member states for their collective economic benefit, through long-term energy sector cooperation, unimpeded energy transit, and increased cross-border electricity trade. The major sources of electricity under the power pool would be hydroelectricity and gas to fuel thermal stations. Hydropower would be mainly generated on the Niger (Nigeria), Volta (Ghana), Bafing (Mali), and Bandama (Côte d’Ivoire) rivers. The World Bank has committed a $350-million line of credit for the development of the WAPP, but a billion more is needed in public and private financing.

Most of the power supply in Africa is provided by the public sector. There is growing interest in understanding the ability of independent power projects (IPPs) in Africa by evaluating a project’s ability to produce reliable and affordable power as well as reasonable returns on investment.\(^ {14} \) In the context of their individual markets the 40 IPPs under consideration here have played a complementary role to state-owned power projects, filling gaps in supply. It was also hoped that, once established, these private entities would introduce competition into the market.

Evidence suggests that there is a dichotomy between relatively successful IPPs situated mainly in the northern African nations of Egypt, Morocco, and Tunisia, and the sub-Saharan examples including Ghana, Kenya, Nigeria, and Tanzania, which have been less successful. A wide variety of country-level factors including investment climate, policy frameworks,
power sector planning, bidding processes, and fuel prices all impacted outcomes for these various IPPs. Despite their private nature, ultimately, it is the perceived balance of commitment between sponsors and host-country governments that plays one of the largest roles in the outcome of the IPP. A leading indicator of imbalance is frequent and substantial contract changes.

The presence of a favorable climate for investment influenced the outcome of the IPPs. In the more successful north African examples, Tunisia carried an investment grade rating, while Egypt and Morocco were both only one grade below investment grade. In contrast, of those nations located in sub-Saharan Africa, none received an investment grade rating. The great demand for IPPs in Africa at the time meant that those with superior investment profiles were able to attract more investors and had a basis for negotiating a more balanced contract.

Few of the nations in question have established a clear and coherent policy framework within which an IPP could sustainably operate. The soundest policy frameworks again are found in the north, with Egypt, which contains 15 IPPs, being the strongest. This policy framework features a clearly defined government agency in the Egyptian Electricity Authority, which has authority over the procurement of IPPs, the allocation of new generation capacity, and the ability to set benchmarks to increase competition among public facilities. Kenya set itself apart in this context with the establishment of an independent regulator—the Electricity Regulatory Board—which has helped to significantly reduce power purchase agreement charges, set tariffs, and mediate the working relationship between the public and private sectors. Evidence suggests that if a regulator is established prior to negotiation of the IPP, and acts in a transparent, fair, and accountable manner, this office can have a significantly positive effect on the outcomes for the host country and investor.
A coherent power sector plan follows from a strong policy framework and includes setting a reliability standard for energy security, supply and demand forecasts, a least-cost plan, and agreements on how new generation will be divided between public and private sectors. It is equally important that these functions are vested in one empowered agency. Failure to meet these goals is apparent in the examples of Tanzania (Songo Songo), Kenya (Westmont plant, Iberafrica plant), Nigeria (AES Barge), and Ghana, which fast-tracked IPPs to meet intermediate power shortages in the midst of drought conditions. The results were unnecessary costs and time delays for all, and in the case of the Nigerian and Ghanaian facilities, an inability to efficiently establish power purchase agreements.

The main lesson learned here is that without a strong legislative foundation and coherent planning, contracts were unlikely to remain intact. Instability of contracts was widespread across the cases studied, and though they did not necessarily deal a death blow to the project, renegotiations always came at a further cost.

**Telecommunications**

Access to timely weather, market, and farming best practices information is no less important for agricultural development than access to transport infrastructure, regular and efficient irrigation, and energy. In Africa, as in much of the developing world, innovations in telecoms offer the potential to bring real change directly to the farm level long before more timely and costly investment in fixed infrastructure. Mobile phone penetration rates now exceed those of landlines and the industry is growing at an average annual rate of over 50% in the region. Mobile phone ownership in Africa increased from 54 million in 2003 to nearly 500 million in 2010. The penetration rate is now over 50%. Ownership rates under-represent actual usage, however, as many small vendors offer mobile access for calls or text messages.
Even in rural areas, mobile penetration rates have now reached close to 42%. Mobile phones are becoming increasingly important tools in agricultural innovation, where they have been used to transfer and store money, check market prices and weather information, and even share farming best practices.

The case of India’s e-Choupal (*choupal* is Hindi for a gathering place) illustrates the increasingly important role telecommunications can play in African agricultural innovation. ITC is one of India’s leading private companies, with annual revenues of US$2 billion . . . The company has initiated an e-Choupal effort that places computers with Internet access in rural farming villages; the e-Choupals serve as both a social gathering place for exchange of information and an electronic commerce hub . . . The e-Choupal system has catalyzed rural transformation that is helping to alleviate rural isolation, create more transparency for farmers, and improve their productivity and incomes. The system has also created a highly profitable distribution and product design channel for ITC—an e-commerce platform that is also a low-cost fulfillment system focused on the needs of rural India.

A computer, typically housed in a farmer’s house, is linked to the Internet via phone lines or, increasingly, by a [satellite] connection, and serves an average of 600 farmers in 10 surrounding villages within about a five-kilometer radius. Each e-Choupal costs between US$3,000 and US$6,000 to set up and about US$100 per year to maintain. Using the system costs farmers nothing, but the host farmer, called a *sanchalak*, incurs some operating costs and is obligated by a public oath to serve the entire community; the *sanchalak* benefits from increased prestige and commissions for all e-Choupal transactions. The farmers can use the computer to access daily closing prices on local *mandi* [a government-sanctioned market area or yard where farmers sell their crops] as well as to track global price trends or find information about new farming techniques—either directly or, because many farmers are illiterate, via the *sanchalak*. 
Farmers also use the e-Choupal to order seed, fertilizer, and other goods from ITC or its partners, at prices lower than those available from village traders; the *sanchalak* typically aggregates the village demand for these products and transmits the order to an ITC representative. At harvest time, ITC offers to buy the crop directly from any farmer at the previous day’s closing price; the farmer then transports his crop to an ITC processing center where the crop is weighed electronically and assessed for quality. The farmer is then paid for the crop and a transport fee. “Bonus points,” which are exchangeable for products that ITC sells, are given for above-normal quality crops.

Farmers benefit from more accurate weighing, faster processing time, prompt payment, and access to information that helps them to decide when, where, and at what price to sell. The system is also a channel for soil testing services and for educational efforts to help farmers improve crop quality. The total benefit to farmers includes lower prices for inputs and other goods, higher yields, and a sense of empowerment. At the same time, ITC benefits from net procurement costs that are about 2.5% lower and more direct control over the quality of what it buys. The system also provides direct access to the farmer and to information about conditions on the ground, improving planning and building relationships that increase its security of supply. The company reports that it recovers its equipment costs from an e-Choupal in the first year of operation and that the venture as a whole is profitable.

By 2010 there were 6,500 e-Choupals serving more than 4 million farmers in nearly 40,000 villages spread over 10 states. ITC is also exploring partnering with banks to offer farmers access to credit, insurance, and other services that are not currently offered or are prohibitively expensive. Moreover, farmers are beginning to suggest—and in some cases, demand—that ITC supply new products or services or expand into additional crops, such as onions and potatoes. Thus, farmers are becoming a source of product innovation for ITC.
By providing a more transparent process and empowering local people as key nodes in the system, the e-Choupal system increases trust and fairness. Improved efficiencies and potential for better crop quality make Indian agriculture more competitive. Despite the undependable phone and electrical power infrastructure that sometimes limit hours of use, the system also links farmers and their families to the world. Some 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, games, and obtaining academic test results. The result is a significant step toward rural development.16

The availability of weather information systems for farmers is also emerging as a critical resource. Although advances in irrigation infrastructure and technology are lowering farmers’ dependency on weather, a second avenue to advance agricultural development is more accurate and more accessible weather information. To address the gap in accurate, timely, and accessible weather information in Africa, the Global Humanitarian Forum, Ericsson, World Meteorological Organization, Zain, and other mobile operators have developed a public-private partnership to (1) deploy up to 5,000 automatic weather stations in mobile network sites across Africa and (2) increase dissemination of weather information via mobile phones to users and communities—including remote farmers and fishermen.

Zain will host the weather equipment at mobile network sites being rolled out across Africa, as achieving the 5,000 target will require additional operator commitment and external financing. Mobile networks provide the necessary connectivity, power, and security to sustain the weather equipment. “Through its Mobile Innovation Center in Africa, Ericsson will also develop mobile applications to help communicate weather information developed by national meteorological and hydrological services . . . Mobile operators will maintain the automatic
weather stations and assist in the transmission of the data to national meteorological services. The initial deployment, already begun in Zain networks, focuses on the area around Lake Victoria in Kenya, Tanzania, and Uganda. The first 19 stations installed will double the weather monitoring capacity of the lake region.”

**Infrastructure and Innovation**

One of the most neglected aspects of infrastructure investments is their role in stimulating technological innovation. Development of infrastructure in a country is often not enough to create sustained economic growth and lifestyle convergence toward that of developed countries. Technology learning is very important to a country’s capacity to maintain current infrastructure and become competitive. In the first model of technology transfer, state-owned or privatized utility firms couple investment in public infrastructure with technological training programs, usually incorporated into a joint contract with international engineering firms. This type of capacity building lends itself to greater local participation in future infrastructure projects both in and out of the country.

The effectiveness of a comprehensive collaboration with foreign companies to facilitate both infrastructure building and technology transfer is seen in South Korea’s contract with the Franco-British Consortium Alstom. The Korean government hoped to develop a high-speed train network to link Seoul with Pusan and Mokpo. The importance of the infrastructure itself was undeniable—the Korean Train Express (KTX) was meant to cross the country, going through a swath of land responsible for two-thirds of Korea’s economic activity. In anticipation of the project, officials projected that by 2011, 120 million passengers would be using the KTX per year, leading to more balanced land development across South Korea.
However, while the project had the potential to increase economic activity and benefit the national industries in general, the project’s benefits lay significantly in the opportunity “to train its workforce, penetrate a new industrial sector, and potentially take the lead in the high-speed train market in Asia.” In other words, Korea sought to obtain new technologies and the capacity to maintain and operate them. Under the contract with Alstom, which was finalized after 20 years of discussion, Alstom provided both the high-speed trains and railways that would help connect Seoul and Pusan and the training to help South Korea build and maintain its own trains.

From the beginning of negotiations, technology transfer was an important factor for the South Korean government. In 1992, bidding between Alstom, Siemens (a German group), and Mitsubishi (a Japanese group) commenced. After the bids were significantly slashed, Korean officials let it be known that in addition to price, financial structures and technology transfers would be major criteria during the final selection. It was in this category that Alstom successfully outbid the other consortia and won the contract, which specified that half of all production would occur in Korea, with 34 of the trains to be built by Korean firms. This would give Korea both production revenue and the experience of building high-speed trains—with the goal of one day exporting them. The contract also stipulated that 100% of Alstom’s TGV (Train à Grande Vitesse) technology would be transferred to the 15 Korean companies that were to be involved in the project. Such technologies include industrial planning, design and development of production facilities, welding, manufacturing, assembly and testing carried out through operating and maintenance training, access to important documents and manuals for technical assistance, and maintenance supervision.

While the overall benefits of technology transfer are clear, more technologically advanced countries face some risks. One risk, known as the boomerang effect, affects the company that
is transferring the technology—Alstom in this case. By giving the technological knowledge to South Korean companies, Alstom runs the risk of essentially creating its own competitor. This risk is especially high in this case because Alstom has transferred 100% of its TGV technology and 50% of the production to Korea. Low labor costs, weak contractual constraints, and Korea’s known tendency to disregard intellectual property rights increase this risk. Other risks include unexpected shifts in economic conditions, currency devaluations, questionable competitive practices, hurried local production, lengthy and cumbersome administrative procedures, restrictive foreign payment rules, management weaknesses, and frail partnership involvement.

While these risks are indeed significant, they should not deter such agreements between countries. There are many ways to decrease such risks. For example, to make sure that payments are timely and that intellectual property rights are upheld, the company of interest should create a detailed contract with large penalties and disincentives for any violations.

Another step that should be taken is to maintain strong research and development projects to ensure that one’s technology will always be superior. A good way to avoid the boomerang effect is to establish long-term relationships, such as Alstom established with Korea. A similar method of preventing the boomerang effect is to establish partnerships with local manufacturers. Finally, Alstom took strides to collaborate with established competitors, like the formation of EUROTRAIN with Siemens, to increase penetration into new markets.

And despite the numerous risks, training and technology transfer did not result in a loss for Alstom, for benefits included numerous cash payments, dividends, and income from giving access to its technology, selling equipment parts, and establishing separate ventures with Korean companies. Additionally, the project gave the company the opportunity to show the
exportability of TGV to Asian markets. In particular, the reliability of Alstom’s products and procedures was demonstrated in the partnership, making other countries more likely to work with the company. Experience in the Korean market, competitive advantages with respect to European countries, and new business opportunities were other advantages that increased Alstom’s market share in Asia. Increased flexibility and experience with international markets as well as decentralized management also benefited Alstom. Finally, Alstom’s technology became the international standard, leading to enormous competitive advantages for that company.

To facilitate the transfer, development, and construction of the high-speed railway system, the Korean government created the Korean High-Speed Rail Construction Authority (KHRC), whose mandate was to construct such systems at home and abroad, to research and find ways to improve the technology, and to oversee commercialization along the railway line. Issues with the project were soon revealed; after two tragedies—the collapse of the Songsu Bridge and of a large store in Seoul—Korean officials began to doubt its civil engineering capabilities. For this reason, KHRC decided to hire foreign engineers. After project delays and other issues, the last section of railway track from Taegu to Pusan was canceled and the building of 34 trains was postponed. However, after renegotiations, construction recommenced.

Other issues show the difficulty of such a project collaboration. A rift developed between France and South Korea due to a withdrawn agreement between two companies. Further, the TGV was unable to function in Korea during an unusually cold winter in 1996–1997, drawing questions and critiques from the Korean press. An economic crisis, which caused an abrupt depreciation of the Korean won against the U.S. dollar, made the purchase of goods and services from foreigners more expensive. A final rift was created by the election of President Kim Dae Jung in 1997, who was a vocal opponent of the KTX
project. As seen here, exogenous interactions between the countries of interest can greatly affect the attempts to collaborate in technological transfer.

Despite the many risks of international technology transfer, the benefits far outweigh the costs. For example, by 2004, 100% of the TGV technology was transferred to Korea. Despite initial setbacks, ridership has increased greatly at the expense of other modes of transportation. More lines are expected to be built, and the success of the technology transfer has become apparent through the construction of the HSR-350x Korean-made train and the order of 19 KTX-II train sets in 2006 from Hyundai Rotem. It is claimed that these trains use 87% Korean technology. As for Alstom, their success is evident in the numerous contracts they have negotiated in the Asian markets.

In conclusion, the KTX project demonstrates how technology transfer can help developing countries to obtain advanced capabilities to build and develop infrastructure, leading to increased economic growth and productivity. The South Korean example serves as a model for African countries and applies to urban and rural projects alike. The lessons are particularly important considering the growing interest among African countries in investing in infrastructure projects.\textsuperscript{19} While African countries will face their own unique issues, the KTX project illustrates costs and benefits that should be weighed in making such decisions and provides hope for new methods of technological dissemination. The tendency, however, is to view infrastructure projects largely in terms of their returns on investment and overall cost structure.\textsuperscript{20} Their role in technological capacity building is rarely considered.\textsuperscript{21} The growing propensity to want to leave infrastructure investments to the private sector may perpetuate the exclusion of public interest activities such as technological learning.\textsuperscript{22}

One of the key aspects of the project was a decision by the government to set up the Korea Railroad Research Institute (KRRI). Founded in 1996, KRRI is the nation’s principal railway
research body. Its focus is improving the overall national railway system to maintain global competitiveness, with the goal of putting Korea among the top five leaders in railway technology. It works by bringing together experts from academia, industry, and government.

**Regional Considerations**

Roads, water facilities, airports, seaports, railways, telecommunications networks, and energy systems represent just a portion of the web of national and regional infrastructure necessary for food security, agricultural innovation, and agriculture-based economic development. Countries and regions must create comprehensive infrastructure investment strategies that recognize how each area is linked to the next, and investments must in many cases pool regional resources and cross numerous international borders. Transportation infrastructure is critical to move inputs to farms and products to market; widespread and efficient irrigation is essential for increasing yields and crop quality; energy is a vital input, particularly for value-added food processing; and telecoms are critical for the exchange of farming, market, and weather information. Alone, however, none of these investments will produce sustainable innovation or growth in agriculture. National and regional investment strategies will be needed to pool resources, share risks, and attract the private actors often critical to substantial investments in such ventures.

It seems obvious that roads would play a critical role in agricultural development, but they have often received inadequate investment. On-farm innovations are critical, but in many cases they depend on inputs that can only be delivered via roads, and they will be of very limited use if farmers have no way to reliably move their products to markets. Countries looking to improve their roads should carefully assess where their competitive advantages lie, identify which new or refurbished
roads would best capitalize on those advantages, ensure that roads are placed within a broader plan for transportation infrastructure, and develop pre-construction plans for long-term maintenance.

Large roads and highways have garnered the bulk of capital and attention in much of the developing world, but smaller, lower-quality rural feeder roads often have significantly higher returns on investment—particularly in areas where major highways already exist. Learning from the Chinese experience, countries should carefully assess the relative return between larger highways and smaller rural-feeder roads, selecting the better investment.

National water policy and programs are notoriously Balkanized into fractious agencies and interest groups, often with competing objectives. This is a problem that countries across the world face, as is evidenced by the small American town of Charlottesville, Virginia. Charlottesville has no less than 13 separate water authorities representing its roughly 50,000 residents. As we saw with the positive example of Egypt (a country with significant water resource pressures but a highly advanced water management system), an initial step to success is streamlining government regulation of water issues under a single national agency, or family of agencies. Water policy and programs should be coordinated at the national, not state, level, and must also look across borders to neighboring states as many key issues in water, including power generation, agricultural diversion, and water quality, are often closely linked to key issues up- or downstream.

Many African states already face water shortages, and the threat of global climate change may further stress those limited resources. Bringing new water assets online through large irrigation projects is important, but those resources are limited; more economical use of water is just as if not more important. Central to this goal are farming techniques that get “more dollar per drip.” As we saw earlier with the case of India, drip
irrigation can be one solution. To overcome the initial capital hurdle, governments, companies, and banks could consider subsidizing and/or providing loans for the purchase of initial equipment.

As with water, energy issues often transcend national borders. In many cases, the best location to produce or sell power may be outside a country’s borders. Regional cooperation will be essential for unlocking much of Africa’s energy generation potential, as many projects will require far more investment than any one country can provide and involve assets that must span multiple national borders. To pool national resources and entice private capital for major energy products, regional organizations will need to help create strong, binding agreements to provide the necessary confidence not only to their member states but also to private companies and investors. The ECOWAS-led Western African Power Pool (WAPP) provides a good model for replication, but it is also an indicator of the high level of commitment and private capital that must be raised to push through large, regional power agreements.

Large power generation and transmission schemes are critical to agricultural development but in some cases may prove too lengthy, costly, or difficult to have large, timely impacts in remote rural areas. One way to complement these larger energy programs is to make additional investment in remote rural energy generation at the local or even farm level. Renewable technologies including solar, wind, biogas, bioethanol, and geothermal can be scaled for farms and small business and have the added advantage of requiring minimal transmission infrastructure and often a low carbon footprint. To encourage this production, governments could consider replicating Tanzania’s Rural Energy Agency, which is funded by a small tax on sales from the national energy utility, as well as partnerships with NGOs, foundations, foreign governments, and businesses.
The transfer of knowledge is nearly as important to agricultural innovation as the transfer of physical inputs and farm outputs. Telecoms can play a unique role in the transfer of farming best practices as well as critical market and weather information. Most of Africa’s telecom infrastructure is owned by the private sector. As we have seen from cases in India, China, and Africa, private companies can play a key role in the development of telecoms as a tool for agricultural innovation. Governments and regional bodies should work with major telecom providers and agribusinesses to form innovative partnerships that provide profits to companies and concrete benefits such as enhanced farming knowledge transfer and market and weather information.

Mobile phone penetration rates are growing faster in Africa than anywhere in the world. Mobile phones and the cell tower networks on which they depend provide a unique platform for the collection and even more important the dissemination of key information, including farming best practices, market prices, and weather forecasts. To reach scale, Africa’s regional organizations should engage their member states, key telecom businesses, and NGOs to harness existing technologies such as SMS (and next generation technologies such as picture messaging and custom applications for mobiles) to provide farmers with access to key agricultural, market, and weather information.

Conclusion

Infrastructure investment is a critical aspect of stimulating innovation in agriculture. It is also one of the areas that can benefit from regional coordination. Indeed, the various REC’s in Africa are already increasing their efforts to rationalize and coordinate infrastructure investments. One of the lessons learned from other countries is the importance of linking infrastructure investment (especially in key areas such as
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transportation, energy, water, and telecommunications) to specific agricultural programs. It has been shown that low-quality roads connecting farming communities to markets could contribute significantly to rural development. An additional aspect of infrastructure investment is the need to use such facilities as foundations for technological innovation. One strategic way to achieve this goal is to link technical training institutions and universities to large-scale infrastructure projects. The theme of education, especially higher technical training, is the subject of the next chapter.

One of the most challenging aspects of investing in infrastructure is the high upfront costs. Making large investments ahead of demand creates a wide range of management and political risks. It is estimated that Africa will need nearly US$500 billion over the next decade to finance infrastructure projects. African countries will need to think creatively about how to secure the funding needed to support this level of investment. One option that remains unexplored is using the engineering and technical capacity in African militaries for infrastructure work in strategic areas such as transportation, irrigation, telecommunications, and energy. Countries such as Senegal have been mobilizing the military to contribute to infrastructure development and maintenance under clear management structures that do not open the door to political mischief. Uganda has been using the military for railway construction. These examples indicate the need to give careful consideration to the existing critical engineering capabilities of African militaries that can be harnessed to lay the foundations of economic security.