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AGRICULTURAL INNOVATION SYSTEMS

The use of emerging technology and indigenous knowledge to promote sustainable agriculture will require adjustments in existing institutions.[1] New approaches will need to be adopted to promote close interactions between government, business, farmers, academia, and civil society. The aim of this chapter is to identify novel agricultural innovation systems of relevance to Africa. It will examine the connections between agricultural innovation and wider economic policies. Agriculture is inherently a place-based activity and so the chapter will outline strategies that reflect local needs and characteristics. Positioning sustainable agriculture as a knowledge-intensive sector will require fundamental reforms in existing learning institutions, especially universities and research institutes. Most specifically, key functions such as research, teaching, extension, and commercialization need to be much more closely integrated.

The Concept of Innovation Systems

Agriculture is considered central to African economies, but it is treated like other sectors, each with their own distinctive institutions and with little regard for their relationship with the rest of the economy.[2] This view is reinforced by traditional approaches, which argue that economic transition occurs in stages that involve the transfer of capital from the agricultural to the industrial sector. Both the sector and stage approaches conceal important linkages between agriculture and other sectors of the economy.

A more realistic view is to treat economies as "systems of innovation." The process of technological innovation involves interactions among a wide range of actors in society, who form a system of mutually reinforcing learning activities. These interactions and the associated components constitute dynamic "innovation systems."[3] Innovation systems can be understood by determining what within the institutional mixture is local and what is external. Open systems are needed, in which new actors and institutions are constantly being created, changed, and adapted to suit the dynamics of scientific and technological creation.[4] The concept of a system offers a suitable framework for conveying the notion of parts, their interconnectedness, and their interaction, evolution over time, and emergence of novel structures. Within countries the innovation system can vary across localities. Local variations in innovation levels, technology adoption and diffusion, and the institutional mix are significant features of all countries.

An innovation system can be defined as a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance. The innovation systems concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. It extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways.[5]

Government, the private sector, universities, and research institutions are important parts of a larger system of knowledge and interactions that allows diverse actors with varied strengths to come together to pursue broad common goals in agricultural innovation. In many African countries, the state still plays a key role in directing productive activities. But the private sector is an increasingly important player in adapting existing knowledge and applying it to new areas.

The innovation systems concept is derived from direct observations of countries and sectors with strong records of innovation. It has been applied to agriculture in developing countries only recently, but it appears to offer exciting opportunities for understanding how a country's agricultural sector can make better use of new knowledge and for designing alternative interventions that go beyond research system investments.[6]

Systems-based approaches to innovation are not new in the agricultural development literature. The study of technological change in agriculture has always been concerned with systems, as illustrated by applications of the national agricultural research system (NARS) and the agricultural knowledge and information system (AKIS) approaches. However, the innovation systems literature is a major departure from the traditional studies of technological change that are often used in NARS- and AKIS-driven research.[7]

The NARS and AKIS approaches, for example, emphasize the role of public sector research, extension, and educational organizations in generating and disseminating new technologies. Interventions based on these approaches traditionally focused on investing in public organizations to improve the supply of new technologies. A shortcoming of this approach is that the main restriction on the use of technical information is not just supply or availability but also the limited ability of innovative agents to absorb it. Even though technical information may be freely accessible, innovating agents have to invest heavily to develop the ability to use the information.

While both the NARS and AKIS frameworks made critical contributions to the study of technological change in agriculture, they are now challenged by the changing and increasingly globalized context in which sub-Saharan African agriculture is evolving. There is need for a more flexible framework for studying innovation processes in developing-country agriculture—a framework that highlights the complex relationships between old and new actors, the nature of organizational learning processes, and the socioeconomic institutions that influence these relationships and processes.

The agricultural innovation system maps out the key actors and their interactions that enable farmers to obtain access to technologies. The "farm firm" is at the center of the agricultural innovation system framework, and the farmer as the innovator could be made less vulnerable to poverty when the system enables him to access returns from his innovative efforts. The agricultural innovation system framework presents a demand-driven approach to agricultural R&D. This transcends the perception of the role of public research institutions as technology producers and farmers as passive users by viewing the public laboratory-farmer relationships as an interactive process governed by several institutional players that determine the generation and use of agricultural innovation. There is opportunity for a participatory and multi-stakeholders approach to identifying issues for agricultural R&D, and agricultural technology could thus be developed with active farmers' participation and understanding of the application of new technologies. The agricultural innovation system approach as an institutional framework can be fostered depending on the institutional circumstances and historical background of the national agricultural development strategies.[8]

This brings us to the agricultural innovation system (AIS) framework. The AIS framework makes use of individual and collective absorptive capabilities to translate information and knowledge into a useful social or economic activity in agriculture. The framework requires an understanding of how individual and collective capabilities are strengthened, and how these capabilities are applied to agriculture. This suggests the need to focus far less on the supply of information and more on systemic practices and behaviors that affect organizational learning and change. The approach essentially unpacks systemic structures into processes as a means of strengthening their development and evolution.

Recent discussions of innovation capacity have argued that capacity development in many countries involves two sorts of tasks. The first is to create networks of scientific actors around research themes such as biotechnology and networks of rural actors around development themes such as dryland agriculture. The second is to build links between these networks so that research can be used in rural innovation. A tantalizing possibility is that interventions that unite research-led and community-based capacity could cost relatively little, add value to existing investments, meet the needs of the poor, and achieve very high returns.

Innovation Systems in Action

University-Industry Linkages

Trends in university-industry linkages (UILs) in Nigeria illustrate three ways in which university-industry collaboration has been experienced in the Nigerian agro-food processing sector. They are principal agent demand-driven, multi-stakeholder problem based, and arms-length consultancy. The examples of university-industry interactions in these three modes are regarded as glimpses of hope demonstrating that universities and firms in Nigeria can be made to work together to build capacity for innovation. However, while the first two modes have contributed to innovative outcomes involving the diffusion and commercialization of local R&D results, the third mode has not engendered innovation.[9]

The first mode of UIL identified as "principal agent demand-driven" is the UNAAB-Nestlé Soyabean Popularization and Production Project which has been a case of interaction between the University of Agriculture Abeokuta (UNAAB) and Nestlé Nigeria since 1999. In this case Nestlé employed UNAAB to help address its challenges in demand for soybeans. Due to its research and extension activities, UNAAB presumably has a knowledge advantage over Nestlé in the area of local sourcing of soybeans. Nestlé Nigeria employs about 1,800 people and soybeans are one of its major raw materials used especially for baby foods. The firm has been the only major external donor and industrial partner with UNAAB. It is thus plausible to consider the principal agent in this case of UIL as Nestlé, and the driver of the UIL as demand for soybeans.

The main objective of the UIL is to stimulate sustainable interest of farmers in soybean production with a view to increasing their capacity to produce seeds of industrial quality and consequently to improving their socioeconomic status. The three specific objectives of the project include ensuring that the soybean becomes acceptable and properly integrated into the existing farming systems in the south-western part of Nigeria; promoting massive production of high quality grains that would meet the needs and quality standards required by Nestlé Nigeria on a continuous basis; and improving the welfare of the farmers through the income that could be generated from soybean production.

The university-industrial linkage can be initially traced to an R&D partnership under a tripartite agreement for soybean breeding between UNAAB, the International Institute of Tropical Agriculture (IITA), Ibadan, and Nestlé Nigeria in the early 1990s. Nestlé Nigeria financed the soybean breeding project. The aim of the project was to obtain soybeans of high quality that fit Nestlé Nigeria's requirements and also to produce significantly improved yields. The research team achieved this objective with the breeding of Soya 1448–2E. This initial partnership ended in 1996.

Around 1999, Nestlé Nigeria came back to ask UNAAB if there could be ways of further partnership. UNAAB told Nestlé that the previous research collaboration had established that soybeans can also be grown in southwest Nigeria. UNAAB thus started a project with Nestlé Nigeria on popularization of soybeans in southwest Nigeria. Nestlé Nigeria had previously believed that soybeans can be grown only in northern Nigeria as it was thought that rain was damaging to soybeans just before harvest. Though this is generally true, UNAAB had demonstrated that soybeans could be profitably harvested in spite of the rains in the southwest.

There are a number of benefits for such university-industry linkages. Learning by interaction between UNAAB scientists and Nestlé Nigeria farm managers and farmers contributed significantly to building capacity for innovation especially at the farm level. It produced improved quality seeds and grains and a new process for growing soybeans. Nestlé Nigeria saved costs by finding alternative to the inefficient Nestlé Nigeria farms located in northern Nigeria and secured a regular supply of high-quality soybeans from farmers in the UIL. The system boosted UNAAB's extension activities resulting in the popularization of its model of soybean cultivation in southwest Nigeria, which in turn became an important soybean producing region. Overall, the linkages improved the livelihoods of the people in the region and enhanced technology adoption for soybean processing, especially threshing technology.

The second mode of UIL identified as "multi-stakeholder problem based" is the Cassava Flash Dryer Project. The project involved one large privately owned integrated farm (Godilogo Farm, Ltd.) that had an extensive cassava plantation and a cassava processing factory; three universities including the University of Agriculture, Abeokuta, the University of Ibadan, and the University of Port Harcourt; the IITA; and the Raw Material Research and Development Council (RMRDC).

Cassava is Africa's second most important food staple, after maize, in terms of calories consumed, and it is widely acknowledged as a crop that holds great promise for addressing the challenges of food security and welfare improvement. Nigeria is currently the world largest producer of cassava. The Presidential Initiative on Cassava Production and Export (PICPE) was officially launched in 2004. Under PICPE the government promotes the diversification of the economy through industrial processing of cassava to add value and achieve significant export of cassava products. Support for research on cassava processing and cassava products was a major aspect of PICPE. Through IITA, PICPE brought together cassava stakeholders to address the challenge of cassava production and industrial processing, which included the design and fabrication of a cassava flash dryer.

Though the principle of flash drying is well known in engineering theory and practice, the principle has so far not been applied in the design of engineering equipment used in processing indigenous agricultural crops in Nigeria. This design gap is perhaps because the engineering properties of most of the Nigerian crops are yet to be determined. The flash dryers available in the market are designed for agricultural products that are grown in industrialized countries that manufacture flash dryers. For example, flash dryers commonly used in Nigeria were originally designed for drying Irish potatoes or maize. They are usually modified with the help of foreign technical partners for use in cassava processing. Attempts to adapt foreign flash dryers have resulted in considerably low performance and frequent equipment breakdowns. This was the experience of Godilogo Farms, Ltd. that had used a flash dryer imported from Brazil, because the design was unable to handle the drying of cassava to required moisture or water content. It was not originally designed to handle cassava but temperate root crops such as Irish potatoes. Efforts by a Brazilian engineer invited from abroad to adapt the flash dryer to effectively process cassava failed.

The farm's cassava plantation could supply its cassava processing factory 250 days of cassava inputs. The farm also has an engineering workshop or factory for equipment maintenance and components fabrication.

The main objective of the cassava flash dryer project was to design and fabricate an efficient cassava flash dryer that can withstand the stress of the local operating environment. The frustration of Godilogo Farm with its imported flash dryer motivated the farm's management to support the cassava flash dryer project. After the farm management was convinced that the flash dryer research team constituted under the PICPE-IITA cassava processing research project had a feasible design, Godilogo Farm made available its engineering facilities and funds for building a cassava flash dryer in situ at the farm's cassava processing factory.

The new locally designed and fabricated cassava flash dryer can produce 250 kilograms of cassava flour per hour. The RMRDC funded the official commissioning of the new flash dryer at Godilogo Farms, Obudu, Cross Rivers State, on August 19, 2008. IITA and PICPE provided the initial funding under the IITA Integrated Cassava Project; the Root and Tuber Extension Program supported the design team's visit to collect data from existing flash drying centers; Godilogo paid for the fabrication of the plant and part sponsorship of the researchers' living costs; and RMRDC provided logistical support for several trips by the design team including sponsorship of the commissioning.

The main outcome of the UIL is the celebrated local design and fabrication of the first medium-sized cassava flash dryer in Nigeria. The technological learning generated was unprecedented in local fabrication of agro-food processing equipment, and there is evident improvement in capacity for innovation in agro-food processing. In the course of the project, there was interactive learning through experimentation by the research team. The impact of government policy through PICPE and government support for the project through RMRDC demonstrated the crucial role of government as a mediator or catalyst for UIL and innovation. Knowledge flows and user feedbacks also played important roles in the success of the university-industry linkage.

Wider Institutional Linkages

Understanding the network relationships and institutional mechanisms that affect the generation and use of innovation in the traditional sector is critical for enhancing the welfare of the poor and overall economic development. Nigeria's development policy emphasizes making agriculture and industrial production the engine of growth. In recent years the revitalization of the cocoa industry through the cocoa rebirth initiative launched in February 2005 has been a major focus of government.[10]

The program essentially aimed at generating awareness of the wealth creation potentials of cocoa, promoting increases in production and industrial processing, attracting youth into cocoa cultivation, and helping to raise funds for the development of the industry. By applying the analytical framework of the agricultural system of innovation it is easier to trace the process of value-addition in the cocoa agro-industrial system, examining the impact of the cocoa rebirth initiative and identifying the actors critical for strengthening the cocoa innovation system in Nigeria.

Cocoa production is a major agricultural activity in Nigeria; and R&D aimed at improving cocoa production and value-addition has long existed at the Cocoa Research Institute of Nigeria (CRIN) and notable faculties of agriculture in Nigerian universities and colleges of agriculture. However, while the export of raw cocoa beans has continued to thrive, innovation in cocoa production and the industrial processing of cocoa into intermediate and consumer products have been limited.

The cocoa innovation system in Nigeria is still relatively weak. There is a role for policy intervention in stimulating interaction among critical agents in this agricultural innovation system. In particular, linkages and interactions between four critical actors (individual cocoa farmers, cocoa processing firms, CRIN, and the National Cocoa Development Committee) in the cocoa rebirth program were identified as being responsible for the widespread adoption of CRIN's newly developed genetically improved cocoa seedlings capable of a yield exceeding 1.8 tonnes per hectare per year. This is in stark contrast to previous experiences of CRIN, which has been unable to commercialize many of its research findings. Periodic joint review of the activities of each of these actors and active participation in specific projects that are of common interest may further innovation especially in value-addition to cocoa beans.

The adoption and diffusion of improved cocoa seedlings under the cocoa rebirth initiative thrives on subsidies provided by government. While subsidies for agricultural production in a developing country such as Nigeria may not be discouraged, it is important to have a phased program of subsidy withdrawal on the cocoa seedlings program when it is certain that farmers have proven the viability and economic importance of the new variety. This should result in a market-driven diffusion that will be healthy for the sustainable growth of the cocoa industry.

Despite success with the diffusion of cocoa seedlings, the findings show that although export is a major concern of the cocoa processing firms, and this appeared to have led to close interactions of the firms with the National Export Promotion Council (NEPC), the export strategy has not been effectively linked with the cocoa rebirth initiative. In order to further encourage export by the cocoa processing firms, it would be good to integrate the NEPC export incentives into the cocoa rebirth initiative within the cocoa innovation system framework. Moreover, the NEPC should also adopt an innovation system approach to export strategy. This would essentially begin by emphasizing demonstrable innovative activities of firms as an important requirement for the firms to benefit from export incentives.

The involvement of the financial sector in the cocoa innovation system is identified as a main challenge. Though the financial sector is aware of the significance of innovation for a competitive economy, its response to the cocoa rebirth initiative has been slow due to perceived relatively low return on investments. It is suggested that the publicly owned Bank of Industry and the Central Bank of Nigeria (CBN) should provide leadership in investing in innovative new start-ups in cocoa processing and in carefully identified innovative ideas or projects in existing cocoa processing firms. This demonstration should be carried out in partnership with interested commercial banks with the CBN guaranteeing the banks' investment in the project. Once the banks are convinced that innovative initiatives in firms are able to provide satisfactory returns on investment, they should be open to investing in such projects.

Skills deficiency is a major constraint on the cocoa innovation system. The result suggests that skills development in the areas of cocoa farm management and the operation of modern cocoa processing machinery would be particularly useful in enhancing cocoa output and the performance of cocoa processing firms. In this respect, renewed efforts are needed by the educational and training institutions to improve on the quality and quantity of skills being produced for cocoa processing firms.

As part of the cocoa rebirth initiative, special training programs should be organized for skills upgrading and new skills development relevant to the cocoa industry. Another important constraint on the cocoa innovation system arises from the difficulty in implementing the demand-side aspects of the cocoa rebirth initiative, such as serving free cocoa beverages in primary schools and using cocoa-based beverages in government offices, practices that should stimulate innovative approaches to increased local processing of cocoa and manufacture of cocoa-based products.

Clusters as Local Innovation Systems

Theory, evidence, and practice confirm that clusters are important source of innovation.[11] Africa is placing considerable emphasis on the life sciences. There is growing evidence that innovation in the life sciences has a propensity to cluster around key institutions such as universities, hospitals, and venture capital firms.[12] This logic could be extended to thinking about other opportunities for clustering which include agricultural regions. Essentially, clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure.

Often clusters extend downstream to channels and customers and laterally to manufacturers of complementary products, as well as to companies in related industries either by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions—such as universities, standard-setting agencies, think tanks, vocational training providers, and trade associations—that provide specialized training, education, information, research, and technical support.[13] The co-evolution of all actors supports the development of dynamic innovation systems, which accelerate and increase the efficiency of knowledge transfer into products, services, and processes and promote growth. As clusters enable the flow of knowledge and information between enterprises and institutions through networking they form a dynamic self-teaching system and they speed up innovation. Local knowledge develops that responds to local needs—something that rivals find hard to imitate.

Although much of the recent literature on clusters focuses on small- to medium-sized high-tech enterprises in advanced industrial countries, a smaller school of literature has already begun expanding the study of clusters to include agricultural innovation. Clusters can and often do emerge anywhere that the correct resources and services exist. However, central to the idea of clusters is that positive "knowledge spillovers" are more likely to occur between groups and individuals that share spatial proximity, language, culture, and other key factors usually tied to geography.

Contrary to scholars who argue that the Internet and other information technologies have erased most barriers to knowledge transfer, proponents of cluster theory argue that geography continues to dominate knowledge development and transfer, and that governments seeking to spark innovation in key sectors (including agriculture) should therefore consider how to encourage the formation and growth of relevant clusters. A key intuition in this argument is that informal social interactions and institutions play a central role in building trust and interpersonal relationships, which in turn increase the speed and frequency of knowledge, resource, and other input sharing.

In developing countries, clusters are present in a wide range of sectors and their growth experiences vary widely, from being stagnant and lacking competitiveness to being dynamic and competitive. This supports the view that the presence of a cluster does not automatically lead to positive external effects. There is therefore a need to look beyond the simple explanation of proximity and cultural factors, and to ask why some clusters prosper and what specifically explains their success.

Shouguang Vegetable Cluster, China

China has a long history of economic clusters in sectors as diverse as silk, porcelain, high technology, and agriculture.[14] One of China's most successful agricultural clusters is the vegetable cluster in Shandong Province. This "Vegetable City," is a leading vegetable production, trading, and export center. Its 53,000-hectare vegetation plantation produces about four million tons annually. Shouguang was one of the poorest areas in the Shandong province until the early 1980s, when vegetable production started. Today five state- and provincial-level agricultural demonstration gardens and 21 nonpolluted vegetable facilities have been established. More than 700 new vegetable varieties have been introduced from over 30 countries and regions. Shouguang also hosts China's largest vegetable seed facility aimed at developing new variety. The facility is co-sponsored by the China Agricultural University. Over the years, vegetable production increased, leading to the emergence of an agro-industrial cluster that has helped to raise per capita income for Shouguang's previously impoverished rural poor.[15] The cluster evolved through four distinctive phases.

In the first emergence phase (1978 to 1984) Shouguang authorities launched programs for massive vegetable planting as a priority for the local development agenda. Shouguang had three main advantages that helped it to emerge as a leading vegetable cluster. These included a long history and tradition of vegetable production, rising domestic and international demand for vegetables, and higher profits exceeding revenue from crops such as rice and wheat. In 1983 Shouguang's vegetable production exceeded 450 tonnes. The local market could not absorb it all, so about 50 tonnes went to waste. The loss prompted Shouguang to construct a vegetable market the following year, thereby laying the foundation for the next phase.

In the second phase of the development of the cluster, local government officials used their authority to bring more peasants and clients into the new market. For example, the officials persuaded the Shengli Oil Field, China's second largest oil base, to become a customer of Shouguang vegetables. This procurement arrangement contributed to the market's early growth. The authorities also helped to set up more than 10 small agricultural product markets around the central wholesale market, creating a market network in the city. The markets directly benefited thousands of local farmers. Despite these developments, high demand for fresh vegetables in winter exceeded the supply.

The third phase of the development of the cluster was associated with rapid technological improvements in greenhouses and increased production. In 1989, Wang Leyi, chief of a village in Shouguang, developed a vegetable greenhouse for planting in the winter, characterized by low cost, low pollution, and high productivity. This inspired peasants to adopt the technology and led to incremental improvements in the construction and maintenance of greenhouses. Communication among peasants and the presence of local innovators helped to spread the new technology. By the end of 1996, Shouguang had 210,000 greenhouses, and the vegetable yield had grown to 2.3 million tons. The Shouguang government focused on promoting food markets. It helped to create more than 30 large specialized markets and 40 large food-processing enterprises. In 1995 the central government authorized the creation of the "Green Channel," an arrangement for transporting vegetables from Shouguang to the capital, Beijing. The transportation and marketing network evolved to include the "Green Channel," the "Blue Channel" (ocean shipping), the "Sky Channel" (air transportation), and the "Internet Channel."

After 1997 the cluster entered its fourth development phase, which involved the establishment of international brand names. The internationalization was prompted by the saturation of domestic markets and rising nontariff trade barriers such as strict and rigorous standards. International safety standards and consumer interest in "green products" prompted Shouguang to establish 21 pollution-free production bases. Foreign firms such as the Swiss-based Syngenta Corporation played a key role in upgrading planting technologies, providing new seed and offering training to peasants. This was done through the Shouguang Syngenta Seeds Company, a joint venture between Syngenta and the local government. Syngenta signed an agreement with the Ministry of Agriculture's National Agricultural Technical Extension and Service Center to train farmers in modern techniques. Since 2000, the one-month (starting April 20) Shouguang vegetable fair has encapsulated and perpetuated this cluster's many successes and has become one of China's premier science and technology events.

Rice Cluster in Benin

Entrepreneurship can spur innovations, steer innovation processes, and compel the creation of an innovation-enabling environment while giving rise to and sustaining the innovation system. Entrepreneurial venture is an embedded power that steers institutions, stimulates learning, and creates or strengthens linkages that constitute the pillars of innovation systems. The dissemination of New Rices for Africa (NERICA) in Benin illustrates what can be considered a "self-organizing innovation system."[16] Through the unique approach combining the innovation systems approach and entrepreneurship theory, this section describes the process by which a class of entrepreneurs took the lead in the innovation process while creating the basis for a NERICA-based system of innovation to emerge.

Benin, which is located in West Africa, covers an area of 112,622 square kilometers and has nearly 8.2 million inhabitants. Its landscape consists mostly of flat to undulating plains but also includes some hills and low mountains. Agriculture is the predominant basis of the country's weak economy; although only contributing 32% of the GDP (as compared to 53.5% of the service sector and 13.7% of the industrial sector), it employs about 65% of the active population.

Despite relatively favorable production environments, Benin's domestic production is weak and meets only 10%–15% of the country's demand for rice. Different people attribute this to different causes, such as policies and institutions that are not suited to supporting domestic production against importations or low quality of products. Irrigation possibilities are not fully exploited, despite the fact that rice production is traditionally rain-fed. There is also minimum input, with improper seeding and lack of fertilizers, pesticides, and herbicides.

NERICA is the brand name of a family of improved rice varieties specially adapted to the agroecological conditions of Africa. It is a hybrid that combines the best traits of two rice species: the African *Oryza glaberrima* and the Asian *Oryza sativa*. It has certain advantages over other species such as high yields, quick maturity, and resistance to local biotic and abiotic stresses such as droughts and iron toxicity. It also has 25% higher protein content than international standard varieties. And it is more responsive to fertilizers. Due to these advantages, different groups that wanted to change the status quo of Benin's agriculture sought to introduce NERICA. They included the government of Benin, the Banque Régionale de Solidarité (BRS), agro-industrial firms such as Tunde Group and BSS-Société Industrielle pour la Production du Riz (BSS-SIPRi), as well as nongovernmental entities such as Songhaï, Projet d'Appui au Développement Rural de l'Ouémé (PADRO), and Vredeseilanden (VECO). These organizations worked closely together to bring to the task skills, knowledge, and interests that could not be found in one entity.

A simple introduction of all of these organizations helps to clarify how they converged on NERICA in their pursuit of agricultural innovation. Songhaï is a socioeconomic and rural development NGO specializing in agricultural production, training, and research. It supports an integrated production system that promotes minimal inputs and the use of local resources. Songhaï was one of the first pioneers of NERICA production in Benin, largely because it was challenged to endorse a framework conducive to rice production as a profitable commodity.

Songhaï came in contact with BRS as it was seeking to fund skilled, competent, and innovative economic agents with sound business plans. Songhaï fit the bill perfectly. Tunde Group was NERICA's production hub and BSS-SIPRi is an enterprise specializing in NERICA seed and paddy production. PADRO and VECO are NGOs from France and Belgium, respectively. PADRO worked with the extension agency, farmer organizations, and micro-finance establishments, and indirectly with the Ministry of Agriculture. VECO focused on culture, communication, sustainable agriculture, and food security.

All of these separate organizations came together through NERICA to challenge Benin's agricultural status quo. Their entrepreneurism not only directly helped the dissemination of NERICA but also pushed the Benin government toward policies for agricultural business development. In February 2008, the government issued a new agricultural development strategy plan aiming to establish an institutional, legal, regulatory, and administrative environment conducive to agricultural activities.

What can be learned from the NERICA case is that the dissemination of this new technology did not follow the conventional process of assistance programs and government adoption. There was a process of self-organization through various nongovernmental organizations. Self-motivated economic entrepreneurs started the process and propelled innovation. As a result, the private sector was able to push the government to adopt new policies that would be conducive to these innovations. These conditions then created more economic opportunities that drew more self-organized entrepreneurs to the program and thereby completed a healthy cycle of economic and technological improvement. This process as a whole can be understood as a “self-organizing system of innovation.”

Industrial Clusters in Slovenia

Slovenia has made substantial economic progress since gaining its independence in 1991. At the end of the 1990s, Slovenia had a stable macroeconomic environment, with an average annual GDP growth rate of 4.3% and US$15,000 GDP per capita. Today Slovenia has nearly doubled that GDP per capita to US$27,000 and has jumped ahead of some of the “old” EU member state members such as Portugal and Greece. Despite favorable macroeconomic indicators, in the 1990s the economy depended on traditional industries with small profit margins and slow growth. Productivity was more than three times lower than the average productivity in the EU countries, while economic growth disproportionately depended on investments in physical assets, not knowledge or technology. Low education, weak public institutions, and insufficient social capital led to a shortage of competency, trust, and willingness to take risks.

In order to speed up the process of change and to stimulate business innovation, in 1999 the Slovenian Ministry of Economy launched an entrepreneurship and competitiveness policy.[17] Clustering was encouraged between similar and symbiotic firms as a way to increase knowledge creation and dissemination in key sectors. An initial mapping of potential clusters was conducted to analyze the geographic concentration of industries and the existing degree of networking and innovation systems, including linkages with universities, research centers, and other traditional centers of innovation.

Although the study revealed generally weak linkages and low levels of geographic concentration, 10 industries were nonetheless identified as having potential for cluster development. The cluster development program was articulated based on three interlinked measures: encouraging cooperation and networking between companies and R&D institutions; strengthening the knowledge, skills, and expertise required by key development actors (people and institutions) to promote the development and functioning of clusters; and forming clusters in practice.

The ministry began by co-financing projects involving companies and support institutions such as universities in the fields of marketing, product development, technology improvements, and specialization in supply chains. Three pilot clusters were supported with the objective of gaining knowledge and experience before any large-scale program was launched. The pilots followed a three-phase cluster development process: the initiation phase in which actors develop a common vision and devise an action plan for its implementation; an early growth phase when they implement the action plan and develop the platforms needed for the final phase; a final phase focused on R&D and internationalization. The model developed by pilots proved to be acceptable to the Slovenian environment, and a full-scale program was launched. Government financing was provided for the first year and then extended for two more years to those clusters with the best strategies. The government financial support was mainly used for R&D activities and training.

The government eventually supported 17 clusters. More than 400 firms and 100 business support institutions, universities, and research institutions participated with more than 66,500 employees. A total of 240 innovative projects have been launched as part of cluster initiatives in the areas of R&D between small and medium-sized enterprises (SMEs) and academic institutions, specialization in the value chain, internationalization, standardization, and training. At the beginning, the most important projects were focused on strengthening the cooperation between companies along the value chain and later on research and innovation. Almost all the clusters have internationalized and connected with foreign networks and clusters in less than two years. In 2006, the cluster program was completed. More demanding technology and research-oriented programs were launched to target specific technology, research, and science fields. Almost all of these post-2006 projects emerged from clustering activities.

Clusters provide crucial formal and informal linkages that increase trust among diverse actors, leading to greater exchange of individuals and ideas and key cooperation in areas no single firm or institution could achieve on its own. Despite advances in telecommunications, innovation in many sectors continues to be generated by and most easily transmitted between geographically proximate actors.

As farmer productivity is often constrained by lack of appropriate technology or access to best practice knowledge, inputs, and services, clusters may be able to provide pronounced benefits in the agro-sector. Certain types of clusters may have a more direct impact on poverty. These are the clusters in rural areas and in the urban informal economy; clusters that have a preponderance of SMEs, micro-enterprises, and home workers; clusters in labor-intensive sectors in which barriers to entry for new firms and new workers are low; and clusters that employ women, migrants, and unskilled labor.

In many African countries the agricultural sector is dominated by family-based small-scale planting. This structure slows down the diffusion and adoption of information and modern technology, a key driver of agricultural productivity and net growth. One of the main challenges is therefore to enhance technology transfer from knowledge producers to users in the rural regions where small-scale household farming dominates. Clusters can overcome these shortcomings by creating the linkages and social capital needed to foster innovation and technology transfer. However, clusters are not a cure-all for African agricultural innovation, and we must therefore look closely at the conditions under which clusters can work, the common stages of their development, and key factors of their success.

Clusters cannot be imposed on any landscape. They are most likely to form independently or to succeed once seeded by government when they are collocated with key inputs, services, assets, and actors. Clusters are most likely to form and succeed in regions that already possess the proper input, as well as in industries that have a dividable production process and a final product that can be easily transported. Clusters are also more likely in knowledge or technology-intensive businesses (like agriculture), where breakthroughs can instigate quick and significant increases in productivity. Clusters also benefit from preexisting tightly knit social networks, which provide fertile ground for more complex knowledge generation and sharing infrastructure.

Policies for Cluster Development

Cluster development could benefit from the experiences outlined above. In the first phase, governments should lead the formation of clusters by identifying strategic regions with the right human, natural, and institutional resources to establish a competitive advantage in a key sector. Governments can then nurture a quick flow of investment, ideas, and even personnel from the public sector to private firms. As government-funded initiatives deliver proof of concept, governments should make way for private enterprise and give up their ownership stakes in the burgeoning agro-industries they helped create.

As government involvement decreases, clusters move to formalize the connections between key actors through producer associations and other cooperative organizations. Strong bonds formed in the early phases of cluster formation allow diverse actors to come together on common sets of standards in key areas of health, safety, and environment. Quality control and enhanced production are critical for clusters to move beyond their local markets and into more lucrative national or international export markets. Despite their decreasing role, governments can continue to play a key part in this process by putting in place regulations that ease, rather than obstruct, firms' efforts to meet complex international health, environmental, and labor standards.

This strong foundation in place, clusters can move to additional cooperative efforts focused on international marketing and export, and complex partnerships with large multinational companies. Firms can band together to accomplish what none of them can do individually: achieve national and international brand recognition.

Innovation systems likewise cannot be imposed by outside actors and must have substantial buy-in from local government, business groups, and citizen groups. Additionally, governments must wrestle with the possibility that although clusters enhance knowledge generation and transmission within themselves, strong social and practical connections within clusters may actually make communications between them less likely.[18] Linkages between clusters are therefore critical, and this is an area in which regional organizations can play a particularly important role.

Local governments played a critical role in determining initial potential for clustering by evaluating natural and human resources, already existing clusters, and markets in which their area might be able to deliver a competitive advantage. Local governments also assessed and in many cases fueled popular citizen, business, and public institutional support for enhanced cooperation, a key precursor for clusters. As clusters depend on physical and cultural proximity to encourage knowledge creation and sharing, local governments can encourage these exchanges between firms, individual producers, NGOs, and research and academic institutions even before funding has been set aside for a specific cluster.

While local authorities are best placed to determine the potential for clusters in specific areas, national governments may be better positioned (particularly in Africa) to provide the financial and regulatory support necessary for successful clusters. National governments use state-owned banks, tax laws, and banking regulations to encourage loans to businesses and organizations in these key clusters. They also help finance investments by constructing key infrastructure, including ports, roads, and telecommunications. Finally, governments play a key role in responding to pressure from the clusters to create regulatory frameworks that help them to meet stringent international environmental, health, and labor standards. National governments can also play a central role in convincing nationally funded research and academic institutions to participate actively in clusters with businesses and individual producers.

While clusters lower barriers to knowledge creation and sharing within themselves, the opposite may be true across different national or regional economic activities. This isolation may limit innovation within clusters, or worse could lead to negative feedback cycles based on the phenomenon of "lock-in," whereby clusters increasingly focus on outdated or noncompetitive sectors or strategies.[19] Regional institutions and linkages can play a key role in making and maintaining these external links by supporting the exchange of information, and in particular personnel, between clusters. In Africa, regional institutions could also support the idea of regional centers of excellence based around key specialties—for example, livestock in East Africa.

The Role of Local Knowledge

Strengthening local innovation systems or clusters will need to take into account local knowledge, especially given emerging concerns over climate change.[20] Farming communities have existed for a millennium, and long before there were modern agricultural innovations, these communities had to have ways to manage their limited resources and keep the community functioning. Communities developed local leadership structures to encourage participation and the ideal use of what limited resources were available. In the past few centuries, colonial intervention and the push for modern methods have often caused these structures to fail as a result of neglect or active destruction. However, these traditional organizational mechanisms can be an important way to reach a community and cause its members to use innovations or sustainable farming techniques.[21]

While governments and international organizations often overlook the importance of traditional community structures, they can be a powerful tool to encourage community members in the use of new technologies or the revival of traditional methods that are now recognized as more effective.[22] Communities retain the knowledge of and respect for these traditional leadership roles and positions in a way that outside actors can not, and they will often adopt them as a way to manage community agricultural practices and learning. It is this place-based innovation in governance that accounts to a large extent for institutional diversity.[23]

India's recent reintroduction of the Vayalagams as a means of water management serves as a good example of how traditional systems can still serve the local communities in which they originated as a means of agricultural development and economic sustainability. A long-standing tradition in India in the pre-colonial period was the use of village governance structures called Vayalagams to organize and maintain the use of village water tanks. These tanks were an important component of rain-fed agriculture systems and provided a reservoir that helped mitigate the effects of flooding and sustain agriculture and drinking-water needs throughout the dry season by capturing rainwater.

The Vayalagams were groups of community leaders who managed the distribution of water resources to maximize resources and sustainability, and to ensure that the whole community participated in, and benefited from, the appropriate maintenance of the tanks. Under British colonial rule, and later under the independent Indian government, irrigation systems became centralized and communities were no longer encouraged to use the tanks, so both the physical structures and the organizations that managed them fell into disrepair.

As the tank-fed systems fell apart and agricultural systems changed, rural communities began to suffer from the lack of sufficient water to grow crops. One solution to this problem has been to revitalize the Vayalagam system and to encourage the traditional community networks to rebuild the system of tanks. Adopting traditional methods of community organization has tapped into familiar resources and allowed the Development of Humane Action (DAHN) Foundation—an Indian NGO—to rally community ownership of the project and gain support for rebuilding the system of community-owned and managed water tanks. The tanks were a defunct system when the DHAN Foundation incorporated in 2002. Now, the Tank-Fed Vayalagam Agricultural Development Programme works in 34 communities and has implemented 1,807 micro finance groups that comprise 102,266 members. It funds the program with a 50% community contribution and the rest from the foundation. This redeployment of old community organizations has resulted in rapid proliferation of ideas and recruitment of farmers.

Reforming Innovation Systems

As African countries seek to promote innovation regionally, they will be forced to introduce far-reaching reforms in their innovation systems to achieve two important goals. The first will be to rationalize their research activities in line with the goals of the Regional Economic Communities (RECs). The second will be to ensure that research results have an impact on the agricultural productive sector. Many emerging economies have gone through such reform processes. China's reform of its innovation system might offer some insights into the challenges that lie ahead.

Partnerships between research institutes (universities or otherwise) and industries are crucial to encourage increased research and promote innovation. Recent efforts in China to reform national innovation systems serve to demonstrate the importance of "motivating universities and research institutes (URIs), building up the innovative capacities of enterprises, and promoting URI-industry linkages."[24] Before the most recent reforms, China's model mimicked the former Soviet Union's approach to defense and heavy industry R&D, in which the system was highly centralized. Reforms allowed for increased flexibility, providing incentives to research institutes, universities, and business enterprises to engage in research. The case study of China's science and technology (S&T) reforms demonstrates the efficacy of using policy and program reform to increase research, patents, publications, and other innovations.

During the pre-reform period from 1949 to the 1980s, China focused on military research, carried out for the most part by public research institutes and very sparingly by universities. Almost all research was planned and funded by the government with individual enterprises (which often had their own S&T institutes and organizations) engaging in little to no research and development.

With the hope of developing the country through education and research, China created the slogan "Building the nation through science and education" to underscore their 1985 reforms. Efforts were made to increase university and research institution collaboration with related business industries, and in the 1990s this was furthered by motivating universities and institutions to establish their own enterprises.

Reforms occurred in three stages, the first of which spanned 1985 to 1992. Here, the government initiated reform by encouraging universities and research institutes (URIs) to bolster their connections with industry—one method used was to steeply cut the research budget for universities and other institutes with the goal of causing the URIs to turn to industry for support and thus facilitate linkages and partnerships. Additional laws and regulations regarding patent and technology transfer were passed, and by the end of 1992, 52 high-tech development zones had been set up, with 9,687 enterprises and a total turnover of renminbi (RMB) 56.3 billion.

From 1992 to 1999, the second stage of reform saw the creation of the "S&T Progress Law" and the "Climbing Program" to encourage research as well as the increased autonomy regarding research given to URIs. A breakthrough that strengthened partnerships between URIs and industry was the 1991 endorsement of enterprises that were affiliated with URIs. Linkages that were encouraged included technical services, partnerships in development, production, and management, as well as investment in technology. Vast improvements were seen immediately: from 1997 to 2000, university-affiliated enterprises experienced average annual sales income growth of 32.3%, with 2,097 high-tech ones emerging in China with a total net worth of US$3.8 billion by 2000.

During the third stage, starting in 1999, China sought to both strengthen the national innovation systems and facilitate the commercialization of R&D results. One key measure was the transformation of state-owned applied research institutes into high-tech firms or technical service firms. Of 242 research institutes that were to be transformed from the former State Committee for Economics and Trade, 131 merged with corporations (groups), 40 were transformed into S&T corporations under local governments, 29 were transformed into large S&T

corporations owned by the central government, 18 were transformed into agencies, and the remaining 24 turned into universities or were liquidated. A total of 1,149 transformations were carried out by the end of 2003.

New policies and programs helped bring about changes during the reform period. The "Resolution on the Reform of the S&T System," released in 1985, aimed to improve overall R&D system management, including encouraging research personnel mobility and integration of science and technology into the economy through the introduction of flexible operating systems. Peer review of projects and performance brought about a degree of transparency. Reform policies promoted more flexible management of R&D, technology transfer, linkages between URIs and industry, and commercialization of high-tech zones.

The many new programs were meant to serve different purposes and have been shown to be effective in general. One particular program was extremely important in the high-tech area. The "863 Program," which was launched in 1986, sought to move the country's overall R&D capacity to cutting-edge frontiers in priority areas such as biotechnology, information, automation, energy, advanced materials, marine, space, laser, and ocean technology. Another goal of the 863 Program was to promote the education and training of professionals for the 21st century by mobilizing more than 10,000 researchers for 2,860 projects every year. An example of another program was "The Torch Program," launched in 1988. By reducing regulation, building support facilities, and encouraging the establishment of indigenous high-tech firms in special zones, the program aimed to establish high-tech firms. Success is evident: "From 1991 to 2003, 53 national high-tech zones had been established" especially in the information technology, biotechnology, new materials, and new energy technologies industries. "The national high-tech zones received RMB 155 billion investments in infrastructure and hosted 32,857 companies in 2003."[25] It appears that these early but critical reform efforts have put China on a path that could enable it to catch up with the industrialized countries in science and innovation.[26]

Because the ultimate goal of the science and technology reforms in China were meant to strengthen national innovation systems and promote innovation activities among the key players in the system, it was necessary for URIs, industry, and the government to interact. The impact of the reforms is seen in the stark contrast between the years 1987 and 2003. In 1987, government-funded public research institutes dominated R&D research, with universities carrying out education and enterprises involved in restricted innovations in "production and prototyping." For this reason, URIs found no reason to conduct applied research or to commercialize their research results.

By 2003, R&D expenditure had risen by more than eightfold. Most distinctive was the large increase in R&D units, employees, and expenditures of enterprises. This was brought about in part from the transformation of 1,003 or 1,149 public research institutes into enterprises or parts of enterprises. Additionally, after the 1991 endorsement of university-affiliated enterprises, a great expansion occurred such that by 2004, 4,593 of them existed with annual income of RMB 97 billion. Another factor was increased competition that created incentive to engage in R&D. Finally, in general the R&D potential of the firms has increased as a result of the more supportive environment resulting from S&T reform.

The increased R&D expenditure from enterprises demonstrates the overall success of the science and technology reforms. This success is also seen in the improved URI-industry linkages, as is shown in the decrease in government spending from 79% in 1985 to 29.9% in 2000. URIs (either transformed or public ones) have forged close links with the private sector "through informal consulting by university researchers to industry, technology service contracts, joint research projects, science parks, patent licensing, and URI-affiliated enterprise."[27] Another success from the S&T reform is the great increase in patents from domestic entities as well as the larger number of publications.

Science and technology reform in China demonstrated the importance of creating linkages between industry and institutes for research and education. Despite the great success, there are a few cautionary lessons to be learned from China's actions. For example, while great improvements were found in the linkages between URIs and industries, there has been a lack of focus on science and technology administration. Because the many governmental and nongovernmental bodies work independently, there is a danger of inefficiency in the form of redundancy or misallocation of R&D resources. The reform's focus on commercializing S&T has also prevented further development of basic research and other research aimed at public benefit (with such research stuck at 6% of all research funding). A final concern is the controversy surrounding university-affiliated enterprises that emphasize the operation, ownership structure, and the de-linking of such enterprises from their original parent universities. Critics believe that commercial goals may hinder other university mandates about pure academics. When creating comprehensive reform of such magnitude, one must be careful to take into account these potential issues.

China's science and technology reforms demonstrate the potential for expanding research by supporting the formation of URI-industry partnerships and linkages. The benefits are clear and developing countries should greatly consider using China's case as a model for the establishment of similar programs and policies.

African countries can rationalize their research activities through an entity that can draw lessons from the Brazilian Agricultural Research Corporation (EMBRAPA). This successful institutional innovation was designed to respond to a diversity of agricultural needs over a vast geographical area. It has a number of distinctive features that include the use of a public corporation model; national scale of operations in nearly all states; geographical decentralization; specialized research facilities (with 38 research centers, 3 service centers, and 13 central divisions); emphasis on human resource development (74% of 2,200 researchers have doctoral degrees while 25% have master's training); improvements in remuneration for researchers; and strategic outlook that emphasizes science and innovation as well as commercialization of research results.[28]

Conclusion

Agricultural innovation has the potential to transform African agriculture, but only if strong structures are put in place to help create and disseminate critical best practices and technological breakthroughs. In much of Africa, linkages between farmers, fishermen, and firms and universities, schools, and training centers could be much stronger. New telecommunications technologies such as mobile phones have the potential to strengthen linkages, but cluster theory suggests that geography will continue to matter regardless of new forms of communication. Groups that are closer physically, culturally, and socially are more likely to trust one another, exchange information and assets, and enter into complex cooperative production, processing, financing, marketing, and export arrangements.

Local, national, and regional authorities must carefully assess where clusters may prove most successful and lay out clear plans for cluster development, which can take years if not decades. Local authorities should focus on identifying potential areas and industries for successful clusters. National governments should focus on providing the knowledge, personnel, capital, and regulatory support necessary for cluster formation and growth. And regional authorities should focus on linking national clusters to one another and to key related global institutions. Throughout these processes, public and private institutions must work cooperatively, with the latter being willing to transfer knowledge, funding, and even personnel to the private sector in the early stages of cluster development.

To promote innovation, the public sector could further support interactions, collective action, and broader public-private partnership programs. The country studies suggest that from a public sector perspective, improvements in agricultural innovation system policy design, governance, implementation, and the enabling environment will be most effective when combined with activities to strengthen innovation capacity. Success stories in which synergies were created by combining market-based and knowledge-based interactions and strong links within and beyond the value chain point to an innovation strategy that has to be holistic in nature and focus, in particular, on strengthening the interactions between key public, private, and civil society actors.