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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
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Agricultural Research in Ghana

An IFPRI-STEPRI Report

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11/18/2012

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WORKING PAPER 29 | November 2012

INTRODUCTION AND OBJECTIVE OF THE STUDY

Ghana's agriculture sector accounts for 35 percent of the country's gross domestic product (GDP) and nearly two thirds (60 percent) of the employment (Breisinger et al. 2011). Ghana is one of the top five performers in the world in terms of agricultural growth. Benefiting from favorable weather conditions, the world market prices for cocoa, and an abundance of arable land, its agricultural sector has been growing at an average annual rate of 5.1 percent over the past 25 years (ODI 2010). However, agricultural production growth patterns have been erratic over a longer period and yields of most crops have not grown steadily (Breisinger et al. 2008). Rather, yields for most crops are 20–60 percent below achievable yield levels (Breisinger et al. 2011). Reaching the productivity targets that Ghana has set for different crops will require growth rates in productivity far higher than that achieved in the past (Breisinger et al. 2011).

Additionally, agricultural performance has not been uniform within subsectors. The forestry and cocoa subsectors were growing more rapidly (at double digit rates) between 1991 and 2005 than crops other than cocoa (1.5 to 4.5 percent). While agricultural production growth rates in Ghana have been impressive, these have come mainly from area expansion rather than yield increases. Gaps exist between current and achievable yields for various crops. For major crops in Ghana such as maize, rice, millet and yam, estimated yield gaps are between 38 and 47 percent, and as high as 58 percent in cassava. By closing these yields gaps, agricultural productivity can be increased significantly. However, tapping into the vast potential of Ghana as well as West Africa to expand its agricultural production requires greater availability and wider use of existing knowledge (Nin-Pratt et al. 2011). More specifically, reducing yields gaps and increasing agricultural productivity can be achieved in part through the adoption of existing crop technologies; the use of improved crop varieties and recommended levels of fertilizer; and the application of adequate farm, nutrient, water, and pest management practices (Nin-Pratt et al. 2011).

The critical role of science, technology, and innovation in promoting economic growth, food security, and poverty reduction in the developing world has become very clear, especially in the agricultural sector (IFPRI 2009). At a time when land and water are becoming increasingly scarce, agricultural growth will increasingly need to come from gains in productivity. At the same time, globalization and new supply chains have obliged farmers to respond quickly to changing market demands (Alcadi et al.2009). Technologies are needed to increase the productivity, stability, and resilience of sustainable production systems. At the same time, farmers find themselves in need of new uses of science and technology to mitigate and adapt to emerging challenges like climate change.

Thus the generation, dissemination, and adoption of agricultural technologies play a critical role in increasing yields (Nin-Pratt et al. 2011). This has been explicitly recognized in Ghana's revised Food and Agriculture Sector Development Policy (FASDEP II), the framework for the implementation of strategies to modernize the agricultural sector. Developed in 2007, FASDEP II aims to enhance the overall environment for all farmers, while specifically targeting the poor, vulnerable, risk-prone, and largely subsistence farmers. The policy objectives outlined in the FASDEP II address critical constraints in Ghana's agricultural sector and fully align with the goals set forth in both the Ghana Poverty Reduction Strategy (GPRS) II and the Comprehensive Africa Agriculture Development Program (CAADP) of the New Partnership for Africa's Development (NEPAD). The six main objectives laid out in FASDEP II are:

Food security and emergency preparedness

- Improved growth in incomes
- Improved competitiveness and enhanced integration into domestic and international markets
- Sustainable management of land and environment
- Science and technology applied in food and agriculture development
- Improved institutional coordination (MOFA 2007)

Technology development and dissemination is one of seven main constraints to increasing agriculture productivity identified by FASDEP II:

1. Human resource and managerial skills
2. Natural resource management
3. Technology development and dissemination
4. Infrastructure
5. Market access
6. Food insecurity
7. Irrigation development and management

Some of the technology development and dissemination constraints in Ghana include limited availability of appropriate technologies, low adoption of existing technologies, and a supply-driven approach to technology generation and dissemination that has led to low technology adoption (MOFA 2007).

Acknowledging these constraints, FASDEP II emphasizes the enhancement of productivity in the commodity value chain through the application of science and technology. This is why *science and technology applied in food and agriculture development* was adopted as a policy objective. High priority will be given to applied research with research initiatives focusing more on supporting on-farm and off-farm innovations for improved production systems, higher productivity, and greater small- and large-scale industrialized processing. The Ministry of Food and Agriculture (MOFA) partners with the national agriculture research system to ensure that research focuses on the development of value chains of commodities targeted for food security, income growth and diversification, external markets, and linkage with industry.

FASDEP II specifically points out that the supply-driven approach to technology generation and dissemination (top-down planning) is associated with low technology adoption and application. For this reason, the Government seeks to improve the uptake of technologies by improving the relevance of technologies to users as well as improving potential users' access to these technologies. The Government also aims to promote demand-driven research, improve the effectiveness of research-extension-farmer linkages (RELCs)[1], and to integrate this concept into the agricultural research system to increase participation of end users in technology development. Moreover, FASDEP II has given considerable importance to effective transfer of available technologies and additional investments in research mainly to develop new varieties that can withstand harsh conditions (MOFA 2007).

This study was motivated by a request several years ago from the MOFA to support a dialogue between MOFA and the Council for Scientific and Industrial Research (CSIR) on technology development issues and to take a stock of technologies developed by CSIR to facilitate this dialogue. Because of disagreements concerning the availability of technologies on the shelf, this study was meant to be a peek at the shelf. A desk study, it was decided, would not yield a complete and accurate stock of technologies. The project therefore grew to include a survey of scientists, in which scientists were asked why they developed the technologies, how they did so, and what they thought about the outcomes.

To gain further insights into how technologies are developed and disseminated, the authors of the present study suggested that case studies of a few technologies would be useful. This background material helped design a more rigorous analysis of the governance and effectiveness of the agricultural research system. This study is being followed by a study on the adoption of maize and rice varieties in Ghana.

The objectives of this study:

1. Obtain a list as complete as possible of technologies generated by agricultural research institutions in Ghana over the past decade; and
2. Gain some insights into how the research system functions as part of an overall innovation system through a survey of scientists and case studies of a selected few technologies.

This study uses the definition of technological innovation by Sumberg and Reece (2004): a "new or improved product or process that is based on new (or a reinterpretation of existing) technical knowledge about the production of goods or services."

The remainder of the report is organized into six sections. Section two outlines the methodology used to conduct the study. This is followed by a brief review of literature on the evolution of thinking about agricultural research systems, which culminates in section three on innovation systems. An overview of the organization and resources of the agricultural system

[1]RELCs were created to ensure that research work addresses the problems of fishers and farmers.

in Ghana is presented in section four, which also includes a short description of the agricultural technologies for which IFPRI and STEPRI jointly administered follow up surveys. Section five contains 10 agricultural case studies that highlight the results of both the scientist survey and on-farm consultations. The concluding section provides a summary of findings and lessons learned.

METHODOLOGY

Stock taking began with a search for information from annual reports of the 13 institutes of the CSIR from 2000 to 2009. It also drew on several earlier stocktaking exercises:

- R&D Projects on Capital Goods, Food Processing and Energy Sectors, published in 1990
- Technologies Developed Within the CSIR, published in 1998
- A technical publication by Aryeetey (2000) that provides an overview of the national agricultural research systems (NARS)
- Agricultural Innovations: Technological inputs for enhancing agricultural production in Ghana, published by STEPRI-CSIR in 2008. This book provides a compilation of 38 of the major agricultural innovations in Ghana developed by CSIR research scientists (particularly ARI, CRI, OPRI, SARI, and WRI); the University of Ghana–Legon, KNUST, and UDS.[2]

Newsletters and reports on national agricultural projects that included the development of agricultural technologies also served as good sources. The Ghana National Agricultural Information System newsletters, quarterly bulletins on agricultural information, were reviewed. Other reports such as performance audit reports and sectoral overviews of the Ghana National Agricultural Research Project (NARP), the National Agricultural Extension Project (NAEP), the National Livestock Services Project, and the Agricultural Sector Investment Project were also examined. Related documents obtained from the respective libraries of the Department of Crops and the Animal Science and Nutrition Department of the University of Ghana were reviewed to solicit information on agricultural technologies developed by the university. Among these are papers that document research projects and the corresponding agricultural technologies produced from the projects. The heads of these departments were also consulted to provide documents on technologies that were developed. From these and other online sources, a total of 159 agricultural technologies were identified.

The desk survey was followed by a survey of all the scientists involved in the development of the identified technologies. This exercise was conducted in the CSIR institutes and a few universities. Structured questionnaires were used to collect information on the characteristics of the agricultural technologies developed by the scientists, including:

- Ideas behind their development
- Motivating factors for their development
- Problems addressed by the technologies
- Challenges in technology development
- Collaborations
- Evaluations of the technologies
- Availability of the technologies
- Scientists' perceptions on both the extent of adoption of the agricultural technologies and the factors that can inhibit adoption

By eliminating duplications and clubbing similar technologies together in discussion with scientists, the list was whittled down to 109. This list of technologies, which is presented in the Appendix, has been fully screened by the CSIR directors.[3]

From the list of 109 technologies, 10 were selected for case studies. Based on the responses of scientists from the survey, the technologies were grouped into three main categories: high-, medium- and low-adopted technologies. The 10 selected for case studies were considered high-adopted. Discussions were held with key informants—farmers, scientists, agricultural extension service agents, and private sector stakeholders. District agricultural extension agents and representatives of institutions who dealt directly with the scientists/scientific institutions were subsequently interviewed through phone calls to validate the categorization of the technologies. For the case studies, discussions with farmers were

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[2] ARI = Animal Research Institute; CRI = Crops Research Institute; OPRI = Oil Palm Research Institute; SARI = Savanna Agricultural Research Institute; WRI = Water Research Institute ; KNUST = Kwame Nkrumah University of Science and Technology; UDS = University of Development Studies

[3] The list of 109 technologies was presented to the CSIR directors for their screening during their 11–12 May 2011 meeting. A presentation of this report's preliminary findings was given to the directors on 12 May 2011.

held in selected communities identified by the scientists as areas of high adoption. The farmers were also identified by district extension officers as those who had adopted the 10 technologies described in the case studies below.

The case studies were drafted and sent individually to the scientists responsible for the development of the various technologies for their review, feedback, and approval. All 10 case studies received approval for dissemination and all comments and feedback provided by the scientists are reflected in this report.

A FRAMEWORK FOR RESEARCH: INNOVATION SYSTEMS

An evolving debate has taken place over the past several decades on how to foster agricultural technology development and promote the successful adoption of these innovations to achieve sustained agricultural and economic growth (World Bank 2006).

One of the initial perspectives on agricultural research was a linear approach to technology development and diffusion commonly referred to as the 'central source of innovation' model (Biggs 1989) or the 'transfer of technology' (TOT) approach (Chambers and Jiggins 1986). This approach assumes a one-way flow of knowledge in which information originates from a single, or central, source. Also referred to as a 'knowledge pipeline', this one-way flow of information describes the process in which technologies are developed and transferred to farmers (Douthwaite et al. 2001). Research centers at one end of this pipeline determine the research priorities, scientists then develop technologies in controlled conditions, and extension agents transfer the agricultural technology to farmers. This model took form with the development of national agricultural research institutes.

According to Chambers and Jiggins (1987), four distinct forces sustained the TOT model:

- Education and training
- Government and commercial funding and influences
- Research methodology
- Professional and personal rewards and incentives

Science and technology were situated at the core of these forces and the notion of 'learn from above and teach to below' prevailed. This model may have benefited resource-rich farmers because their farming conditions are more similar to the conditions under which technologies are developed in research stations. Additionally, they are able to effectively articulate and even influence or set the priorities for agricultural research (Chambers and Jiggins 1987).

An example of the TOT model in Ghana is the government-run NAEP, which used a training-and-visit (T&V) approach.[4] In 1992, as part of NAEP, multiple extension organizations were fused together under a national hierarchical system to provide modern, technical knowledge to farmers. Although T&V contributed to increased growth, productivity and high rates of return, it proved unsustainable and quickly became associated with a bulky bureaucracy that consumes excessive costs. Furthermore, although one of its initial goals was to empower farmers through the provision of information, T&V was criticized for assigning farmers a passive rather than an active role. As Cramb (2003) notes, the replacement of the TOT top-down model with more participatory approaches was more evident in literature than in practice. The linear paradigm evolved into what Eponou (1993) refers to as a 'chain-link' model, which maintained a sequential flow of information but allowed for linkages between farmers and scientists in the form of feedback mechanisms that promoted the testing and redesign of technology innovations. While this model was found to be somewhat successful for individual export crops in developing countries (such as cotton, rubber, and palm oil), it had a negligible impact on smallholder subsistence farming communities (Eponou 1993).

Increased pressure from governments and development agencies to meet unmet expectations for technological change in agriculture produced a greater awareness of the deficiencies of central source models, from which the second distinct perspective on innovation in agricultural technology evolved. This was the 'multiple source of innovation' model (Biggs 1989). Recognition of a range of sources contributing to agricultural development helped replace the single source paradigm with a systems perspective. Under this perspective, agricultural research institutions and extension agencies, public and private universities, non-governmental and farmers' organizations, and non-agricultural government ministries all represent components of a NARS framework (Rivera et al. 2006).

[4] The T&V approach, introduced by the World Bank in the 1970s in over 50 developing countries, sought to unify existing agricultural agencies into centralized government systems. The approach assumed a knowledge gap between rural farmers and professional extension agents. The extension agents, who were trained by their governments, used their knowledge to assist farmers in modern technologies during on-farm visits. They often did so by encouraging farmers to adopt certain agricultural practices over others (Anderson et al. 2006).

Through its identification of three distinct systems, the NARS framework was able to pave the way for a slightly more nuanced perspective that drew on principles of knowledge economics; specifically, the agricultural knowledge and information systems (AKIS) perspective (Spielman 2006). This perspective highlights the critical linkages between research, education and extension. Viewing NARS, NAES, and NAETS (National Agricultural Education and Training System) as sub-systems of a larger agricultural knowledge system triangle, the AKIS perspective focuses on the process in which knowledge flows between and among these sub-systems (Rivera et al. 2006; Spielman 2006). Through this triangular depiction of knowledge flows and its promotion of greater integration among all relevant actors and organizations, the AKIS perspective has been able to raise the appreciation of farmers and stakeholders from that of end user or pipeline recipients to central actors in the agricultural development process.

The systems perspective broadened further to accommodate a more central focus on innovation. Moving beyond production and the identification of linkages, an innovation systems approach examines the nature of interactions within a network of actors and organizations that affects efforts to generate, disseminate, and utilize useful knowledge or technologies (Hall et al. 2001, 2006; Spielman 2006). Multidirectional and multifunctional knowledge flows among a wide range of actors with the potential to influence or contribute to agricultural innovation processes present open opportunities for generating feedback, supporting interactive learning, and advancing progress (Hall et al. 2006). According to Hall et al. (2006), the "innovation systems framework recognizes that (i) a broad spectrum of actors outside the State have an important role; (ii) the relative importance of different actors changes during the innovation process; (iii) as circumstances change and as actors learn, roles can evolve; and (iv) actors can play multiple roles—sometimes as a source of knowledge, sometimes as a seeker of knowledge, sometimes as a coordinator of linkages between others."

In promoting the concept of innovation as a change catalyst for development, the innovation systems approach has gone further than earlier approaches to acknowledge the complexities involved in agricultural innovation development, diffusion and adoption. However, it has not gone far enough in terms of operationalizing these concepts into implementable mechanisms (Rivera et al. 2006). Gijsbers and van Tulders (2011), who conducted an assessment of management practices that drive agricultural innovations, identified as critical an institution's capacity to:

- Select research priorities
- Plan strategies
- Respond to changes in the environment
- Evaluate research results
- Manage linkages and partnerships with a range of different actors (government, private sector, farmers, etc.)

The findings of Gijsbers and van Tulders demonstrate that the most significant weaknesses result from ineffective linkages.

Though some gains have been made over the past two decades, research in developing countries—West Africa in particular—have on the whole been unable to achieve this desired outcome (Nederlof et al. 2007; Fafchamps 2009; Yengoh et al. 2009). Understanding why greater advancements in innovation are not taking place has become all the more urgent in view of the overwhelming consensus on the vital role of innovations in agricultural science in boosting productivity, increasing economic growth and development, and reducing poverty (Doss 2006; von Braun 2009; Pratt and Fan 2010).

- In their attempt to identify indicators for innovation system, Spielman and Birner (2008) identified three domains in an innovation system:
- *a knowledge and education domain* comprising agricultural research and education systems in which technology generations may take place;
- *a business and enterprise domain* that makes use of the knowledge domain but also innovates independently; and
- *bridging institutions* such as extension services that facilitate transfer of information and knowledge between the first two domains.

These domains interact in the broader context of policies and informal institutions that govern innovation. They identify indicators related to inputs, outputs or outcomes for the three domains largely to enable comparison with other systems.

Although innovation systems necessarily include farmers in the complex network of actors engaged in innovation process, this study is limited to innovations emerging from a research system. Since this study examines only the outputs of research institutions, we want to know if the research system operates as part of a larger system. Our focus is therefore on the indicators that suggest multiple agents acting together as parts of national and international networks, forming collaborative linkages, working with extension systems, and above all nourishing a culture of working together.

THE AGRICULTURAL SYSTEM IN GHANA

The NARS in Ghana is composed of various agencies. CSIR, established in 1968, is the largest and oldest government research and development (R&D) institution in Ghana and is part of NARS. It has its origins in the National Research Council that was established in 1958 to coordinate scientific research.[5] The mission of CSIR is to generate and apply innovative technologies which efficiently and effectively exploit science and technology for socio-economic development in the critical areas of agriculture, industry, health, and environment and improve scientific culture of the civil society (CSIR 2010). The CSIR coordinates all aspects of scientific research in Ghana and aims to encourage and promote the commercialization of research results. Through Act of Parliament (Act 521) in 1996, CSIR's objectives were reoriented towards private-sector concerns and the commercialization of research.

The CSIR encompasses 13 research institutes, 9 of which conduct agricultural research: the Animal Research Institute (ARI), the Crops Research Institute (CRI), the Forestry Research Institute of Ghana (FORIG), the Food Research Institute (FRI), the Oil Palm Research Institute (OPRI), the Plant Genetic Resources Research Institute (PGRRI), the Savanna Agricultural Research Institute (SARI), the Soil Research Institute (SRI), and the Water Research Institute (WRI). The CSIR Secretariat is the central administrative body for CSIR agencies. The CSIR falls within the Ministry of Environment, Science and Technology and is headquartered in Accra. Each CSIR institute and center is managed by a council-appointed board. One main task of the board is to evaluate, authorize, and examine research and commercialization programs proposed by the institute and center directors (Gage and Sarr 2001).

Non-Csir Agriculture-Related Research Agencies

Other government agencies not coordinated by CSIR but which conduct agriculture-related research include the Cocoa Research Institute of Ghana (CRIG), the Biotechnology and Nuclear Agricultural Research Institute (BNARI), and the Marine Fisheries Research Division (MFRD) of MOFA (Flaherty et al. 2010).

CRIG, which was established in 1957 and currently managed by the Ghana Cocoa Board (COCOBOD), is the largest of these three non-CSIR agriculture-related research organizations. Although its mandate for research on Ghana's primary export crop, cocoa, is by far its most important commodity focus, CRIG also conducts research on coffee, kola, shea nut, and other indigenous oil tree crops (CRIG 2003).

BNARI, which was established in 1993, focuses on the use of biotechnology and nuclear technologies to address sustainable agriculture, health, and industrial needs in Ghana (BNARI 2010). MFRD, established in 1963 under MOFA, conducts fisheries research for the rational exploitation of Ghana's fisheries resources and assists in the design/update of marine fisheries management plans.

Agricultural Higher Education Agencies

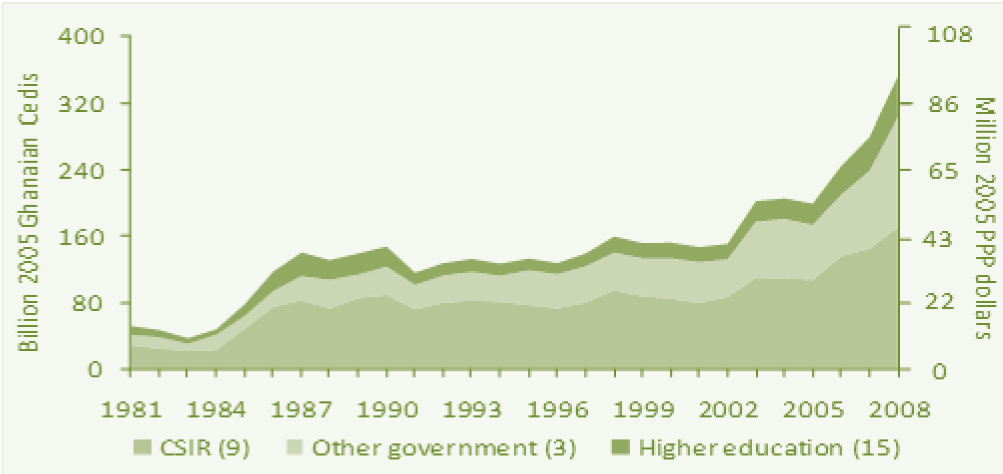
Agricultural Science and Technology Indicator (ASTI) (2011) identified 15 higher education agencies in Ghana, many of which conduct agricultural research. That list did not include some private universities such as Valley View University and Central University College, which have agricultural degree programs. However, in the ASTI survey of 2009 (Flaherty et al. 2010), the higher education institutions were sampled to follow up both on previous surveys and on what kind of research the institutions were engaged in at that time. Based on full-time equivalent (FTE) research staff, the largest agricultural higher education agency was the College of Agriculture and Consumer Sciences at the University of Ghana (UG). Other agricultural higher education agencies are various faculties and departments at the Kwame Nkrumah University of Science and Technology (KNUST), the University of Cape Coast (UCC), the University for Development Studies (UDS), and the University of Education, Winneba (UEW). The longer established colleges and faculties of agriculture, biological sciences, and natural resources at the UG, KNUST, and UCC are the main providers of agricultural research.

[5] From 1968 to 1979, CSIR was under the supervision of the Ministry of Finance and Economic Planning. In 1979, it was transferred to the new Ministry of Industries, Science and Technology. It was then placed under the aegis of the Ministry of Education, Science, and Sports until the recent ministerial restructuring in 2009 placed it under the Ministry of Environment, Science and Technology.

Agricultural Research and Development Resources

In Ghana, expenditure on agricultural R&D more than doubled between 2002 and 2008, climbing from 151 billion Ghana cedis (GHC), equivalent to $41 million[6], to GHC 352 billion7 ($95 million) (Figure 4.1). The reasons for this rise in spending on agricultural R&D are twofold: first, the increased funding for CRIG from growing revenues in the sector; and second, the increase in personnel emoluments of all civil servants in the country (Flaherty et al. 2010) (Figure 4.2). The CSIR currently employs about 4,000 workers of all categories.

Figure 4.1—Agricultural R&D spending (constant prices), 1981–2008



Figures in parentheses indicate the number of agencies in each category. Financial data are presented in old Ghanaian cedis. The new cedi, introduced on 1 July 2007, is equivalent to 10,000 old cedis.
Source: Flaherty et al. 2010.

The share of capital and operating costs, however, has continuously declined. The picture that emerges is that staff is employed without providing the means to engage in research. World Bank and UNCTAD (2010) report that CSIR is running down its assets and is faced with problems such as inadequate funding, particularly with regard to equipping labs and workshops, as well as inadequate and late release of funds and unsatisfactory resources for infrastructure and farm machinery.

Figure 4.2—Cost category shares of CSIR, 2001–2008

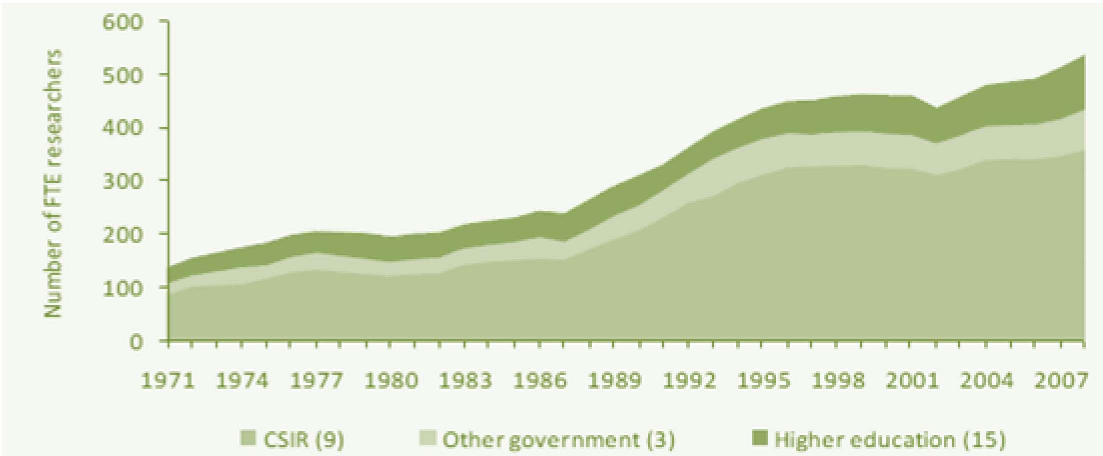
Source: Flaherty et al. 2010.

Between 1971 and 2008, the total number of agricultural staff in FTEs increased steadily (Figure 4.3) with the largest increase having taken place within the CSIR, where FTE researchers jumped from only 87 researchers in 1971 to 358 in 2008 (Flaherty et al. 2010). Ghana's total agricultural R&D FTE researchers reached 537 in 2008, of which 67 percent were

[6] $ = US dollars.
[7] Prices adjusted for inflation.

employed by CSIR. While there has been a growth in research staff overall, many agencies are faced with an aging pool of scientists, recruitment restrictions, limited support for training, and a government proposal to significantly cut salary costs (Flaherty et al. 2010). For CSIR, a main concern is finding a way to retain existing staff and to attract young staff.

Figure 4.3—Public agricultural research staff in full-time equivalents, 1971–2008



Figures in parentheses indicate the number of agencies in each category.
Source: ASTI 2011.

AGRICULTURAL TECHNOLOGY CASE STUDIES

Specialized agricultural research institutions account for bulk of the agricultural technologies generated in Ghana. Most of the 109 agricultural technologies that we identified through desk review and the scientist survey (91 percent) were developed by CSIR researchers. Only a small percentage of the 109 identified technologies covered in the survey were from academic institutions. About 5 percent of the technologies covered were developed from the University of Ghana, 2 percent from KNUST, 2 percent from UDS, and 1 percent from UEW.

Table 5.2—Distribution of technologies by research institute

Item	No.	%
Agency		
CSIR	99	91.8
UG	5	4.6
KNUST	2	1.8
UDS	2	1.8
UEW	1	0.9
Total	**109**	**100**
CSIR institute		
SARI	28	28.3
CRI	25	24.2
ARI	13	13.1
FRI	9	9.1
OPRI	7	8.1
SRI	7	7.1
FRI	4	4.0
Institute of Industrial Research	4	4.0
PGRRI	1	1.0
WRI	1	1.0
Total	**99**	**100**

Source: IFPRI-STEPRI survey 2010.

The majority of the technologies (64 percent) related to crop production (Table 5.3). About 16 percent were agro-processing technologies, 14 percent were applicable to livestock and poultry production, and only about 2 percent were fisheries-related. Roughly 4 percent of the technologies are grouped together as “others”. Examples of agricultural technologies that fall under this category include sediment filter technology, development of mushroom seedlings, development of clones of *Odum* resistant to the pest *Phytolys lata*, improved planting materials for teak, and geo-spatial modeling for agro-ecological assessment.

Table 5.3—Distribution of agricultural technologies by application and classification

Item	No.	%
Category		
Crops	70	64.2
Agro-processing	17	15.6
Livestock/poultry	15	13.8
Fisheries	2	1.8
Other	5	4.6
Total	**109**	**100**
Crop -related technology by type of research area/theme		
Introduction of new high-yielding or pest-/disease-resistant varieties	33	47.1
Soil fertility improvement/land management	12	17.1
Pest management	11	15.7
Field management practices	7	10.0
Plant breeding	4	5.7
Intercropping	3	4.3
Total	**70**	**100**
Classification		
Hard technology	65	59.6
Soft technology	44	40.4
Total	**109**	**100**

Source: IFPRI-STEPRI survey 2010.

Most of the crop-related technologies (47 percent) are improved varieties with potential for higher yields and greater resistance to diseases and pests. The second largest group of crop-production related technologies includes those designed to improve soil fertility and land management practices. Agricultural technologies are also classified as either a “hard” or “soft” technology. Hard technologies refer to physical technologies that have been developed. Examples include crop varieties, machines, and animal breeds. Soft technologies refer to non-physical technologies and mainly involve techniques, farming methods, knowledge, and management practices. Out of the 109 technologies in the survey, 60 percent were hard technologies.

The technologies selected for case studies represent various subsectors, and types. Of the 10 studies, five are crop production oriented, three of which are varieties (cowpea, cassava and soybean) and the other two are integrated pest management (IPM) practices (oil palm and groundnut). One is on industrial processing of cassava. The remaining four fall into livestock category: snail farming, local breed of poultry, improved brooding for guinea fowl, and fish farming. Of the ten, only four require commercialization. The rest represent knowledge that can be disseminated. The case studies cover the motivation for developing the technology, the nature and extent of collaboration, the technology development process, dissemination or commercialization, and the outcomes in terms of adoption.

Improved Cowpea Variety Asontem

Local varieties of cowpea cultivated in Ghana are low-yielding and particularly susceptible to infestations by the cowpea weevil *Callosobruchus maculates*. Asontem, which was released in 1987, was one of several high-yielding, disease- and pest-resistant varieties released in the late eighties and early nineties.

The variety was developed by CRI in collaboration with the International Institute of Tropical Agriculture (IITA), SARI, FRI, and MOFA. IITA supplied the germplasm and offered technical backstopping, which included training for some CRI research staff. SARI tested the variety in northern Ghana while CRI tested in the south. FRI examined the chemical composition and conducted nutrition and sensory evaluations. MOFA assisted in the organization of trials on farmers’ fields. The Women in Agriculture Division (WIAD) of MOFA worked on incorporating the new variety into some of the local dishes.

The variety was selected for release after testing for nearly two years on research stations and farmers’ fields in five different agro-ecological regions. It was found suitable for all ecological conditions except for deciduous forest areas in the western region. Agronomic evaluations were conducted by external reviewers. The socio-economic group at CRI also looked at the costs and benefits before the variety was released by the national varietal release committee. In addition to offering higher yields, the variety proved to be resistant to major diseases and insect attacks. The variety was found to be early-maturing and produced more pods per seed than other varieties. Asontem's grain yield was 200 percent higher than the farmers' traditional varieties and roughly 44 percent higher than the most improved variety in the same maturity class. Some trials indicated that the yields could be as high 3 t/ha compared to 0.5 t/ha obtained by farmers. The scientists felt that the variety itself accounted for about 30 percent of the increase in yields.

The principal scientist indicated that although it was not priority then, if they had an opportunity to expand the scope of their research, they would have tried to develop varieties with higher protein content and would have looked for high sulphur amino acid content in protein profiles. They would also have liked to develop cowpeas resistant to pod-sucking insects. The project, however, was implemented without any funding.

The Grains and Legume Board (GLDB) produced foundation seed for distribution to certified seed producers for further multiplication. Asontem also informally entered the market as the farmers who participated in on-farm demonstrations passed on or sold the seeds to fellow farmers. The technology was disseminated through publication of varietal release reports and on-farm demonstrations. The scientists involved in the development also participated in radio discussions about the variety. WIAD suggested ways to incorporate the variety into local dishes.

The principal scientist felt that adoption of the variety was high, particularly in the first five years after release, as it met farmers' expectation of yields and resistance to major diseases. It was also early-to medium-maturing and possessed seed characteristics that yielded a premium in the market. By 2005, Asontem was the most widely cultivated improved cowpea variety in Ghana and was particularly popular in the coastal savanna regions (Asafo-Adjei et al. 2005).

The principal scientist also indicated that the variety had been successfully adopted throughout the country, but that adoption was particularly high in the three northern parts of Ghana as well as in Ejura, Kenyase, and Ofinso. However in 2009, the research team at Ejura was informed that the cultivation of the Asontem variety had been abandoned long before, although the informants during the focus group discussion organized by the research were unable to say exactly when. It had been replaced by better varieties. According to the informants, the seeds of Asontem broke easily when the pods were threshed. Also it did not meet the consumer preference for white cowpeas with black eyes and a thick coat. The informants also felt that the variety took longer to cook than other varieties such as Mallam Yahaya and also released an unpleasant aroma during cooking.

From discussions with the informants, it became clear that getting an indication of the extent of adoption was difficult because Asontem had been replaced better varieties. Another problem was that farmers use various names for their cowpea varieties.

Overall, few farmers in the districts visited still cultivate Asontem, preferring varieties such as Mallam Yahaya, Yaamini, Uganda, and Allan Cash, among others. It was also noted that insects and pests remain a persistent challenge as the insects that attack the cowpea have developed resistance to popular insecticides.

Early Warning System for the Control of Oil Palm Leaf Miner

The oil palm leaf miner (*Coelaenomenadera lameensis*) is the most destructive pest of oil palm in West Africa, causing great havoc on oil palm plantations if not checked during early stages of infestation. Both larval and adult forms of the miner damage the palm, leading to rapid desiccation of fronds and arresting of photosynthetic activity. Defoliation of up to 90 percent of fronds in severely attacked trees has been reported, resulting in a 50 percent loss in fresh fruit bunch yields over a 1–2-year period. The larvae mine through the leaves and reside there until they develop into adults. As a result, chemical control of larvae is very difficult. Oil palm farmers use hazardous pesticides mainly to control external adults. In addition to being ineffective against larvae, external application of pesticides raises environmental concerns and heavy use may lead to the pest developing resistance to insecticides. Additionally, the costs of these pesticides have become prohibitive to smallholder oil palm farmers, who produce a signification portion of Ghana's oil palm output. As part of developing an IPM regime for leaf miner control, an early warning system was developed (Appiah et al. 2007; Yawson et al. 2009).

The early warning system for the control of oil palm leaf miner involves the sampling of representative fronds for a thorough visual assessment and for counting the number of pests in various stages of development to work out a live index for further action. The early warning system helps to detect incipient or low levels of infestation before the pest builds up to levels that cause economic damage. Early detection of the pest results in great savings in resources—both human and material—needed to affect control in the event of an outbreak of the pest. Main features of the technology include:

- Visual assessment of the plants to observe defoliation and browning due to activity of the pests
- Sampling of lower fronds, a lower leaf that is still green (i.e. 1 frond/tree/ha)

- Pulling of fronds if easily accessible for observation or cutting of fronds where the trees are tall
- Assessing the presence of leaf minor in various stages of development
- Working out a live index or the average number of live insects per frond
- Undertaking a special census with larger sample, if the live index exceeds the economic threshold of 1.5

OPRI established 1.5 as the economic threshold at which further control action needs to be taken. Depending on the extent of infestation, the next line of action could be early pruning and burning of the lower fronds complemented with selective use of insecticides. Pesticide use involves the use of recommended insecticides, appropriate equipment and proper timing of application to ensure minimal destruction of non-target species, but maximum effect on the target species.

OPRI developed an integrated application for the management of leaf miner with the early warning system as the basis for triggering appropriate action. Early warning systems are fundamental for sustainable crop protection and various centers, including the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), have developed such systems for economic pest management. The work got under way with a review of literature on pest monitoring systems. The project was funded by NARP and the Agricultural Services Sub-Sector Improvement Program (AgSSIP). The principal scientist involved felt that if additional resources were made available, the research could be extended to studying the prospects of using biological agents, parasitoids, and pathogens in the management system (Obirih-Opareh et al. 2008). Also, because of inadequate funding, the team was unable to work on small plantations without direct links to larger plantations (Obirih-Opareh et al. 2008).

The technology was demonstrated at the Twifo Oil Palm Plantation (TOPP). It has been disseminated through technical reports, journal publications, seminars, and agricultural shows. Personnel from some of the larger plantations such as Benso Oil Palm Plantation (BOPP) and Juaben Oil Palm Plantation were trained on the monitoring system. According to the principal scientist, four large plantations (BOPP, TOPP, Juaben, and NORPALM Ghana Limited) tried the technology and were satisfied with the outcome. All four plantations still use the technology. The plantations were expected to transfer the technology to smallholders who work with them. MOFA staffs in Ashanti, Central, and Western Regions were also trained to transfer the knowledge to both large and small farms. RELC also has been used to transfer the technology.

Discussion with TOPP suggests that the company views the technology favorably, and that almost all large plantations are using it. But some challenges to the use of the technology were reported (Obirih-Opareh 2008). Although the plantations appreciate the value of monitoring, they are unclear about making decisions on the basis of information collected through observation. Previously, the large development estates hired consultants at substantial cost to advise them on monitoring and control. OPRI now offers such services itself upon request and also as part of its R&D activities. This experience has enabled OPRI to collate data from both estates and smallholder farms to avert potential threats, thus ensuring profitability through sustainable oil palm production. However, the OPRI is constrained in its effort to deliver timely services owing to insufficient funds and logistics to conduct regular visits to advise and guarantee work quality on the plantations.

Overall, results suggest that the early warning system for management of oil palm leaf miner is being used and is perceived favorably. The remaining challenge is to scale up the innovation. Because the early warning system involves a process that must be taught, its effective dissemination requires significant resources and funds for extension services. In terms of the innovation user population, illiteracy and a lack of appreciation by other key management staff to provide a budget line for crop protection services appear to be the two main obstacles impeding further adoption of the early warning system.

Aribro Broiler Nucleus Population

The breed was developed to reduce the high cost of importing day-old chicks, broiler hatching eggs, and broiler parent stock. The near collapse of Ghana's poultry industry was the number one motivating factor behind the development of the Aribro broiler chicks. Ghana's overreliance on foreign hatcheries contributed to high input and production, the nation's inability to compete in the poultry industry, and resultant losses in the Ghana's foreign exchange. The country's Veterinary Services Directorate estimated that about 220,000 hatching eggs and 1.5 million day-old chicks were imported into Ghana in 2008 (GNA 2009).

In 2009, ARI introduced the Aribro broiler, a new breed of chicken well-adapted to the local environmental conditions of Ghana. The first phase of the project sought to produce rapidly growing birds (2kg in 6 weeks) and relatively cheaper birds with a comparatively low mortality rate. When recommended husbandry practices were followed, the Aribro birds had less than 2 percent mortality, as they were accustomed to the Ghanaian environment. The husbandry practices were not markedly different from that already practiced: for one to three weeks the birds were given starter feed, followed by developer feed for two weeks, and finisher until sold.

The development of the Aribro parent lines made it possible to produce day-old chicks domestically at a lower cost than those produced by imported parent lines. In 2009, parent lines cost a minimum of three euros (equivalent to 4.29 USD) per parent chick (GNA 2009). Aribro chicks were sold at GHC 1.6 (1.10 USD) compared to GHC 2.2 (1.52 USD) for imported chicks, saving farmers GHC 0.6 (0.41 USD) per bird.

ARI developed the technology with its own resources. Dr Kwame Boa-Amponsem, the Aribro project leader, acknowledged that due to the limited availability of research materials, it took the ARI roughly 30 years to accomplish what could have been achieved in about 4 years given adequate resources (GNA 2009). Nonetheless, he indicated that the technology has been highly adopted.

Since its development, the technology has been disseminated through mass media. The second phase of the project sought to build sheds and expand existing facilities to increase housing capacity to accommodate a 3,000-bird nucleus flock and a hatchery. The current facilities can only accommodate 800 birds.

The principal scientist produced a list of poultry farms that have used Aribro chicks: Tako Farms, JB Farms, Adom Farms, MP Farm, and Friends City Farms, as well as the ARI Credit Union (ARICUS) farm. The research team held discussions at the ARICUS farm, an umbrella body (credit union) under ARI governed by a project committee. The farm is owned jointly by ARI and the credit union, each with a 50 percent share. The discussion with informants suggested that farmers are willing to buy the chicks if they are made available, but to date the supply of birds has been limited.

ARICUS farmers explained that they took three batches of 300 chicks and recorded a 100 percent survival rate. Though objective tests have not yet been conducted to confirm this, the farmers also indicated that the broilers seem resistant to gumboro, a devastating disease of poultry. Aribro broilers are able to withstand the disease even when vaccination is delayed by about a week. They were also reported to be less susceptible to paralysis. Compared to other stocks, which might have one paralyzed bird out of every 100 birds, the Aribro records only 5–10 paralyzed birds out of every 500. Though growth rate is dependent upon the feed used, the farmers claimed that ARIBRO broilers also grow faster than imported breeds. Aribro broilers exhibit outstanding feed efficiency and are expected to reach 3kg in about eight weeks; however, they appear capable of reaching that weight in only six weeks.

Additionally, adoption of Aribro broilers remains constrained since production and supply of the breed remain strictly within the domain of ARI. ARI reports that, similar to all breeds, the Aribro broiler undergoes annual selective breeding and that they were able to produce about 2,300 chicks a week for the market. If the institute were to receive greater assistance from the government, however, it could produce even more (GNA 2009). Until production and supply of the Aribro broiler is commercialized, market demand will not be met. This situation is exacerbated by poor planning. The day-old chick market is seasonal, lasting only two months a year (September and October). Also, the number of hatcheries is insufficient, and the Aribro parent stock is aging. It should be noted that the project is in the process of acquiring its own hatchery, and with control of a nucleus population, production of day-old chicks can be expanded if demand continues to increase.

Integrated Approach to Pest Management of Groundnut

Groundnut is an important leguminous crop in Ghana. It is estimated that more than 90 percent of households residing in a typical northern farming community cultivate groundnuts (Tsigbey et al. 2004). In the mid-1970s and early 1980s, Ghanaian farmers were turning away from the groundnut cultivation because of high disease and pest incidence. The diseases that cause the most damage are early and late leaf spot, rust, rosette, root rot, and southern stem rot. Major pests are leaf hoppers, soil arthropods (particularly termites), earwigs, white grubs, symphilids, millipedes, wireworms, and mealy bugs (Tsigbey et al. 2004). In extreme cases, uncontrolled diseases, especially early and late leaf spot, have been found to defoliate up to 80 percent of leaves on groundnut plants. During very wet years, in crops affected by several diseases, yield losses can be as high as 100 percent (Tsigbey et al. 2004). In less extreme cases, diseases result in yield losses of up to 50 percent (Nutsugah et al. 2007).

Dr. Mike Owusu-Akyaw, the groundnut research coordinator for the Peanut Collaborative Research Support Program (Peanut CRSP) at CRI, put together a multidisciplinary team of 13 scientists to develop an IPM approach (Obirih-Opareh et al. 2008). The team included entomologists, virologists, nematologists, weed and soil scientists, and plant pathologists (Brandenburg 2003). Collaborators on the project included:

- SARI, which provided both knowledge and expertise
- MOFA, which participated in the conduct of on-farm farmer field schools

- NCSU, which provided knowledge, expertise, access to publications, as well as funding from the United States Agency of International Development (USAID)
- KNUST, which supported the development of the technology with knowledge and expertise

Funding from USAID through NCSU provided the research team with use of vehicles and other items to facilitate the project activities, such as digital cameras and global positioning system devices. NCSU/USAID funds were also used to provide team members with memberships in the American Peanut Research and Education Society. The program covered three phases: 1997–2001, 2002–07, and 2008–12.

The integrated approach to pest management of groundnut is an environmentally friendly technology designed to control soil arthropods (invertebrates) and foliar pests (particularly aphids). The aphid is the vector that introduces rosette virus into the plant, which has a debilitating effect on the plant. The IPM regime also involves the use of local *alata* or *amonkye* soap instead of agro-chemicals to control aphids. The soap is dissolved in water and sprayed on the plant four times, at bi-weekly intervals, starting from four weeks after planting. The soap spray kills the aphids by dehydrating them. The sprays also have a limited effect in controlling early and late leaf spot. In addition, a small quantity of sugar is incorporated into the soil along the rows of the groundnut plants at planting and 50 days after planting. The sugar attracts black ants to the root zone of the plants where they act as natural predators of soil arthropods.

The local scientists led in the identification of the problem, choice of methodology and the development and dissemination of the technology. The technology was evaluated by external consultants hired by USAID. On the whole, groundnut fields recorded increases in yield that met and even surpassed the research team's original expectations. The team anticipated a fivefold increase in groundnut production over production without IPM. They were correct. Yields were indeed five times greater and some farmers even recorded yield increases nearly 15 times more than previous yields (Obirih-Opareh et al. 2008). These findings were also evaluated by a socio-economic group in CSIR-CRI. The major benefit of this technology is the reduced cost of production and the environmentally sound practice of controlling pests and diseases without the use of synthetic agro-chemicals. The project did not face any major problems in its implementation. The team leader, however, felt that with more resources, the technology could have been extended to most of the groundnut-producing areas in Ghana.

The groundnut IPM approach was publicized and disseminated through a variety of channels. Transfer of the technology, however, officially started in 1999 when the interdisciplinary research team selected approximately 500 different locations for research (Obirih-Opareh et al. 2008). Farmers, extension officers, and researchers participated in the development of the technology through on-station research trials, on-farm demonstrations, and farmer field schools. These participatory approaches were used to introduce the technology to farmers as well as to train them in the specifics of the management approach to enable them to train other farmers in their communities (Obirih-Opareh et al. 2008). The technology was discussed on TV and radio and at field days. Electronic (DVD) and hard copies of documents for training farmers were also prepared, and several journal articles were published.

As a result of this extensive publicity, the project coordinator estimated that by 2009 groundnut IPM was used by roughly 3,000 farming households. He also indicated that the technology had been adopted widely throughout the areas where it was demonstrated, such as Hiawoanwu in the Ejura Sekyeredumase district, Somanya in the Yilo Krobo district of Eastern Region, Atebubu in the Asutifi district of the Brong-Ahafo Region, and Derma in the Brong-Ahafo Region.

The research team visited and held consultations with informants in three districts: Asutifi, Ejura Sekeredumasi, and Offinso. The technology was demonstrated in two of these districts, Asutifi and Ejura Sekeredumasi, and the technology was highly adopted in both. In all three districts, the local MOFA representative was also interviewed. In all three areas, neither the farmers nor the extension officers were able to report that the groundnut IPM technology was practiced. Indeed, this technology is still not well-known in the visited areas. The farmers continue to use chemicals despite the fact that it costs virtually nothing to adopt IPM.

Of all the places visited, groundnuts are still cultivated on large scale only in Ejura, where the farmers were not using the technology although they were aware of it. They believe that since they have cultivated groundnut on the same fields for years, pests and other infections are so high that they can only be controlled with agro-chemicals.

Snail Farming

In 2004, the annual consumption of snails by Ghanaians was over 15,000 tonnes (GNA 2004). Less than a quarter of the consumption came from domestic supplies. The vast majority of the snails consumed by Ghanaians came from Côte d'Ivoire, with imports of about 13,000 tonnes (GNA 2004). Snails are a popular food in West Africa and they remain in high demand.

Snails are high in protein (12–16 percent), iron (45–50 mg/kg), and low in fat (0.05–0.8 percent). They are also believed to have medicinal value for treatment of anemia and whooping cough. Snails are vegetarian and feed largely on fruits and vegetables that are rich in protein and low in fat (GNA 2008).

Wild snail populations have been rapidly declining because of deforestation, spontaneous bush fires, traditional slash-and-burn farming, indiscriminate applications of pesticides, and the continuous harvesting of wild snails including juveniles for consumption and trade. The principal scientist who developed the technology at FORIG was inspired by an award conferred on him by the Italian Snail Farming Association through FAO in 1988 following a research paper published in the *Snail Farming Research Journal*. The snail farming technology development was supported by the then Development of Appropriate and Intermediate Technology of Ghana's Ministry of Science and Technology. The technology includes comprehensive management practices that include snail breeding, production, marketing, and consumption. Providing snails with a diet of leafy greens and vegetables, fruits, tubers, and calcium supplements ensures healthy and optimal growth.

Snail management practices include housing, feeding, and disease and predator control. A suitable site needs to be selected to construct a snailery. About 20 fully grown snails can be housed in a 1m2 space. Optimum stocking density depends on the age and size of the snails. They have to be fed twice a day with greens, usually with pawpaw (papaya) leaves, which are plentiful in humid areas. The housing units need to be observed closely for dead snails and predators. Any eggs found should be picked up and buried in fresh sterilized soil for hatching. The newly hatched snails take about one year to mature. Because snails can multiply very quickly, provision should be made to accommodate expected population increases. A snail farmer in Offinso started snail rearing with only one hutch box, but within 18 months he had 12 boxes filled with snails.

Snail farming technology has been disseminated widely through workshops, journal publications, and books. The books have been translated into all major local languages in Ghana by the Institute for Scientific and Technological Information, a CSIR institute. In 2004, a MOFA employee disclosed that she was receiving an average of three calls per week from people from different churches and organizations across Ghana asking for information and professional advice on snail farming (GNA 2004). Snail farming has been promoted as a livelihood initiative through various training programs to farmers and youth in particular by NGOs such as Action Aid as well as by MOFA itself.

The principal scientist indicated that the technology has been adopted widely not only in humid forest areas in Ghana but also more broadly in Africa. The research team continues to organize focus group discussions with snail producers to share new findings and address farmers' problems. Snail farmers have formed various associations in the Offinso district. One such group, the Amonwi Cooperative Association, has been nurtured by the local WIAD officer. The women farmers, numbering about 230, have been receiving regular assistance and training from the WIAD officer as well as from the district agricultural officer. Snail farming is also widely practiced in Kenyase and surrounding communities in the Asutifi District, primarily supported by Action Aid. In certain communities such as Gambia No. 1 and 2 within the Asutifi District, snail production is a serious occupation.

According to informants, snail production is profitable because the farmers do not have to buy the feed. The only cost they incur is in building a simple structure and an initial 20 snails. Though the construction of the structure is not overly difficult, the cost of startup capital is the main hindrance to the adoption of the technology. Snails have a large market and command high prices. The technology has provided lucrative livelihoods to many people in the forest belts and transitional zones.

Improved Cassava Variety Afisiafi

Cassava and cassava starch products make up an important part of many Africans' diets. In Ghana, cassava is the main starch staple for approximately 80 percent of the population (Gibson 2005). The cassava crop occupies more farmland than any other crop in Ghana, and after Nigeria, Ghana is the second largest cassava producer in the African continent (Gibson 2005). Cassava remains an important source of Ghana's food security since it is cheap, easy to transport, can withstand storage for long periods, and compared to other staples has minimal problems with weeds. However, a range of pests and diseases attack the cassava crop and contribute to periodic epidemics nationally as well as regionally (Gibson 2005).

The Afisiafi cassava variety was developed to replace low-yielding local varieties in 1993. It yields two and a half times the traditional varieties and is also disease and pest-resistant. It is also more suitable for making *gari,* a granular flour of varying texture made from cassava tuber, and *agbelima*, a fermented cassava meal, but is not as suitable for making *fufu*.

In the development of the Afisiafi variety, CRI collaborated with several national and international organizations and programs. These collaborating institutes included MOFA, FRI, the International Fund for Agricultural Development (IFAD), IITA, and the IFAD-sponsored Smallholder Rehabilitation and Development Program. These various institutions and programs contributed by conducting on-farm trials, identifying and selecting farmers, funding credit to farmers, food processing, providing germplasm and planting material, technical backstopping, and training.

Afisiafi was disseminated through the Business Development Unit of CRI. In 1993, CSIR-CRI, in collaboration with MOFA, officially released Afisiafi to farmers, along with two other improved varieties, Abasafitaa and Gblemoduade (Gibson 2005). Discussions with MOFA, exhibitions and the mass media all played a role in the dissemination of the variety. MOFA extension agents supplied cassava sticks free of charge. Though evaluations were undertaken nationally through on-station and on-farm trials at selected farms, from the variety's release in 1993 until 2001 there was little documentation about its diffusion and adoption (Nweke 2005). In 2001, however, CRI researchers reported that Afisiafi, as well as the other two main varieties released in 1993, covered large portions of farmers' fields in Ghana's Eastern, Volta, and Greater Accra regions—all important regions for processing much of the *gari* sold in Ghana's urban centers (Nweke 2005).

Afisiafi has also been among the varieties used for the Presidential Special Initiative (PSI) on cassava. PSI is a Ghanaian government initiative launched in the following areas: cassava starch production, oil palm production, salt mining, garment and textiles, and distance learning. This initiative was designed to diversify Ghana's economy and to transform smallholder production methods, thereby increasing the nation's foreign exchange earnings (Tonah 2006).

The CSIR-CRI scientist interviewed for this report indicated that Afisiafi is cultivated throughout the country, especially in Kenyase, Ejura, and Offinso districts in the Ashanti Region. The research team visited these three places to gain insight on the extent of adoption.

Discussions with informants in these regions revealed that approximately 12 varieties of cassava are cultivated in Asutifi district of the Brong Ahafo Region. These include Afisiafi, Esi Abayaa, Debo, Nkabom, IFAD bankye, Bankyehemaa, and Essam bankye.[8] Cassava is widely cultivated in the region and the research team was informed that the Afisiafi cassava was one of the more popular varieties. The informants gave varied reasons for their preference: early maturity, high starch content, high yields, and suitability for making *gari*. Although many farmers cultivate Afisiafi on a large scale, MOFA continues to distribute planting material free of charge. One of the limitations to its wider adoption may be its unsuitability for *fufu*, a staple food in Ghana. Also, varieties that mature faster have been released since then. Since 1993, the cassava crop underwent further improvement. CSIR-CRI released four new varieties in 2005 and three more in 2010. KNUST and UCC also released new cassava varieties. But overall, Afisiafi appears to have been well received.

Development of Fufu Flour

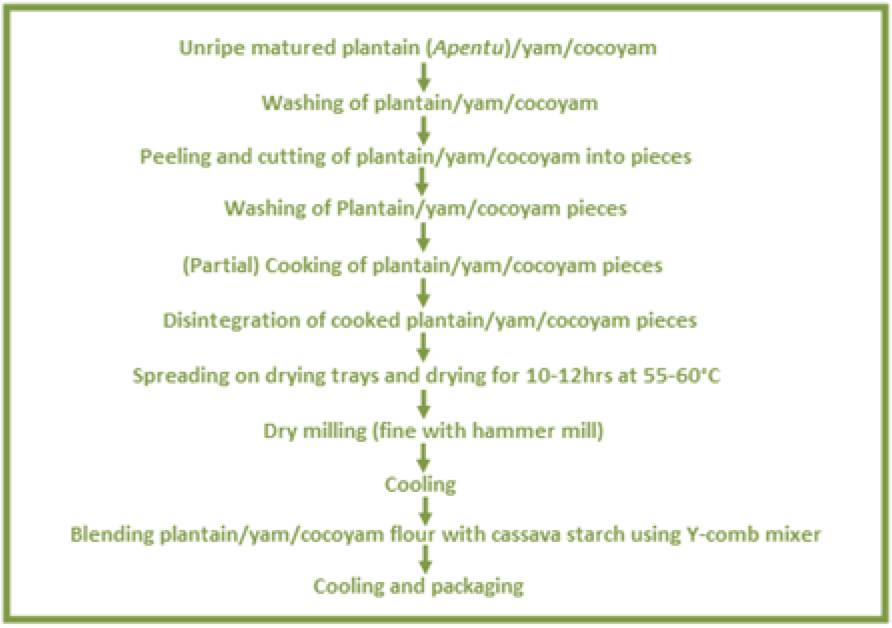
Fufu, which is usually made from a combination of plantain and cassava, is a staple diet for most Ghanaians in the south and the middle belt. The traditional method of preparing *fufu* involves pounding boiled cassava roots together with cocoyam/plantain/yam pieces in a wooden mortar using a pestle to turn the substance into a thick paste. This process is laborious, usually requiring two individuals. Normally, one worker stands and thrusts the pestle downwards into the mortar in rhythmic movements with full force while the other sits at the mortar inserting the cooked foodstuffs along with water, continually turning the fufu inside the mortar while taking care to avoid getting her hands crushed by the pestle (Yeboah 2008).

Fufu flour, although usually made with cassava and plantain, can also be made by substituting cocoyam or yam in place of plantain. It was developed by FRI after a three-year R&D program in 1989 (Yeboah 2008). FRI developed the process without any collaboration with other institutions. *Fufu* flour is not only a product innovation[9] but a process innovation as well. Process innovation involves a new way of making a product or a new/modified method in which business organizations respond to changes in the market prices, resource endowment, or economic change (Owusu-Bennoah et al, 2007).

The preparation of *fufu* flour, depicted in Figure 5.1, involves dehydration of pre-cooked cassava and cocoyam followed by milling to required particle size and mixing with a small proportion of cassava starch to improve the binding of the **fufu** flour when reconstituted.

[8] The latter two varieties were released by CSIR-CRI in 2005.
[9] Product innovation involves a new or modified product.

Figure 5.1—Flow chart for preparation of *fufu* flour



The stickiness of the final *fufu* product, however, is not at the level that is usually desired by all consumers. While the technology is now being adopted by a number of food manufacturers, it is currently being improved upon in two main ways: (i) the addition of potato flour at the blending stage of *fufu* flour production; and (ii) the substitution of cassava starch with cassava flour at the blending stage of *fufu* flour production.

The addition of potato starch was undertaken not by CSIR-FRI but by some *fufu* flour manufacturers because the properties of the added starch contributed to the final quality of reconstituted *fufu*. Some people feel that when potato starch is added, the properties of the reconstituted flour are closer to traditionally prepared (pounded) *fufu*. Though the addition of potato starch to *fufu* flour production is viewed favorably, it is important to note that potato starch must be imported.

The substitution of cassava starch with cassava flour was carried out by CSIR-FRI. The preparation of cassava flour also involves blanching and drying. The team subjected cassava slices to three different blanching time and temperature variations:

- Blanching for 7 minutes and drying at 54.1˚C
- Blanching for 10 minutes and drying at 60˚C
- Blanching for 15 minutes and drying at 60˚C

All drying took place in a mechanical dryer until a moisture content of 8–10 percent was attained. The dried slices were then milled into flour. The innovation of substituting cassava starch with cassava flour was evaluated nationally and the evaluations included panels to assess the taste, texture, and appearance. The results were positive. The innovation was promoted and received publicity through the organization of workshops, exhibitions, and mass media. Training was also offered to food manufacturing companies such as Amasa Agro-processing, Elsa Foods, Praise Foods, and Neat Foods. Now that the process has become available, the annual potential demand for *fufu* flour is estimated at 1,000 –17,100 tonnes (Collinson et al. 2003). The lower figure already represents a substantial new opportunity for Ghanaian food manufacturers.

According to Mr. Joseph Gayin, four companies—Amasa Agro-processing, Elsa Foods, Praise Foods, and Neat Foods—have all adopted *fufu* flour technology and are currently selling their products in both local and international markets. Amasa is a subsidiary of Motherwell Farms and located at Ayikai Doblo, a village 25km north of Accra, near Amasaman in Ga district. Aside from *fufu* flour, the company produces and supplies intermediate products such as cassava flour, fermented cassava flour, *gari*, *agbelima*, and *kokonte* flour to other agro-processing firms such as Elsa Foods, Western Veneer, and Lumber Company Limited at Takoradi, Rimon Haijiar in Burkina Faso, and Cabisco Company Limited. The manager of Amasa indicated that they produce fufu flour three times per week and each time approximately a tonne of flour is produced. He also reported that it was a challenge to meet the demand for *fufu* flour due to lack of raw materials such as cassava.

Although the principal scientists felt that adoption was not high, individuals in the food processing industry, those in Amasa Agro-processing in particular, suggest that even small firms are making use of the process and the demand for the product is high. The manager indicated that the company has continuously worked with researchers and technologists from FRI, the universities and other organizations.

The availability of cassava, on the other hand, was mentioned as a major constraint to flour production. The manager added that the Ayensu Cassava Starch project,[10] if implemented successfully, could have provided the raw material needed for making cassava flour. Places where cassava is available are often inaccessible, leading to high transportation and raw material costs. To ensure adequate supplies, Amasa has established cassava farmer groups in Kwaha Tafo, Nteso, Ankoma, Abisu, Kwadukro, and Asikam. The company also plans to establish similar cassava farmer groups in Brong Ahafo.

Improved Brooding Management of Local Guinea Fowl

The local guinea fowl (*Numida meleagris*) is an important source of meat and eggs for many Ghanaians. Traditionally, guinea fowl are allowed to scavenge freely and fend for themselves. In such a system, the mortality of keets (newly hatched guinea fowl) is high, ranging from 63 percent (Karbo et al. 2002) to 100 percent (Adam 1997) before they are 10 weeks old. Causes of mortality have been attributed to adverse weather conditions, predation, poor nutrition, accidents, and diseases, all of which are related to the environmental management of the birds (Dei et al. 2009).

An improved system of brooding management of local guinea fowl was therefore developed. The system essentially consists of a set of recommendations on artificial brooding, which calls for the confinement of birds from 0 to 8 weeks of age, such as practiced in the commercial poultry sector. This artificial brooding was expected to reduce the effects of some of the causes of keet mortality. On-farm research was therefore conducted on proper housing, feeding, and watering of keets. In this practice, keets are confined in cages made of hardwood, wire-mesh, and aluminum roofing sheet. The cages, which have a one square meter floor space and are raised 0.25 meters from the ground, can house between 20 and 40 keets (Dei et al. 2009). The cages are constructed so that they can be opened from either the top or the side and fitted with padlocks to prevent theft. Birds are fed with broiler chicken starter mash (210 g/kg crude protein) made of 300 g/kg broiler starter concentrate, 500 g/kg maize and 200 g/kg wheat bran. Feed and water are provided *ad libitum.* Heat is provided in the night and during cooler periods of the day using kerosene lanterns.

The improved brooding management of guinea fowl was a collaborative effort between the Animal Science Department of UDS, ARI, the Department of Animal Science of KNUST, and the School of Agriculture of UCC. During experimentation and post-experiment stages, the Agricultural Services Sub-Sector Investment Project provided funding.

The work was based on articles on mortality of guinea fowls and earlier work done at ARI. However, according to Dr Herbert Dei, the scientist involved in the development of the guinea fowl technology, funding was a major challenge. Funding was inadequate to finance both the development and extension/transfer of the technology. According to Dr Dei, due to limited funding his team could not go beyond the demonstration stage.

To develop this technology, on-farm experiments were conducted in three villages near the Nyankpala campus of the University for Development Studies in the Tolon-Kumbungu district of the Northern Region of Ghana within the Guinea Savanna Zone. Two experiments were conducted on-farm to determine the viability and growth performance of confined local guinea fowl of 0-8 weeks of age. In both experiments, confined keets exhibited steady growth at similar rates and mortality rates that were markedly lower than free-range keets. Overall, artificial brooding of local guinea fowl improved their liveability and growth performance as well as increased overall cost effectiveness).

The technology was disseminated by MOFA and a few NGOs working with smallholders. As the researchers did not have the resources to take their technology to potential adopters, they depended on the ministry and some NGOs to transfer the technology to farmers. The scientists published a couple of papers and also wrote in the *Savanna Farmers Journal.* The principal scientist felt that the technology was adopted widely, although he acknowledged that the considerable resources required for construction and feeding of birds would discourage adoption.

In the Kpaachi communities, where the scientists conducted the research, four respondents who participated in the experiments took part in discussions with the research team. It became clear that the brooding management of local guinea fowl was not used in the community beyond the experiment stage. The reason given for this was that farmers could not

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[10] The Ayensu Cassava Starch Project is an indicative and integrated employment program that emanated from the PSIs. PSIs are economic development strategies based on initiatives whereby Ghana could cultivate a competitive advantage. The employment generating potential of these initiatives is large due to linkages with labor-intensive production processes along the supply chain. The Ayensu Starch Company in the Central Region of Ghana was the first step in the overall plan for the cassava starch PSI (Heintz 2004).

formulate feed for the keets. Apparently they were not taught how to formulate the feeds. In the on-farm research that was conducted, the researchers prepared the feeds and the farmers were not involved. Farmers mentioned that in addition to this knowledge gap, there also was an economic reason—the high initial capital outlay for the procurement of the cages. Consequently, farmers went back to the traditional ways of keeping guinea fowl. Farmers did acknowledge the usefulness of the technology in relation to the survivability and better growth of the keets; however, they were unable to adopt the technology.

Improved Soybean Variety Jenguma

Soybean is gaining prominence in northern Ghana because of its multi-purpose usage. However, soybean farmers have been faced with a problem of early shattering of pods with existing varieties, particularly Salintuya I and II. Pod shattering can cause complete loss of the crop on the field if it is not harvested in a timely fashion, leading to a loss of investment by farmers. For individuals and oil mills to maintain sustainable and high soybean production, Jenguma variety was developed. Jenguma's pods do not shatter significantly (only up to 3 percent) even after several weeks following maturity. Another advantage is that it grows well even in the phosphorous-poor soils frequently encountered in northern Ghana. Other notable characteristics of Jenguma are its high protein and oil content (40 percent and 14 percent, respectively) making it suitable for industrial use. Its yield is superior as well—at least 25 percent over previous varieties. Jenguma matures at 110 days and yields 8–10 bags per acre as against 5–8 bags for Anidaso and Salintuya I. Finally, it acts as a trap-crop against *Striga hermonthica,* which causes yield losses in cereal crops estimated at $7 billion annually in Africa (Kim et al. 2004).

Developed by SARI, Jenguma came about in response to farmers' requests through the Research and Extension Linkage Committee for a solution to the early shattering problem in soybean. SARI developed the technology in collaboration with several institutions including IITA, FRI, CRI, the Food Crops Development Project and MOFA. Specifically, IITA provided technical backstopping and germplasm, while FRI was involved in testing of nutritional qualities. SARI introduced early generations from IITA and advanced them through several generations, identifying suitable lines selecting for yield, shattering resistance and stability of yield through genotype x environment interaction studies. On-site evaluation, varietal selection, and testing were conducted using CRI data at four SARI stations—Nyankpala, Damongo, Yendi, and Manga.

Jenguma is suited to Ghana's varied agro-ecology and tolerates the specific stresses of the climatic conditions of the region. MOFA provided support in on-farm testing and conducted demonstrations on farmers' fields. The Food Crops Development Project, funded by the African Development Bank, provided financial support to FRI for suitability for proximate or chemical analysis and to MOFA (through WIAD) for food preparation. The National Varietal Release Committee's inspection visits were also sponsored by the Food Crops Development Project.

Scientifically, the new soybean variety was designated TGX 1448-2E, but upon its release in 2003, it was christened Jenguma, which in the Lobi dialect means "stay and wait for me." To promote large-scale production of the crop in the three northern regions, SARI introduced Jenguma to farmers at Nyankpala, near Tamale (Modern Ghana 2003). Upon examining the performance of the Jenguma variety—which is suitable for cultivation throughout Ghana, and indeed, the whole of West Africa—the National Varietal Release Committee approved its release. It should be noted that it took SARI 12 years to develop this variety (from 1991 to 2003) due to breaks in funding of the research process and for due diligence in generating the relevant scientific data to support its release. According to Dr Nicholas Ninju Denwar, the lead scientist involved in its development, testing could have been done faster but was delayed due to lack of funds.

Currently, seeds are made available for cultivation by a few seed growers, and by three public sector agencies: the Ghana Grains and Legumes Development Board (which produces foundation seed from breeder seed supplied by SARI), the Crops Services Department, and MOFA's extension services. Moreover, the current block farming program of the government, which involves targeting large tracks of arable land for the production of commodities with comparative advantage in specific areas and locations, created an avenue for the cultivation of Jenguma. In the program, beneficiary farmers are supported with land preparation and inputs. Recoveries from the farmers' produce are based on the amount of support the farmers receive. In the case of Jenguma, its adoption has benefited from the program as farmers are provided with seeds and other inputs by Ghana Seed Company for cultivation. Because Ghana Seed Company deliberately phased out previous soybean varieties, farmers have no option but to use this variety under the soybean block farming program of MOFA.

The research team visited the West Gonja District of Northern Region to learn more about the adoption of the technology. Discussions with a seed and chemical dealer within the province revealed that soybeans were no longer produced by commercial farmers in the district because of recent surpluses in the area. Observations and discussions by the research team confirmed that Jenguma was not present in the district.

The research team then visited Tamale, the regional capital, and held discussions with representatives of Ghana Seed Company to find out where the variety is being adopted. The team was directed to the Savelugu-Nanton, Yendi, and Karaga districts in the Northern Region. At Savelugu-Nanton, the team asked the District Agriculture Director to identify a community where further discussions on Jenguma could be held. He suggested the Tibale community for the exercise. In Tibale, 12 farmers joined discussions with the research team. They informed the team that previously they cultivated Salintuya II variety, which was associated with shattering. Joining with other farmers with similar problems in the area, they formed a farmer-based organization (FBO). In 2009, their FBO received financial support from the Millennium Development Authority (MiDA) to cultivate soybeans, and Jenguma was recommended to them by the Ghana Seeds Company.[11]

According to the farmers, Jenguma can be stored for four and half months without shattering, which was very good for the type of farming practiced in the community. Farmers practice crop rotation of maize and soybean. The maize is harvested first, followed by the soybean. The non-shattering characteristic of Jenguma is thus beneficial. Aside from resistance to shattering, other benefits of Jenguma mentioned were its fast growth and ability to be used in different ways (e.g. for local foods such as *kooshe* and *tubani*).[12] On the other hand, Jenguma was reported to be labor-intensive. Also, chemicals are needed to eliminate pests. Finally, timing is very important. If it is not sown at the right time (15 June to 10 July), it is unlikely to perform well.

While there was no adoption in West Gonja, the situation was quite different in Savelugu-Nanton (Tibale). It was highly adopted in Tibale since it was the recommended variety from Ghana Seed Company to both individuals and farmer groups. Jenguma seed is produced by the Seed Growers Association of Ghana and sold to Ghana Seed Company for onward distribution to the market or to farmers. Jenguma seed is cultivated according to the rules and regulations of the inspectorate division of MOFA, which monitors seed production. Currently, Jenguma is the sole variety used under the Government of Ghana's soybean block farming scheme in Northern Region. Formerly, Anidasu variety was used under this scheme but it was replaced by Jenguma in 2009 due the latter's non-shattering and high-yielding traits.

Overall, Jenguma has been well received due to its good qualities. Importantly, the development of Jenguma was a demand-driven response to farmers' expressed need for a non-shattering variety. Through the Research and Extension Linkage Committee, farmers were able to communicate their request for such a technology. The Government's block farming scheme also contributed to the variety's adoption.

Polyculture of Tilapia with Catfish

The polyculture technology focuses on producing two fish species—*Oreochromis niloticus* (Nile tilapia) and *Clarias gariepinus* (catfish)—in a single pond. The objective is to identify stocking practices that improve productivity and incomes through better utilization of natural food resources in a pond. Though cultivating tilapia and catfish together is not a new idea, this project sought to find appropriate stocking ratios to achieve higher levels of productivity. The culture of catfish:tilapia in the ratio of 1:2 per square meter was found to be most appropriate (Obirih-Opareh 2008).

WRI developed this technology through a project funded by AgSSIP. The project was implemented in two phases. On-station trials were first conducted at the CSIR-WRI Aquaculture Research Development Center at Akosombo. The trials featured polyculturing Nile tilapia with various species: *Clarias gariepinus, Heterobranchus longifilis*, prawns, and grey mullet in various combinations (Dankwa et al. 2006). Several experiments were conducted, and the polyculture of tilapia with catfish produced the highest yield. The reason is that while catfish make use of the resources at the bottom of the pond, tilapia makes use of the food resources, especially algae, in the water column. After on-station trials for seven months, on-farm trials were carried out in collaboration with local farmers.

The AgSSIP project, which funded the work, also organized an evaluation of the technology, which found that polyculture was more profitable than monoculture. The findings of the research were disseminated through a workshop. In addition to on-farm demonstrations, visits to Akosombo were organized. The principal scientist indicated that insufficient resources were available to organize adequate demonstrations, but felt that the adoption of polyculture would likely be high, particularly on small farms.

The polyculture technology is widely practiced Sogakope in Volta Region. The team organized a discussion there with 280 pen and cage fish farmers who formed an association. The discussions revealed that apart from one informant who was

[11] MiDA, together with its partners, trains farmers in value chain approaches to agricultural production and assists in the growth and development of FBOs. Farmers receive three weeks of field training on a specific crop and are also assisted with a starter kit of inputs for the chosen crop (MiDA undated).

[12] *Kooshe* is a fried cake made from beans; *tubani* is a steam-cooked bean cake.

advised by a Volta regional agriculture officer to introduce catfish to feed on tilapia fingerlings, no one had received any information from extension officers on polyculture. Moreover, the lone fish farmer who received extension information was told to add catfish to ponds to keep down the population of tilapia fingerlings (so as to produce the desired fish size). He was informed that catfish can be used as a predator to regulate the number of tilapia to prevent overcrowding. This is not the same as the polyculture technology from WRI. None of the fish farmers had heard of the WRI polyculture technology. It is worth noting that some of the fish farmers already rear catfish and tilapia together based on their own experimentation.

When told about the polyculture technology, the farmers expressed interest in finding out more. It is possible that the technology has not been widely adopted because it has not been disseminated through the extension system, which usually focuses on crops and livestock. Fish farmers also indicated that it is difficult to obtain catfish fingerlings in their locale. The farmers proposed that MOFA give as much attention to fisheries as they do to crops and livestock. They also suggested that local hatcheries should be established.

SYNTHESIS AND LESSONS

To achieve success, an innovation system must sustain the technical changes it introduces. Successful innovations are brought about by groups of organizations and individuals working together or through mediating organizations under an appropriate policy environment that fosters efficient improvements. These actors from both the public and private sectors include both those who generate the ideas and technologies and those who find ways to profit by applying them. Although a system that sustains technical change through innovation is necessary for agricultural transformation, it is likely to be as much an outcome of the exercise as a contribution to its development. In any case, it is important to consider which features are essential to a system regardless of what is being examined. In this section, we examine Ghana's research system in terms of indicators of an innovation system using information gleaned from the case studies and the scientist survey.

Responsiveness and Mediating Institutions

Are the research organizations responsive to the needs of the sector? A significant majority—nearly 70 percent—of the scientists surveyed indicated that they developed the technologies in response to demands from MOFA as well as from farmers. This response level was followed by their career interests (31 percent), availability of funds (28 percent), and the interest of collaborating institutions (27 percent). Their key objectives in developing agro-processing technologies were to reduce the drudgery involved in the current practices and to reduce the costs of production. For crop-related technologies, 41 percent were developed due to recognition by the scientists on the limitations or undesirable traits such as size, color, late maturation, susceptibility to pests/diseases, low yield, non-suitability for industrial purposes, and low multiplication ratio.

The motivation for developing technologies reflects the quality of linkages within the system. In all cases, technology development efforts got under way once an existing problem had been observed or when an opportunity to increase farmers' incomes presented itself. The articulation of the problem did not always emerge from farmers but from scientists who were aware of the situation faced by farmers. An exception was the case of Jenguma, where the need for the technology was articulated through a RELC. One possible reason for such a focus on problem solving may be because in most of the cases, technologies are developed through projects and external funding, which might require far more stringent articulation of the need than in gaining access to internal funds.

Funding and Institutional Adequacy

In the survey, the scientists complained of familiar difficulties:

- Inadequate and untimely release of funds (25)
- Lack of laboratory facilities (41)
- Inadequate technical knowledge and institutional support (22)

When asked what activities were not implemented because of inadequate resources, 30 percent mentioned that they should have carried out further analysis or testing. About 13 percent indicated they could have conducted trials at other locations to better identify the most suitable areas for a given technology. However, 20 scientists did not respond to this question and 15 percent indicated that nothing need have been done differently. Though the question pertained strictly to the technology development process, seven scientists gave answers relating to technology transfer. These respondents mentioned that they should have had the resources to go to other communities to disseminate information or to extend the technology to other areas.

The bulk of the technologies studied were developed with funding from special projects or sources outside the research system. Many were funded by projects managed by MOFA. Only in two cases were the technologies developed with funds from internal sources, but these took much longer to develop—20 years in the case of Aribro and 10 in the case of Jenguma.

Linkage and Collaboration

The bulk of the case technologies were produced under collaborative arrangements between organizations within the country and international research organizations. Collaboration was guided by the need to bring together organizations with mandates over different ecologies and those with specific capabilities. These collaborations were particularly evident in the case of efforts funded by external sources. It is quite likely that the funding organizations required collaboration between relevant organizations.

Collaboration was also common among the larger set of technologies identified. The collaborations may take the form of one organization funding the other, or knowledge sharing by providing equipment and technical support. Of 109 agricultural technologies covered, 43 percent had both national and international collaborating institutions engaged in the development of the technologies. Roughly 24 percent of the technologies were developed through collaborations with other institutions in the country, and 11 percent were developed with only international partners. Noteworthy is that a significant percentage (22 percent) of the agricultural technologies were developed with no collaboration at all.

Approximately 85 agricultural technologies were developed through collaboration with at least one partner. MOFA was also considered a partner in the development of nearly all the technologies, often providing support by conducting on-farm testing and demonstrations, and by identifying and selecting farmers. The next most common collaboration was with IITA in the form of funding, sharing of knowledge and expertise, and in the provision of germplasm. As one might expect, collaboration with internal organizations was more common in the development of crop technologies.

Technology Development Process

Are technologies developed under sufficiently rigorous processes and do they include mechanisms to elicit producer perceptions? Almost all (94 percent) of the agricultural technologies were agronomically or technically evaluated. Only 5 percent did not undergo any technical evaluation. Additionally, a little over half of the 109 technologies (53 percent) underwent both on-station and on-farm testing. Conducting on-farm testing is important since it can separate the effects of natural field variability from the effects of treatments being compared. On-farm testing also provides an accurate basis for farmer management decisions. Farmers are able to participate in identifying problems and priorities, managing the experiment, and evaluating results. It is usually used as a means to ensure that technologies developed on-station will be relevant to the targeted client adopters (AFNETA 1992). Thus, on-farm testing facilitates the adaptation of the technology to the needs of farmers. About 18 percent of the technologies in the survey were only tested on-station.

It is difficult to find out how many of the technologies in the survey were economically evaluated since 37 percent of the scientists did not provide any response to this question. Roughly 57 percent were economically evaluated, while 7 percent indicated no economic evaluation was done.

Perceptions on Adoption and Availability of Technologies

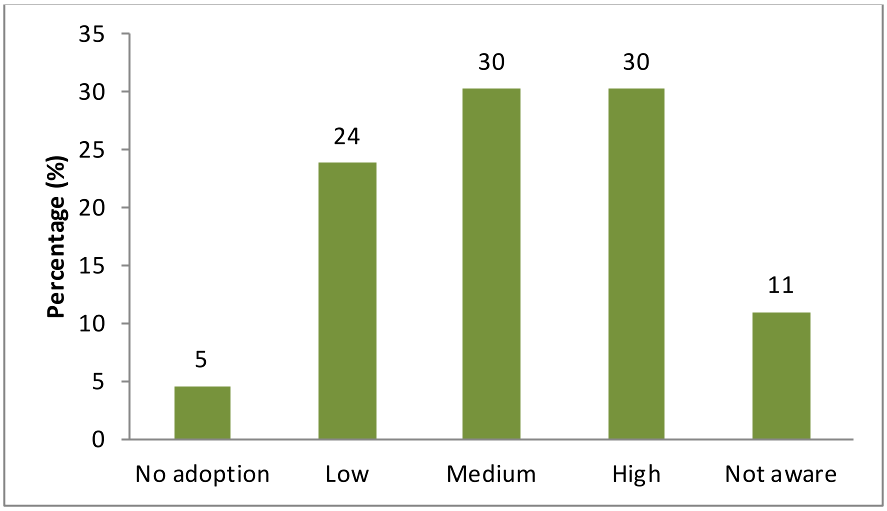
Fifty-three percent of the scientists interviewed indicated that the technologies they developed are or were available on the market, while about 31 percent responded that the technologies were unavailable (Table 6.1). About 18 percent of the respondents, however, were not aware of the availability of the technologies they developed. The scientists were further asked if they were aware of whether or not farmers were using the technologies. Eighty-nine percent of the scientists claimed they were aware, and 11 percent were not (Table 6.2). The scientists were also asked to report their perception of the extent of adoption of the agricultural technologies they developed. Roughly 30 percent rated the adoption of their technologies as high (Figure 6.1). The same percentage of scientists also rated the adoption of the technologies as medium. About 24 percent responded that the technology had low adoption. It should be noted that about 5 percent indicated that their technologies were not adopted at all, and 11 percent claimed to have no knowledge about the adoption rate.

Table 6.1. Scientists' perceptions on availability of technology in the market

Item	No.	%
Perception on availability of technology in the market		
Available	58	53.2
Not available	31	28.4
Not aw are	20	18.4
Total	**109**	**100**
Aw areness on farmer technology use		
Yes	97	89.0
No	12	11.0
Total	**109**	**100**

Source: IFPRI-STEPRI survey 2010.

Figure 6.1—Perception of scientists on adoption of agricultural technology



Source: IFPRI-STEPRI survey 2010.

The scientists also identified some factors that hindered the adoption of the agricultural technologies they developed. Approximately 28 percent of the scientists identified limited publicity as a major factor hindering adoption (Table 6.2). Moreover, about 21 percent indicated limited supply or poor distribution of technology as a limiting factor. Another 28 percent indicated high cost of adopting the technology (either high cost of the technology itself or the required inputs for its use) as inhibiting adoption. This was particularly true for hard technologies such as high-yielding varieties. A number of scientists mentioned poor seed distribution networks in Ghana and the inability of GLDB to produce enough foundation seed as an impediment to adoption. GLDB, the sole producer of quality foundation seed in Ghana under the National Seed Program, obtains breeder seed of cereals and legumes from CRI at Kumasi and from SARI at Nyankpala to produce foundation seed. The foundation seed is then supplied to registered seed growers to produce certified seeds for farmers.

Table 6.2. Scientists' perceptions of critical factors that hinder adoption and transfer of agricultural technologies in Ghana

Factors that hinder adoption	No.[a]	%
Limited publicity/limited extension	31	28.4
Cost of adopting the technology	31	28.4
Limited supply or poor distribution of technology	23	21.1
Undesirable characteristics of the technology	17	15.6
Unavailability of necessary inputs to use technology	9	8.3
Attitude of farmers to new technology	8	7.3
No response	9	8.3
None	4	3.7
Others	15	13.8

[a] Multiple responses.

Source: IFPRI-STEPRI survey 2010.

Technologies can be categorized as soft or hard. Soft technologies essentially involve knowledge, the adoption of which can be sustained by producer-to-producer exchanges or sustained dissemination by extension agencies. Hard technologies require that a product made available for adoption, the typical example being a new variety. To guarantee continued adoption, the technologies must be either publicly distributed or commercialized and made available to producers at a reasonable cost so that making a profit is possible.

Many of the soft technologies appear to have fallen through the cracks (such as IPM) although some were found to be very profitable. This is despite the fact that MOFA itself is a partner in technology development because it facilitates field trials. Project orientation of these technology developments could be one source of the problem. When asked what they would like given additional resources, a common answer was to put more effort into dissemination of technologies. This suggests that they feel that if they do not oversee the technology's dissemination themselves, no one else will. Grasscutter production, a soft technology, has done well because it was taken up by NGOs as well as MOFA. Technology development is invariably followed by workshops, production of brochures, meetings, radio talk shows, and so forth, but these efforts are not always sustained. They are not mainstreamed into technologies that are promoted by the extension system.

Hard technologies require commercialization. An example of an effective technology whose dissemination is constrained by the absence of commercialization is Aribro. One policy that in fact may discourage public research organizations to develop partnerships with private companies is the pressure on the former to become financially independent or generate more of their resources. Without the property rights that might bring royalties, genetic material in particular may not be commercialized. Where the hard technologies are made available to producers through public or private channels, they are disseminated better (Jenguma, cassava).

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APPENDIX: 109 AGRICULTURAL TECHNOLOGIES

No.	Technology	Institution	Objective/description
1	Scouting system for managing bollworms on cotton	SARI	The technology is a management practice in which the farmer scouts the cotton plant on the farm to detect bollworm before spraying. This technology leads to lower production costs for both cotton companies and farmers.
2	Bio-control of *Striga hermonthica* with soybean	Crop Science Dept, UDS	The technology, which enables the use of a biological agent to control weeds, is a cultural practice that involves growing the soybean line TGC 1834-5E on a piece of land for 2years to reduce the seed-bank population of *Striga hermothica* before growing sorghum. Plant sorghum, maize, or millet on the land after 2years of growing soybean for another two years and repeat the cycle. With the technology, neither hand-pulling nor spraying is needed.
3	Bud manipulation technology	CRI	Developed to increase both the availability of healthy planting materials and the multiplication ratio of plantains and bananas, this technology comprises three different propagation techniques: split corm, decapitation, and tissue culture.
4	Cotton-cowpea relay intercropping	SARI	The technology ensures crop diversification, thus enabling farmers to harvest at least one crop if the other fails, as well as encouraging farmers to incorporate cotton into their cowpea farm to improve cotton production in Ghana. The practice involves three stages: • Planting cotton at a spacing of 90cm from May to June • Skipping a row after every two rows of cotton to make room for strips of cowpea • Planting cowpea at a spacing of 60 cm by 20 cm, 2 WAP cotton; and applying 200 kg (4 bags) of 15-15-15 NPK/fertilizer/ha. 14 days after planting cotton.
5	Cowpea variety Bawutawuta	SARI	Bawutawuta is resistant to *Striga* and pest infestation. It is high-yielding and tolerates drought. It also improves soil fertility and has high biomass potential.
6	Cowpea variety Padi Tuya	SARI	The variety was developed to improve yield and resistance to aphids. It has large white seeds, is early-maturing (65 days), and requires a shorter cooking time.
7	Cowpea variety Songotra	SARI	The variety is high-yielding, early-maturing and is resistant to *Striga gesnerioides*.
8	Cowpea variety Vallenga	SARI	Vallenga is a red-seeded, early-maturing (60-65 days) cowpea variety with high yield potential (about 2.0 t/ha).It is also drought-tolerant and tends to have green leaves after harvesting, thus providing fodder for livestock.
9	Cowpea variety Zaayura	SARI	The new variety is high-yielding, early-maturing, and resistant to aphid pest infections.
10	Mako Ntoose	CRI	Mako Ntoose is a crop that shares features from both tomatoes and peppers. It is very high in vitamin C, mild in taste, and can be use to feed children. It grows with little moisture, has a long shelf life, and can be cultivated throughout the country. It is often used in place of tomatoes during lean tomato seasons.
11	Cowpea variety Bengpla	CRI	Bengpla is an early-maturing variety (65 days) derived from a complex cross ([TVx 33-1J x TVu 6203] x TVx 33-1J) x TV x 6332. The parents of TVx 33-1J are TVu 37 and TVu 530, which represent Pale Green from South Africa and Ibadan. It contains 29.75 percent protein and 1.91 percent oil and is resistant to pod shattering, lodging, and various diseases (anthracnose, web blight, brown blotch, *Cercospora* leaf spot, *Septoria* leaf spot, bacterial blight, etc).
12	Drought-tolerant maize varieties Enii-Pibi, Omankwa, Aburohemaa, and Abontem	CRI	The drought-tolerant maize varieties are Quality Protein Maize (QPM) varieties. They are early-maturing (75-90 days) and *Striga*-resistant.

13	Oil palm food crop fertilizer management strategy	OPRI	The technology is a fertilizer application and management strategy developed to maximize yield of oil palm intercropped with food crops. It involves the following steps: • Line and peg field at 8.8m triangular for oil palm. • Plant oil palm with protective collars around them. • Systematically plant food crops in the inter rows of the oil palm 1m, 1.5m, 2.m away from the oil palm rows in the first, second, and third years after establishment of the oil palm. • Broadcast fertilizer at the following established rates: oil palm with plantain at N25-P35-K50; oil palm with maize at N50-P75-K100. • Oil palm with cassava at N75-P115-K150.
14	Groundnut variety F-Mix	SARI	The variety has high levels of resistance to early and late leaf spot and is well-adapted to the high rainfall belts of northern Ghana. The variety has high oil content (about 49 percent), matures in 120 days, and yields an average of 2500 kg/ha.
15	Plant-derived insecticide	FORIG	Neem and jatropha are mixed together to form an insecticide for use on cereal, grain, and vegetable crops.
16	Early warning system for the control of oil palm leaf miner	OPRI	The technology involves the early detection of warning signs or symptoms and employing non-chemical and environmental friendly means of curtailing the spread. The technology works as follows: • Assess plants visually to observe defoliation and browning due to activity of pests. • Sample lower fronds that are green (i.e. one frond/tree/ha). • Pull fronds if easily accessible for observation of stages or cut fronds where the trees are tall. • Assess the various stages of the leaf miner by counting the stages. • Work out the index by dividing each number of stages by the representative frond number. If the index is beyond 1.5, then the tree should be fogged with the appropriate chemical.
17	Field management of plantain nematodes using *Pueraria phaseoloides* cover crop	CRI	The technology, developed to address high susceptibility to nematodes in plantain, uses *Pueraria phaseoloides*, a leguminous cover crop, as a component in plantain-based cropping systems. Exudates from *P. phaseoloides* roots are toxic to nematodes, which cause root damage. This technology results in an increase in plantain's uptake of water and nutrients.
18	Golden Jubilee maize variety for use as human food and in industry	CRI	The Golden jubilee maize variety is a yellow version of the Obatanpa, which is a QPM variety. It contains lysine, carotene, and tryptophan – all essential amino acids necessary for normal growth and development in both humans and animals.
19	Grafting of nutmeg	PGRRI	The technology involves the grafting of a known sex of matured plants that have flowered. It reduces the flowering period and enables female plants to be known. The technology increases the number of plants.
20	Groundnut variety Sinkarzei	SARI	Sinkarzei was developed to improve yield and oil content of groundnuts. It originates from variety ICGS 114, which was derived from a three-way cross between two adapted cultivars in India and an introduced germplasm line ([GAUG 1 x NC Ac 17090] x Kadiri 3).
21	Herbicide use and efficacy in oil palm	OPRI	The technology was developed to make scientific recommendations for local farmers in order to reduce the cost of weed management in oil palm farms and to protect the environment. It involves the use of 2 liters of salts to 1 liter of herbicide (Roundup). The mixtures were: Roundup + sodium chloride, Roundup + ammonium sulphate, and Roundup + urea.

22	Identification of soil suitable for economical oil palm production	OPRI	The technology provides an inventory with descriptions of soils at Kusi, Twifo Praso, and Adum Banso—all areas climatically suitable for optimal oil palm production. The soil descriptions cover land characteristics and physico-chemical properties. The soils were evaluated for their suitability for oil palm cultivation. The technology includes production forecasting, which considers not only climate (rainfall and water deficits) but also soils. The agro-management practices necessary to manage the limitations associated with the soils are outlined and recommended for implementation.
23	Improved fallow systems for soil fertility maintenance	SARI	The technology addresses low soil fertility due to N deficiency, high cost of purchasing inorganic fertilizer, environmental pollution, and issues of releasing carbon into the atmosphere (carbon concentration in the soil). The technology involves the cropping of fallow lands with legume *Calopogolitan mucunoides* for a year or two, then plowing it into the field. The land is thus ready to be planted with crops. Through this practice, fertilizer costs can be reduced 40 percent.
24	Improved groundnut variety Nkatesari	SARI	Developed to diversify varieties suitable for confectionary, the variety shows improved resistance to foliar disease and good field dormancy. It is medium-maturing (110 days), has a kernel yield potential of approximately 2 t/ha, and has an oil content of 47 percent.
25	Improved production of groundnut through deployment of IPM practices	SARI	Developed to counter pest attacks in groundnut production, the technology uses neem powder to control pest infections in the soil and, as a result, increases groundnut productivity.
26	Improved rainwater productivity through combination	SARI	Developed to address the problem of erratic rainfall pattern on agriculture and its effect on soil productivity. The technology increases rainwater productivity by 200 percent, reduces soil erosion, and prevents silting of dams.
27	Improved rice variety Sikamo	CRI	Developed to replace non-performing rice varieties in inland valleys and irrigated ecologies across the country, Sikamo is a disease-resistant and high-yielding variety. Though it is less tolerant of drought, Sikamo has a potential grain yield of 5.5 t/ha.
28	Improved cassava variety Afisiafi	CRI	Afisiafi is a disease- and pest-resistant variety that yields about 2.5 times the traditional varieties.
29	Improved cassava varieties Ampong, Broni Bankye, Sika Bankye, and Otuhia	CRI	These varieties resist African cassava mosaic disease, are drought-tolerant, and yield as much as 35 t/ha. They also demonstrate the highest starch yield ever recorded in Ghana.
30	Improved cassava variety Dokuduade	CRI	This variety is resistant to African cassava mosaic disease, has low cyanide content, and produces yields of about 2.5 times traditional varieties.
31	Improved variety of cowpea	CRI	The technology is best suited for the forest savannah, forest transition and savannah zones. It solves the problems that accompanied existing varieties like Soronko, which although high-yielding makes harvesting difficult since it spreads on the ground.
32	Improved cowpea variety Apagbala	SARI	Developed with the aim of improving the yield of local cowpea varieties, Apagbala matures 60–65 days and the percentage of harvest in the first round is 70–80% of the pods.
33	Improved cowpea varieties Bengbla, Ayiyi, Anidaso, and Bengbie	SARI	Developed to provide alternatives to low-yielding local varieties susceptible to pests and diseases.
34	Improved cowpea variety Marfo Tuya	SARI	Marfo Tuya matures in 65–70 days and can stay erect without the use of runners. It has the potential of yielding 2.5 t/ha and yields 10 percent more than the Bengpla variety (the most common improved variety) and 13 percent more than the traditional variety. It tolerates high night temperatures during reproductive development and has a higher content of iron and calcium than Bengpla.

35	Improved cowpea varieties Nhyira and Tona	CRI	Tona, variety IT87D-2075, is resistant to leaf hoppers, Cercospora leaf spot, and other viruses. It is medium-maturing (71–80 days), tolerates drought, and has high nutritional content (mainly iron, phosphorus, and energy). Nhyira, variety IT87D-611-3, is early-maturing (65–68 days), high-yielding (2.3 t/ha), resistant to anthracnose and Cercospora leaf spot, tolerates drought, resists leaf hoppers, and is high in iron, phosphorus, and energy.
36	Improved cowpea variety Asontem	CRI	Asontem is an early-maturing variety (65–70 days) that resists diseases like anthracnose, web blight, and brown blotch. It has narrow leaves, red color, and a medium-sized seeds.
37	Improved groundnut variety Kpanielli	SARI	The variety matures in 120 days and has a potential yield of 2.4 t/ha. It is resistant to Cercospora leaf spot and has high oil content (51 percent).
38	Improved groundnut variety Mani Pinta	SARI	The variety has high oil content (about 53 percent) and is high-yielding. It resists common diseases, particularly leaf spot. It is late-maturing (120–130 days) and has a kernel yield potential of approximately 2.2 t/ha. With good field management, farmers can easily obtain an additional 1.7 t/ha.
39	Improved groundnut variety Edorpo-Munikpa	SARI	This variety has higher oil content than earlier varieties such as Mani Pinta. It is high-yielding (kernel yield 1.2 t/ha), early-maturing (100 days), and moderately resistant to early and late leaf spot. The pods are typically two-seeded, slightly beaked, and the constriction between the seeds is slight with seed weight of 65 grams.
40	Improved groundnut variety Jusie Balin	SARI	Developed to improve yields in groundnut production, Jusie-Balin has a high level of resistance to leaf spot disease, is early-maturing (approximately 104 days), and the kernel yield potential is approximately 2.0 t/ha. With good field management, farmers can easily obtain additional 1.5 t/ha. The kernel is particularly suitable for a range of confectionary products and contains about 46 percent oil.
41	Integrated approach to pest management in groundnuts	CRI	The technology employs an environmentally friendly pest management approach that considers the phenology of the plant as well as the life cycle of the pest and its interaction with the environment. The practice involves the use of local soap (*alata*) instead of agro-chemicals to control aphids. The soap is dissolved in water and sprayed on the plant 4 weeks after planting. The solution is applied four times at bi-weekly intervals. The soap dehydrates the aphid until it eventually dies. Although minimal, it also has an effect on early and late leaf spot diseases.
42	Integrated practice to control pest and diseases of citrus	CRI	Improves citrus productivity and solves the problem of indiscriminate use of insecticide in citrus production.
43	IPM for control of sorghum head bugs	SARI	Developed to counter the damage caused by head bugs (a perennial problem in sorghum production), the IPM involves planting sorghum early in the cropping season, intercropping sorghum with cowpea, and spraying with either 5% neem extract or 10% Hyptis extract.
44	IPM package for controlling pests and diseases of cowpea	Crop Science Dept, UG	The technology is an integrated crop production and pest management strategy for cowpea, which involves the following steps: • Select weedy sites with deep loamy soil. • Do minimum tillage by applying contact (systemic) herbicide. • Conduct germination tests to select healthy seeds. • Plant on time and at optimum plant population. • Use recommended resistant variety. • Control weeds on time. • Apply insecticide when necessary.

45	Management of acid soil	SRI	The technology involves the following steps. Step 1. Soil should be analyzed to determine the pH. A soil pH below 5.0 needs to be improved. The situation is critical when the pH falls below 4.5. Step 2. Materials necessary for improvement of soil pH include: • Lime (agricultural lime, oyster/clamshells, ash from rice straw or saw dust): improves soil pH, neutralizes aluminum and other ions, and improves levels of exchangeable calcium—proper lime should be used when pH is 4.5 or below • Organic materials (farmyard manure, manure, compost): adds some nutrients in the soil, binds aluminum, may improve the soil pH • Rock phosphate: improves soil pH, adds phosphorus, calcium and other nutrients, is more soluble when pH is below 4.5 • High amount of single or triple super phosphate: overcomes P-fixation capacity of the soil and makes phosphorus available Step 3. Application of liming materials – it is safe to use 0.5 t/ha lime in combination with organic materials or phosphorus; however, 1.0 t/ha lime should be used when the pH is below 4.5.
46	Management of banana weevil	CRI	Developed to reduce the population of the banana weevil, increase the number of banana suckers produced, and facilitate more vigorous growth and higher yields. The technology involves the following steps to manage weevils: • Paring as a means of reducing weevil load on planting materials • Trapping split pseudo stems • Soaking parrel suckers in pesticide solution prior to planting • Use of neem extract as a botanical insecticide • Clearing field of dead leaf material • Planting suckers immediately following removal from mother stands
47	Minisett technology	CRI	The technology, developed to increase the ratio of yam produced, involves cutting yam stored for 3 months at room temperature into sets (50 g each) from the head, middle, and tail portions. The cut surfaces of the sets are treated with sawdust or ash containing an insecticide (Cymethoate at 2ml L^{-1}), fungicide (Dithane M45 at 5g L^{-1}), and wood ash (5g L^{-1} water). These sets are then air-dried for 24 hours. To induce sprouting, the sets are each dipped into ethephon solution for 1 hour. Whereas traditional methods produce a 1:6 yam propagation ratio, the Minisett technology has the potential to produce a 1:40 ratio.
48	Neem-incorporated management strategy as an insecticide for cowpea pest	SARI	Developed to reduce the use of synthetic fertilizer and minimize environmental pollution from pesticide usage and insecticide spraying by farmers, this technology uses neem seed power (at 10 percent by weight or neem seed oil at 2-3 ml/kg) to protect stored cowpea/bambara seed.
49	Oil palm intercropped with rice	OPRI	The technology was developed to enhance the outputs of oil palm plantation farmers by determining which rice spacing with oil palm could permanently sustain rice production without constraining oil palm production. It recommends the following steps: • Line and peg valley bottom field at 8.8m triangular. • Plant oil palms with protective collars around them. • Kill weeds in the inter-rows of oil palm using 200ml Roundup in 15 liters of water to provide a 3-month weed-free cover. • Plant rice 1m, 1.5m, and 2m respectively away from oil palm rows in the first, second, and third years of the establishment of the oil palm. • Space rice at 20x20 cm by dribbling. • Apply fertilizer to rice $N_{20}.P_{60}.K_{90}$.

50	Optimum date of planting, plant population and fertilization of soybean	SARI	The technology helps in weed control and better seed quality. It involves the following recommendations: • Planting date: 15 June to 15 July • Plant population: 16 kg per acre /45 kg per ha • Fertilization: 25kg of N, 30kg of KO and 60kg of P_2O_5 per ha
51	Organic production of yard-long bean	Crop Science Dept, UG	Developed to supply nutrients to boost the production of yard-long beans (which do not respond well to inorganic fertilizer), the technology addresses the difficulties farmers face in terms of costly fertilizers, poor soil fertility, and the high demand for organically produced commodities.
52	Post-harvest maize and seed production	CRI	A drying process developed to improve the storage capacity of maize and cereals and to reduce post-harvest losses.
53	Procedure for producing healthy citrus seedlings	CRI	Procedural steps developed and published in a book to serve as a reference for farmers.
54	Rate and timing of N fertilizer application for improved production	CRI	Research determined the optimum N rate for improved production of rice in inland valley and irrigated systems. By following the proper rate and timing of N fertilizer, drought- tolerant, fine grain quality rice is produced.
55	Rock phosphate recapitalization: A phosphorous fertilizer for matured oil palm in the semi-deciduous forest zone of Ghana	SRI	The technology—a recommendation to incorporate rock phosphate in the production of oil palm—is an environmentally friendly and affordable phosphorous fertilizer that improves soil nutrients.
56	Sawah technology: for lowland rice production (effective land, water and nutrient management)	SRI	Seeks to improve lowland rice production in Ghana through effective management of land, water and nutrients.
57	Selective use of insecticide for oil palm leaf miner control	OPRI	The technology reduces the indiscriminate use of insecticides. It complements culture control (e.g. early pruning) and natural enemy action of leaf miner larvae to tolerable levels.
58	Soil database and information bank	SRI	This technology is a database that manages soil, geology, and environmental resources information generated from field soil surveys, classification, and soil productivity research activities. The technology provides information on the properties of soil resources for the development of appropriate soil management interventions for agriculture, forestry, and general land use planning.
59	Soil, plant, water, and fertilizer testing calibration/correlation	SRI	Determines the presence of N and phosphorus in soil, important for determining the amount of water and fertilizer necessary for effective growth of a particular crop.
60	Sorghum variety Naga white	SARI	Naga white is a white-seeded, early-maturing (95 days) sorghum variety with the potential to yield 5/ha and is easy to cook.
61	Sorghum variety Kapaala	SARI	Developed to give better results for yield and quality compared to previously released varieties like Naga white and Kadaga. The variety is high-yielding and has good grain, malting and brewing qualities, is slightly tolerable to drought, and has high ability to improve soil fertility.
62	Soybean varieties Salintuya 1 & 2	SARI	Salintuya 1 & 2 soybean varieties have high-yielding potential of 1.8–2.5 t/ha. They are disease-resistant, cream bold seeded, and have good storability. Salintuya1 is a medium-maturing (115 days) variety, while Salintuya 2 is late-maturing (130 days).
63	Soybean varieties Jenguma and Quarshie	SARI	Developed to solve the problem of early shattering associated with Salintuya 1 and 2, the varieties do not shatter easily and they grow better in phosphorous-poor soils compared to Salintuya. Jenguma has 40 percent protein and 20 percent oil and is suitable for industrial use. It has a high-yielding potential (1.8–2.5 t/ha), is field resistant to pod shattering, and has the ability to kill *Striga*. Quarshie is drought-tolerant and suitable for cultivation in the Upper East Region because of its erratic rainfall pattern and poor climatic conditions.
64	Timing and frequency of weeding	CRI	The technology involves weeding in the 3 weeks after sowing (21 days after planting) to coincide with fertilizer application. If land preparation is done well, weeding would be done once followed by hand removal of only a few weeds.

65	Undercropping oil palm with cocoa	OPRI	Crops are spaced effectively to obtain maximum yield from both crops. Recommended triangular spacing of the oil palms is 9.9 and 10.5 meters, with the cocoa being under-planted at a spacing of 2.4 meters triangular (using mixed hybrids).
66	Use of crotalaria/ calopegenium with rock phosphate for improved soil fertility	SARI	Developed to improve soil nutrient by using a leguminous plant for a short period of fallow coupled with the use of rock phosphate.
67	Maize variety Abeleehi developed	CRI	Abeleehi is an improved maize variety that is streak-resistant, has a white dented grain/seed, matures in 105 days, and can yield 5 t/ha.
68	Maize variety Obatanpa developed	CRI	Obatanpa is an open-pollinated QPM variety. It matures in 110 days and has high levels of lysine and tryptophan.
69	Maize variety Okomasa developed	CRI	Okomasa is a streak-resistant maize variety that matures in 120 days, yields 6 t/ha, and can be grown throughout Ghana. This variety addresses the problem of low yield resulting from major production constraints, including maize streak virus.
70	Regime for Newcastle disease vaccine	ARI	The vaccine was developed in 1973 to counter Newcastle disease, a previously pandemic poultry disease. Vaccinations were administered at 2, 6, and 8 weeks of poultry growth.
71	Aribro broiler nucleus population	ARI	Aribro is a new breed of chicken that is well-adapted to local environmental conditions. The technology was developed to reduce the high cost of importing day-old chicks, broiler hatching eggs, and broiler parent stock.
72	AF Bosbek grandparent stock (broiler and layer breeds)	ARI	The technology was developed to provide day-old commercial layers and broiler chicks for the poultry industry.
73	A three-stage feeding regime for broiler production	ARI	The technology involves the use of three different poultry feeds: starter, developer, and finisher feeds. The technology facilitates a faster broiler growth rate and demonstrates a better feeding conversion ratio than the two-stage system.
74	Gumboro vaccination schedule	ARI	The vaccination schedule was prescribed to poultry farmers to counter the high mortality rate of poultry from the infectious bursal disease (gumboro).
75	Use of sugarcane as a vehicle for administrating anthelmintics in grasscutters	ARI	Developed to address problem of high grasscutter mortality rates on account of the helminthic parasite, the technology uses sugarcane to administer anthelminthics to grasscutters and results in better grasscutter growth and reproduction.
76	Evaluated pasture for animals: drought-tolerant plant species and nutrient value	ARI	Identify highly nutritious forage materials that can survive droughts. The technology resulting from these experiments is a mixture of nutrient-rich indigenous and exotic plant materials. It leads to better growth performance of animals and makes feeding materials available in dry seasons.
77	Improved feed packages and housing for small ruminant production	ARI	Farmers were assisted to establish feed gardens of leguminous forages (*Gliricidia sepium* and *Cajanus cajan*) to serve as protein sources. These forages were harvested, wilted and mixed with dried cassava peels proportionally and fed as supplement to the animals at a rate of 100 to 150 g/adult animal/day. This improved growth rates of both sheep and goats. Using local material, farmers were assisted technically to put up improved houses with two partitions: does/ewes occupied one pen with their kids/lambs and the older animals occupied the other pen. The houses had runs where the animals were fed, observed and handled. Houses were designed to avoid the young ones being trampled upon by the older animals to reduce mortality. They were also easy to clean, thus ensuring good sanitation. They also protected the animals from adverse weather conditions and predators.
78	DNA technology for plant identification	ARI	The development of this technology was in response to the lack of technology for diagnosing biological poisoning in livestock.
79	Pelletized feed for domestic grasscutter	ARI	Developed to relieve grasscutter farmers from the drudgery of feeding their animals and also enabled faster growth of grasscutters.

80	Local mineral saltlick block	ARI	The technology is composed of a special clay (alluvial clay), common salt, dicalcium phosphate, anthill and forage. The saltlick block ingredients are mixed in predetermined quantities to give a final product whose mineral composition is beneficial to ruminants. Non-poisonous binding agents of plant material such as cassava and okra are dissolved in water to make the water slimy. The solution is then poured on the mixture of ingredients and the resulting product is mixed into a semi-solid paste. With the help of a mould, the paste is cut into various shapes and allowed to dry in the open. The final product contains calcium, magnesium, phosphorus, iron, potassium, sodium, sulphur, chlorine, cobalt, copper, iodine, manganese, selenium, zinc, and lead in varying quantities but within the maximum tolerable limits for ruminants. The saltlick block increases animals' access to minerals essential for proper growth and development.
81	Combined starter/finisher broiler diet	Animal Science Dept, KNUST	Prior to the development of this broiler feed, poultry farmers were administering two main feeding phases. The technology resolves these feeding regime challenges by providing a single diet for broiler chickens.
82	Intensive production of keets at brooder stage	ARI	The technology involves the following process: • Up to one week old guinea fowl eggs are set in forced-air electric incubators (300 guinea fowl egg capacity). The temperature within the incubator is maintained at 38°C until the eggs begin to pop, then the temperature is reduced to 36°C until the eggs complete hatching. • Water is provided in a bowl placed inside the incubator throughout the incubation period. • The eggs are turned roughly 5 times—each time uniformly spaced over every 24 hours—from the second day to the day the eggs begin to pop. • Newly hatched keets survive on water with glucose and vitamin C for 3 days, after which feed is introduced. • The keets are intensively kept on deep litter for a minimum of 4 weeks. Drugs are given to the keets during this period (antibiotics, coccidiostat, dewormer, minerals-vitamins mixture). • The keets are stocked at 35 keets/m^2. Room temperature is maintained at 35°C in the first week, 33°C in the second week, 31°C in the third week, and 29°C from the fourth week. • Feed and water should be changed daily and containers properly washed. With this approach, a keet survival rate of 95% should be expected.
83	ARIPEED	ARI	The technology produces pig feed with local materials with the aim of preventing poor pig farming practices. ARIPEED consists of ingredients such as rice bran, maize mill waste flour, pitomash, fishmeal, soybean meal, oyster shell, common salt, and a mineral-vitamin premix. The feed is given at 5% of pig body weight per day just like with the commercial feed.
84	Improved brooding management of local guinea fowl	Animal Science Dept, UDS	The technology, a combination of housing, heating/lighting, medication, and feeding is designed to ensure the survival of keets. It is recommended that keets are kept in confinement for 8 weeks before they are released on free range.
85	Snail farming technology	FORIG	The technology is a set of management practices that include identifying suitable species, choosing a site, constructing a snailery (hutch boxes, etc.), feeding and breeding practices, and more. The technology encourages profitable snail rearing.
86	Polyculture of tilapia and catfish	WRI	The technology involves management practices for producing tilapia and catfish that increase pond productivity and income. The resources required for this technology are ponds, feed, and fingerlings available locally throughout Ghana. Stocking ratio is 1 mudfish to 2 tilapia. The fish are fed twice daily, morning and evening, at 10 percent body weight for the initial 2 months and 5 percent body weight for the succeeding months.

87	Preservation of *wagashi* (soft cheese)	Animal Science Dept, KNUST	20 grams of *Xylopia aethiopia* and 40 grams of *Piper nigrum* are blended and added to one liter of water to produce brine for prolonging the shelf life of *wagashi*. 10–15 percent brine concentrations are optimal for extending *wagashi* shelf life from 3 to 12 days.
88	Fufu flour	FRI	Fufu flour is dehydrated pre-cooked cassava and cocoyam milled and mixed with a small portion of cassava starch.
89	Agronomic recommendation for seed maize production	CRI	The technology involves three sets of farm management recommendations: the use of modern varieties, planting in rows, and appropriate application of fertilizer.
90	Hot air cabinet dryer	FRI	The technology, a replica of a foreign-made food dryer, partly solved some of Ghana's problems associated with post-harvest losses and food security. It is used to dry roots, tubers, fruits, and vegetables (dehydratable crops) and can be used nationwide.
91	Natural convention solar dryer	FRI	The technology, constructed from local materials, helps extend the shelf life of perishable food crops, making fruits available over a long period of time even during lean seasons.
92	FRI smoking oven	FRI	Developed to eliminate labor inputs needed for interchanging tray positions during smoking, the ovens also reduce heat loss while reducing tar deposits.
93	Improved kokonte flour	FRI	Kokonte flour is made from sun-dried and mechanically dried fermented cassava chips, which are milled and sifted into flour. This technology has a shelf life of 1 year and has the potential to reduce post-harvest losses of cassava.
94	Bin dryer	FRI	The technology is designed for drying all dehydratable foods, including roots, tubers, fruits, and vegetables. The bin dryer is a replicated version of the maize dryer originally developed in Alvan Blanch (England). It is constructed with local materials, an imputed heat exchanger, and a control system for use with local food products.
95	Chorkor smoker	FRI	The chorkor smoker was developed to enhance traditional ways of smoking fish. It is a rectangular structure with openings at the base where fire is set. On top of the rectangular structure are trays on which the fish are arranged for smoking. The trays form a chimney-like structure and they must be interchanged many times to ensure that the fish is well smoked. This technology accommodates large volumes of fish; however, it is quite labor-intensive.
96	Afrismo 150 smoker	FRI	The technology improves on the chorkor smoker. The curved design of the oven, the positioning of the sliding shelves, and the build of the chimney guarantee uniform smoking and serve to eliminate the laborious process of interchanging tray positions during smoking with the associated heat loss and the formation of excess tar deposits.
97	Sugar-free chocolate 'ASPIRE'	Dept of Nutrition &Food Science, UG	Developed to promote healthy eating habits due its sugar-free nature, this technology, which uses the sweetener *Maltitol*, aims to add value to local raw cocoa and increase employment.
98	Groundnut processing equipment	IIR	Developed to increase productivity and increase the shelf life of groundnut paste, the technology separates roasted groundnut into dehulled groundnut and chaff. The latter is removed from the machine by means of a blower and the dehulled groundnut is collected via a chute ready for grinding into groundnut paste.

99	Integrated cassava processing plant/machine	IIR	The technology is a complete factory set up with basic food processing and handling equipment with high production efficiency. The equipment includes grater, slicer, hydraulic processor, manual pressers, disintegrator, sifter, electronic dryer, sealing machine, hammer mill, dispenser, solar dryer, shredders, pelletizers, centrifuge, roasters, and fixed mixers.The technology produces diverse products from cassava such as cassava flour for human consumption, cassava starch for textile industry, dry cassava meal for animal feed, and dry chips in addition to the traditional products (gari and agbelima). The resulting solid wastes could be used as inputs material for biogas production.
100	Refining process for crude soy oil	IIR	The technology involves degumming, neutralization, bleaching, and deodorization of crude soy oil to obtain edible refined oil.
101	Liquid soap	IIR	The technology diversifies traditional soap (*alata*) and has a desirable pungent scent, enhanced color, and a reduced amount of totil-solid.
102	Improved iced kenkey	Dept of Nutrition & Food Science, UG	Developed to improve the texture, aesthetic appeal, quality, consistency, and safety of iced kenkey (a beverage food) by improving the nutritional contents, bottling, and pasteurizing in order to increase the shelf life of the kenkey.
103	Peanut-cowpea milk	Dept of Nutrition & Food Science, UG	Developed to address the low availability and high cost of animal milk products, the technology is a vegetable milk-based infant formula that serves as a substitute for animal milk. The milk follows a 3 × 2 factorial design, with enzyme treatments and peanut–cowpea ratios of 1:1, 1:2, and 1:3. The milk is dehydrated and then milled using a hammer mill (mesh size 40).
104	Locally constructed solar dryer for vegetables	College of Agriculture Education, UEW	The technology helps prevent post-harvest losses by extending the shelf life and ensuring the continuous supply of vegetables. Using the traditional method of drying, toxins are prevented during drying. The technology features white polythene sheets which concentrate the sun's radiation onto the drying products and black polythene sheets that retain heat to prolong drying in the panels.
105	Sediment filter technology	SRI	Grass filters, sand bags, mosquito nets or cement are placed at the boundary of water banks to protect water bodies from sedimentation and to enhance catchment protection and erosion control on farmlands. This technology also helps with settlement erosion control and flood mitigation.
106	Development of clones of *Odum* resistant to the pest *Phytolys lata*	FORIG	Clones of *Odum* resistant to *Phytolyma lata* were developed to increase the survivability of the *Odum* species, to reduce extensive damage to younger plants, and to salvage the timber industry as a whole.
107	Improved planting materials for teak	FORIG	The technology uses several clones of teak selected from plus trees to establish a clonal seed orchard.
108	Geo-spatial modeling for agro-ecological assessment	SRI	In its simplest form, the model contains three elements: • Selection of agricultural production systems with defined input/output relationships, and crop-specific environmental requirements and adaptability characteristics (land utilization types [LUTs]) • Geo-referenced land resources data (climate, soil and terrain data) • Procedures for the calculation of potential yields and procedures for matching crop/LUT environmental requirements with the respective environmental characteristics contained in the land resources database, by land unit and grid cell. The suitability model functions as a spatial model operating entirely within an ARC-INFO GIS environment. A set of ARC-INFO macros was designed to implement the logic and essential elements of the model.

109	Development of mushroom seedlings	FRI	Technologies to produce mushroom seedlings were developed to address nutritional deficiency and unemployment in the 1990's. Two main methods of production were developed: the plastic bag and the low bed method. The plastic bag method, which uses sawdust as the main substrate, is used to produce oyster, woodear, and monkey seat mushrooms. The low bed method, which uses rice straw, banana leaves, cotton waste, sorghum stover, and peelings from root tubers as substrates, is used to produce oil-palm mushrooms.

IIR = CSIR's Institute of Industrial Research
UG = University of Ghana
UEW = University of Education at Winneba

ABBREVIATIONS AND ACRONYMS

AgSSIP	Agricultural Services Sub-Sector Improvement Programme
AKIS	Agricultural Knowledge and Information System
ARDC	Aquaculture Research Development Center
ARI	Animal Research Institute
ARICUS	Animal Research Institute Credit Union
ASTI	Agricultural Science and Technology Indicators
BNARI	Biotechnology and Nuclear Agricultural Research Institute
BOPP	Benso Oil Palm Plantation
CAADP	Comprehensive Africa Agriculture Development Programme
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
CRSP	Collaborative Research Support Program
COCOBOD	Ghana Cocoa Board
CRI	Crops Research Institute
CRIG	Cocoa Research Institute of Ghana
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agriculture Organization of the United Nations
FASDEP II	Food and Agriculture Sector Development Policy
FBO	Farmer-Based Organization
FORIG	Forestry Research Institute of Ghana
FRI	Food Research Institute
FTE	Full-Time Equivalent
GDP	Gross Domestic Product
GLDB	Grains and Legume Board
GNA	Ghana News Agency
GPRS	Ghana Poverty Reduction Strategy
IFAD	International Fund for Agricultural Development
IIR	Institute of Industrial Research
IITA	International Institute of Tropical Agriculture
IPM	Integrated Pest Management
KNUST	Kwame Nkrumah University of Science and Technology
LUT	Land Utilization Type
MFRD	Marine Fisheries Research Division
MiDA	Millennium Development Authority
MOFA	Ministry of Food and Agriculture
NAEP	National Agricultural Extension Project
NAETS	National Agricultural Education and Training System
NARP	National Agricultural Research Project
NARS	National Agricultural Research System
NCSU	North Carolina State University
NEPAD	New Partnership for Africa's Development
NRC	National Research Council
OPRI	Oil Palm Research Institute
PGRRI	Plant Genetic Resources Research Institute
PSI	President Special Initiative
QPM	Quality Protein Maize
R&D	Research And Development
RELC	Research-Extension-Farmer Linkage
SARI	Savanna Agricultural Research Institute
SRI	Soil Research Institute
STEPRI	Science and Technology Policy Research Institute
TOPP	Twifo Oil Palm Plantation
TOT	Transfer of Technology
T&V	Training-And-Visit
UCC	University of Cape Coast
UDS	University of Development Studies
UEW	University of Education at Winneba
UG	University of Ghana
UNCTAD	United Nations Conference on Trade and Development
USAID	United States Agency for International Development
WIAD	Women in Agriculture Division
WRI	Water Research Institute

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This Working Paper has been prepared as an output for the Ghana Strategy Support Program, funded by USAID, and has not been peer reviewed. Any opinions stated herein are those of the author(s) and do not necessarily reflect the policies or opinions of IFPRI.

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