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Status of Agricultural Innovations, Innovation Platforms and Innovations Investment in

Ghana

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Agricultural Innovations, Innovation Platforms and Innovations Investment in Ghana

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STUDY BACKGROUND

Science and technology remains the fulcrum for development over the ages. There is hardly any national development in contemporary history that is not based on consistent efforts from the science and technology sector. The spate of development in agriculture follow suit; the state of efficiency in science and technology generation correlates highly with the development of agriculture. In Africa, agriculture is considered as the sector with the best potential to lead the socioeconomic development of countries on the continent. However, the sector is bedevilled with many constraints that could be categorized as technological, socio-cultural, institutional, infrastructural, and economical. The poor productivity of the enterprise stream in the sector is clearly seen from its contribution to a country's GDP versus the number of active workers engaged in the sector. Africa's agriculture currently engages about 65% of the working population and its average contribution to GDP still stands at 22.9%.

The crave to develop Africa has received good attention in recent years, starting with the political will of the heads of states, under the auspices of the Africa Union Commission, to develop and implement the Comprehensive Africa Agricultural Development Programme (CAADP), the Science Technology and Innovation Strategy (STISA). The Forum for Agricultural Research in Africa (FARA) also came up with a handful of continental initiatives, such as the Sub-Saharan Africa Challenge Programme (SSA CP), *Strengthening Capacity for Agricultural Research and Development in Africa* (*SCARDA*), Dissemination of New Agricultural Technologies in Africa (DONATA) and several others. The different initiatives aim to foster change by addressing specific issues that constitute constraints in the path of progress in Africa agriculture. The notion that African agricultural research system has generated a lot of technologies with great potentials, but which are not realized due to different institutional and organizational constraints—more specifically, the way agricultural research and development systems is organized and operated—is prevalent among stakeholders in the sector. Indeed, this notion appeals to reasoning. However, there is no known cataloguing or documentation of existing technologies and their veracity in delivering broad-based outcomes. The possibility of finding some documentation in annual reports of research institutes, journal articles and thesis in the universities is known, but this will not meet an urgent need.

Thus, the Programme of Accompanying Research for Agricultural Innovation (PARI) commissioned the three studies reported in this volume to provide a compressive analysis of the state of agricultural technology generation, innovation, and investment in innovations in the last 20 years in selected countries in Africa.

Study 1 is the “situation analysis of agricultural innovations in the country” and provides succinct background on the spate of agricultural innovation in the last 30 years. It provides useable data on the different government, international and private sector agricultural research and development interventions and collates information on commodities of interest and technologies generated over the years. It also conducted an assessment of the different interventions so as to highlight lessons learnt from such interventions, with regard to brilliant successes and failures.

Study 2 concerns a “scoping studies of existing agricultural innovation platforms in the country”. It carried out an identification of all the existing Innovation Platforms (IP) in the country, including identification of commodity focus, system configuration, and partnership model. The study provides an innovation summary for each IP for use in the electronic IP monitor platform. It further synthesises the lessons learnt from the agricultural IPs established through different initiatives in the country in the last ten years.

Study 3 was an “Assessment of the national and international investment in agricultural innovation”. It is an exhaustive assessment of investments in innovation for agricultural development, food and nutrition security in the country. It collates updated data on investment levels in the past and present, including a projection for the next decade requirement to assure food and nutritional security in the country.

The three studies form the comprehensive collation on the state of agricultural innovation in the 12 countries where the PARI project is being implemented. It is expected that these studies will benefit all stakeholders in Africa’s agricultural research and development, including the users of technologies, research stakeholders, extension system actors and, more importantly, the policymakers.

STUDY ONE

Inventory of Agricultural Technological Innovations (1995 to 2015)

INTRODUCTION

This study was commissioned by the Forum for Agricultural Research in Africa (FARA) in partnership with the Germany Government, which is represented by the Centre for Development Research (ZEF) of the University of Boon within its 'One World No Hunger' initiative, known as Programme of Accompanying Research for Agriculture Innovations (PARI). Fundamentally, PARI focuses on exploring the successes of research and innovation initiatives in African agriculture and in consideration of the concept of integrated agricultural research and development (IAR4D), a pet dream of FARA. Through this framework, the programme seeks to build an independent accompanying research programme that will focus on scaling up of agricultural innovations in identified countries across Africa as a way of contributing and transforming agricultural sectors of the countries involved. Generally, this project is nested within a broader macro policy of various countries' national agricultural research institutes (NARIs), which aims at reducing poverty and ensuring socioeconomic development of rural farming communities.

It has been observed that efforts by the Ghanaian government to achieve international targets within the framework of MDGs (now SDGs) and national policy objectives contained in the medium development plans (METASIP) and other development agenda documents need to rally the potential of all stakeholders, particularly agricultural research institutes, as a critical institutions that can bring the change that it deserves. Agriculture provides the single most important platform for expansion of employment, income generation and food security in Ghana. About 65% of the Ghanaian population live in rural areas, with 70% of rural households dependent on agriculture as the main livelihood pillar. The agriculture sector holds an important key to poverty reduction through increased productivity, value addition, improved marketing and linkages to other sectors. Agriculture has largely remained unattractive to young people– men and women- for a variety of reasons. Although this claim seems to be ubiquitous in the literature, there are cases which seem to suggest the opposite.

This consultancy is to be executed in three but one studies. The three elements of the study are:

1. Carry out inventory and document existing functional promising agricultural innovations in Ghana,
2. Scoop existing agricultural innovation platforms in Ghana, and
3. Assess the state of national investment on agricultural innovations system.

2 Programme for Accompanying Research in Innovation (PARI)

Generally, the study aimed at reviewing and assessing the extent and level of national and international investments in agricultural innovations in Ghana.
With a sub-grant provided by FARA, the study specifically looked at the following:

1. Review the national and international investments that may have taken place in agricultural innovations in the countries targeted in the PARI project.
2. Review the context(s) within which the investments were made.
3. Assess the extent of investments and the specific innovations targeted.
4. Analyze and determine the value addition of these investments to the target innovations.
5. Identify possible areas of investments by the PARI project and the likely value it would add to the realization of the PARI objectives.
6. Suggest appropriate measures or steps to properly position the BMZ initiative for agricultural innovation centers.

Ghana is one of the five English-speaking West African countries. It lies between latitudes 4' 44 and 11' 15N and longitude 3' 15W and 1' 12E and has a coastline of about 550km. Ghana borders on the east with the Republic of Togo, west with Cote d'Ivoire and in the north by Burkina Faso. With a population of over 23 million, Ghana covers a total land area of 238,539 square kilometres, comprising diverse ecological areas. Statistics show that Ghana is a typical agrarian economy, where agriculture is the main occupation of majority of the population. Total cultivable land of the country is estimated at 57% of total land size of Ghana, and has only about 44% of this land under the cultivation of diverse crops and the rearing of animals. According to the United Nations Food and Agricultural Statistics, agricultural land per capita in Ghana decreased from 1.56 ha in 1970 to 1.11 in 1984 and then to 0.74 ha in 2000 (FAO, 2002).

Generally, agriculture forms the mainstay of the economy of Ghana. It accounts for a large share of gross domestic product (GDP) and foreign exchange earnings as well as providing vital raw materials for national and international industry. As pointed out earlier, this sector provides the main livelihood, generating income and employment for the vast majority of people in the country. While this may represent opportunity for growing the agricultural sector and broadening economic impacts, there are some challenges which need to be dealt with if the country is to reach its full potential. Typical of these include how to translate the growth rates into greater food security for Ghana. Over the years, Ghana's GDP has been growing at a rate of 4–8% per annum. It is expected the sector will continue to show robust performance over the coming years, especially as offshore oil production came online in 2011. Although declining, agriculture contributes close to 30% of GDP (ISSER, 2014). Despite this, the sector remains the largest employer of the active labour force in different sectors of the economy. The sector alone employs more than half of the total labour force, roughly 49% of men and 51% of women. Eighty percent of agriculture is conducted by smallholder farmers with an average of 1.2 hectares, who produce food and cash crops. The sector has therefore been one of Ghana's major drivers of poverty reduction, especially in the southern parts (Haussman et al., 2010).

Historically, Ghana's traditional export crop is cocoa. In view of this, the crop has always featured in discussions on the country's socioeconomic development, reforms and poverty alleviation strategies. This is because export of this crop brings in a lot of exchange earnings for the development of the country. The cocoa sub sector alone offers a bigger source of livelihoods for over 700,000 farmers and therefore Ghana cannot be discussed without a mention of its cocoa sector. All cocoa grown for export must be sold to the Ghana Cocoa Board (COCOBOD), which aggregates the crop for sale in the international market. Another area for which Ghana is becoming prominent is fruit cultivation and exports. In recent times, crops referred to as non-traditional have been added to the export sector, expanding the revenue from exports. In addition, Ghana produces a number of fruits, including pineapple and mango, which are exported to Europe.

In the midst of all this, there are a number of challenges that need to be dealt with before the opportunities can be actually translated into real positive growth and development variables. Among the key challenges are the subject of lack of technological change, poor basic infrastructure and changing rainfall patterns. There are also issues of inadequate credit to farmers and traders, low organic matter and declining soil fertility. Although government is making efforts to tackle these inadequacies, there is the need to identify and better understand the state of affairs in relation to agricultural innovations in the country. These are in line with the targets of CADDP, as well as the government's objective of improving the welfare of the people through productive engagement in agricultural activities.

The literature on innovation is diverse and wide. The concept of innovation itself has been used by diverse people to suit different purposes. Indeed, it is no longer profitable to argue about the realism or idealism of technological innovations as key to development and growth. Indeed technological innovation has been and is seen to have occupied a central and permanent position in economic and social development agendas of countries. The inception of the global sustainable development goals (SDGs) and national development visions on science, technology and innovations (STIs) make renewed attention to technology even more convincing. The World Bank (2010) has suggested that two-thirds of the differences in the growth performance of

Ghana and the Republic of Korea over four decades were attributable to technology-related improvements. This suggests that if developing countries like Ghana need ways to achieve inclusive growth, then technological innovation is imperative.

In the main, it has been observed that the world is already counting losses due to the emerging impacts of climate change. The threat of food insecurity in several communities of the world due to the seriousness of current economic crises is a reality. The major environmental challenge today, therefore, is how to prove the need for a wide-range change in production and consumption patterns, especially in the agricultural sector. Knowledge of the role of science and technology in development shows that innovations often lead to the creation of a better world. This brings to mind the need to identifying current innovations in critical areas, such as agriculture, that can be scaled for greater adoption and welfare improvement. This initiative promises to uplift agricultural and industrial productivity and, consequently, increase the overall welfare of society especially in areas of nutrition and health.

Although the term 'innovation' has received several definitions and conceptualizations, in this report, it implies technology or practice that is new to a given society—in other words, it does not necessarily mean that it new in absolute terms. The critical part of this definition is that the technology or practice should have undergone some level of diffusion and be used by a section of the target population. According to the World Bank (2010), an innovation is often about finding new solutions to existing problems; it should ultimately benefit many people, including the poorest for it to qualify as such. Innovations are 'babies' of entrepreneurs who make them happen and ultimately depend on society's receptiveness or acceptability—they are thus fundamentally social processes; and hence, should not be embedded within core sciences or else knowledge and innovations of indigenous people will be ignored, even though they might have good and promising results.

The crucible in which innovation and, for that matter, innovation processes develop is referred to as "innovation systems." An innovation system is a network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman, 1987). The interactions among these institutions bring together the technical, commercial, and financial competencies and inputs required for innovation development. It is on such systems that government innovation policies focus.

METHODOLOGY

This study was based on primary and secondary data sources. The work commenced with a search on relevant data on the Internet and websites of public academic and research institutions in Ghana. The physical libraries of the Institute of Scientific and Technological Information (CSIR-INSTI) and Science and Technology Policy Research Institute (CSIR-STEPRI) were also used. The search found three documents that were used as major sources of information for the study. The documents were: (1) 'agricultural innovations', produced by CSIR-STEPRI in 2008, (2) profile of marketable technologies developed by the CSIR, which was produced by CSIR in 2015, and (3) 'agricultural technologies (2001-2006)' produced by CSIR in 2006. Other reference documents were annual reports of various CSIR institutes. These documents were reviewed to obtain a list of all the technologies that have been developed and disseminated to farmers between 1990 and 2014. The technologies were further analysed by categorised into various domains. The inventory was presented under the following headings:

i. Name of technology
ii. Brief description of technology
iii. Current dissemination status
iv. Year technology was developed
v. Institutions that developed the technology

Based on the level of dissemination, seven technologies were selected and analysed using case study approach. Five of the technologies were selected because they had been extensively disseminated and beneficiaries were applying them to generate socioeconomic outputs. The remaining two technologies were selected because they had received limited dissemination and adoption despite their potential to give high socioeconomic impacts. These technologies, also referred to as innovations, were analysed in-depth, taking into consideration the following:

i. Characteristics of the innovation and how it works,
ii. Funding and collaborations,
iii. Dissemination and adoption of the innovation,
iv. Impact of the innovation on beneficiaries, and
v. Challenges and opportunities.

To obtain information on the impact of the innovations on beneficiaries, some selected beneficiaries were interviewed, while additional data were collected from various project documents that reported on their impact. The findings are presented in charts, tables and narratives. There is also a synthesis of the results.

RESULTS

6 Programme for Accompanying Research in Innovation (PARI)

The agricultural technologies and innovations identified in this study were developed by the Council for Scientific and Industrial Research, which is a public research institution, and public universities in Ghana over the past two decades. In total, 270 technologies were identified and categorised into ten domains as follows:

- Crop variety improvement
- Improved agronomic and cultural practices
- Crop pest and disease management
- Weed control
- Soil fertility management
- Water management and irrigation technologies
- Poultry-related technologies
- Fisheries technologies
- Ruminants and other livestock-related technologies
- Agro/food processing technologies
- Food engineering-related technologies
- Other technologies

The inventory of technologies is presented as an annex to this report. The number of technologies developed per domain is shown in figure 1. Crop variety improvement has been an area that has received much research and development accounting for 44% of all the technologies. Livestock-related technologies, which include poultry, fisheries, ruminants and other food animals such as snails constituted 13.3% while agro- and food processing and engineering technologies accounted for 17.8% of the technologies. Technologies for improved agronomic and cultural practices together with pest and disease, soil fertility, weed and water managements accounted for 22.6% of all the technologies identified.

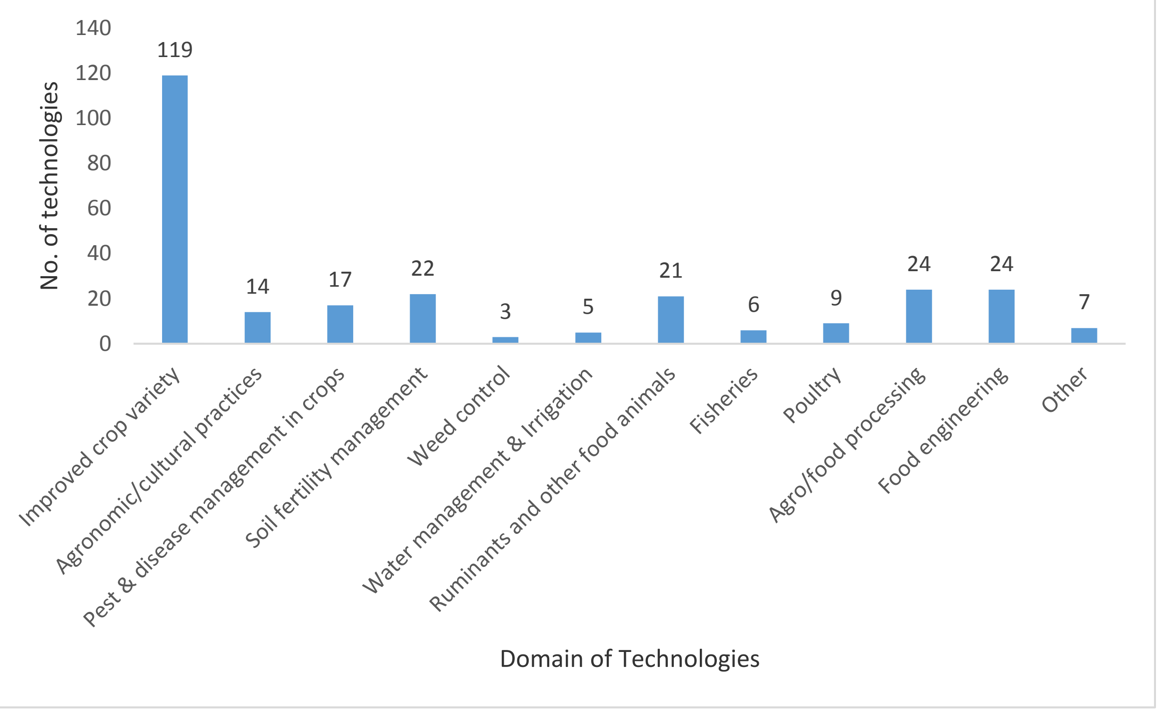

Figure 1. Domain and types of technologies

i. **Crop Variety Improvement**

Crop improvement is an approach that depends on finding a crop variety that can give high yield and added characteristics such as disease tolerance, response to fertilizer, product quality, and shorter maturation duration. Crop variety improvement is very critical for Ghana where the underlying causes of low agricultural productivity are poor soil conditions, low and poor distribution of rainfall, diseases and pests, limited access to planting materials and seeds. For new varieties to be accepted it is necessary that the variety produces high yields under different conditions found in different areas. Cultivation practices and crop yields are related to weather, soil quality and availability of water and weather conditions like drought and floods are unpredictable therefore varieties that can be grown in diverse climatic conditions are useful.

The focus of the crop improvement technologies have been on the development of *high yielding varieties* (e.g. maize variety Enibi developed by CSIR-CRI and CSIR-SARI, which maturity period of 75-90 days), *drought tolerant varieties* (e.g. soybean variety Quarshie developed by CSIR-SARI as a drought-tolerant variety suitable for cultivation in the Upper East Region because of its erratic rainfall pattern and poor climatic conditions), *disease tolerant and pests resistant varieties* (e.g. groundnut variety- CRI-Adepa developed by CSIR-CRI between 2001-2006 and resistant to rosette and Cercospora leaf spot), *wide adaptability varieties* (e.g. soybean variety Songda developed by CSIR-SARI, which is very acceptable by consumers and is broadly adapted to various ecologies). *Crop quality improvement* was also a major area of focus as in the case of cassava variety Otuhia developed by CSIR-CRI in 2010 to have higher starch content and it has since demonstrated the highest starch yield ever recorded in Ghana. Other quality improvement varieties are obatanpa maize variety developed by CSIR-CRI in the '90s to have high levels of lysine and tryptophan, which are essential amino acids in limiting quantities in traditional maize varieties, and groundnut variety CRI- Jenkarr, which has high oil content. These quality characteristics make the varieties suitable for certain applications both at the household and industrial levels.

The various crops that were improved over the two decades are shown in figure 2. Most of the crop variety improvements focused on maize, cowpea, groundnut, rice, cassava and sweet potato (in that order) based on the number of technologies. Maize is a leading and important staple cereal in Ghana, yet the country is not self-sufficient in its production; hence the focus of most of the crop improvement research on maize is a matter of priority. The increasing rice imports being experienced in Ghana has been attributed to the changing preferences of consumers in the country toward imported rice. The focus of research and development activities on rice variety improvement stemmed from the fact that government of Ghana is undertaking rice upscaling programme with the goal of achieving rice production growth rate of 20% per annum, to attain self-sufficiency by 2018 (and reach a surplus of 13% or 111,940 metric tonnes). This initiative is in response to the massive dependency on rice imports, which has always been a concern for Ghana government. Indeed, in May 2008, Ghana was one of the first countries within the Coalition for African Rice Development (CARD) to launch its National Rice Development Strategy (NRDS) for the period 2009-2018. The objectives of the NRDS include increasing domestic production and promoting consumption of local rice through quality improvement by targeting both domestic and sub-regional markets. The government of Ghana through several public private partnership arrangements has initiated investments through projects such as the NERICA Rice Dissemination Project, Inland Valley Rice Development Project, Rice Sector Support Project, and Sustainable Development of Rain-Fed Lowland Rice Production Project. Through the West Africa Agriculture Productivity Programme (WAAPP), researchers have developed improved variety of aromatic rice and produced breeder seeds including upland varieties and the Nerica varieties.

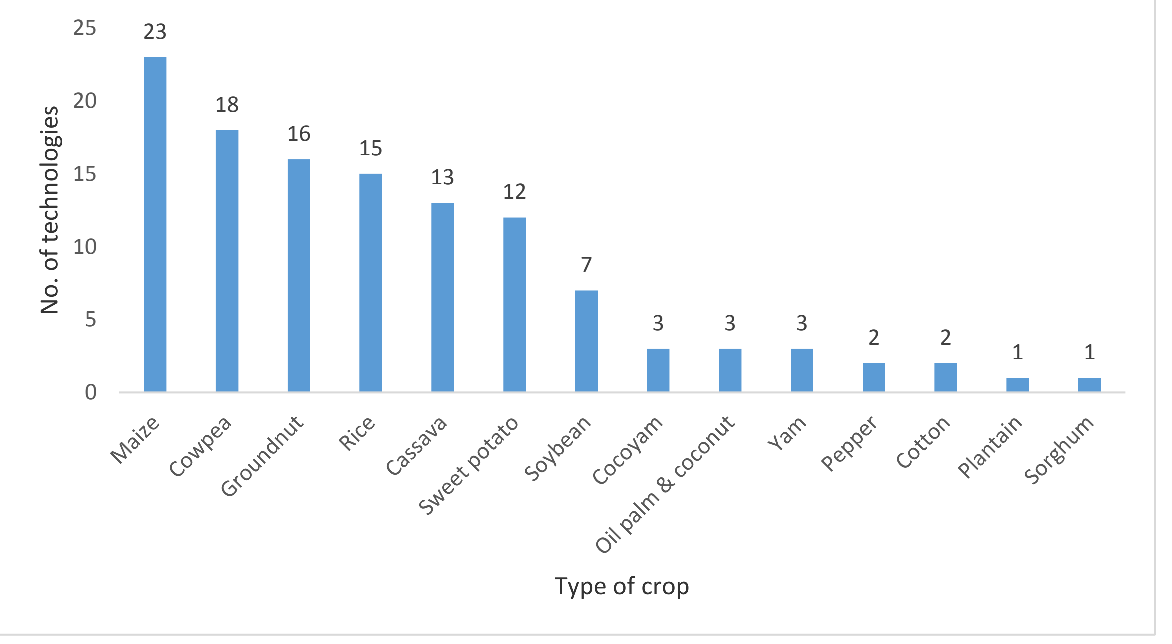

Figure 2. Types and number of crop variety improvement technologies

Yam and plantain are also important food crops hence it is surprising that research and developments in their improvements have been low. Notably however, a significant amount of research has been undertaken to develop value addition technologies to produce shelf-stable products from yam and plantain and even cassava, which are highly perishable. Much research has also focused on the improvement of sweet potato varieties mainly because of the national promotion of the orange fleshed variety as a rich source of vitamin A.

ii. **Improved Agronomic and Cultural Practices**

Agronomic practices are steps farmers incorporate into their farm management systems to improve soil quality, enhance water use, manage crop residue and improve the environment through better fertilizer management. These steps not only improve a farmer's bottom line by decreasing input costs, but also improve the environment by decreasing water use and over-fertilization. Agronomic practices are a vital part of sustainable agriculture and when used in conjunction with improved varieties farmers can see significant increases in yield and improved product quality. Research institutions have been engaged in the development of various agronomic procedures to boost crop production. The technologies developed in this category include (1) bud manipulation technology in plantain and banana, (2) grafting of nutmeg, (3) minisett technology for yam production, (4) timing and frequency of weeding, (5) agronomic recommendation for maize seed production, and (6) procedures for production of healthy citrus seedling.

iii. Crop Pest and Disease Management

Technologies have been developed for chemical and biological control of pests and diseases. Pest infestations have been a major pre- and post-harvest problem in several crops in Ghana. This has even affected Ghana's horticultural exports to the EU, where in 2013, Ghana's produce accounted for 3% of all crops intercepted due to pests (EC 2013). In fact, in the same year, Ghana was ranked third next to India and Pakistan as countries with the highest number of intercepted produce due to harmful organisms. Pests and diseases reduces crop productivity and result in loss of crops, loss of income and food insecurity. Research and development has been able to generate 17 technologies that have been transferred to farmers to combat pests and diseases. These technologies include (1) field management of plantain nematodes using Pueraria phaseoloides cover crop, (2) neem-incorporated management strategy as an insecticide for cowpea pests, (3) selective use of insecticide for oil palm leaf miner control, (4) bio-control of *Striga hermonthica* in soybean, (5) early warning system for the control of oil palm leaf miner, and (6) field management of the banana weevil.

iv. Soil Fertility, Weed and Water Management and Irrigation Technologies

A significant proportion of arable land in Ghana has soils with poor physical properties and low content of organic matter. Agricultural production is generally dependent on rainfall, although an estimated 6,000 farm enterprises nation-wide were using some means of irrigation in 1999 (MOFA 2007). However, annual rainfall varies between 800 and 2400 mm, generally decreasing from south to north and from west to east. In 2002, the total area under formal irrigation was around 11,000 hectares whereas the potential area – including inland valleys – that could be developed for irrigation is estimated at 500,000 ha. The Ghana Irrigation Development Authority (GIDA) in 2000 identified 32,000 hectares of under-developed inland valleys throughout the country that could benefit from moisture improvement technologies for food production (MOFA 2007). As a result, crop productivity is very low making it critical for research to find solution to address these problems. In the last two decades technologies have been developed and transferred to reduce the negative effects of poor soils, low rainfall and weeds. The soil fertility-related technologies were 22 in total and they include (1) use of crotalaria/ calopegenium with rock phosphate for improved soil fertility, (2) sediment filter technology, (3) utilization of Azolla as manure in lowland rice cultivation on the vertisols of the Accra plains, (4) sesbania and mimosa for sustainable rice production, and (5) improved fallow systems for soil fertility maintenance. The weed control technologies were (1) the use of mixture of common salt, ammonium sulphate and Urea for weed control in oil palm farms, (2) knapsack spray shield for herbicide weed control in field crops and (3) herbicide use and efficacy in oil palm. Water and irrigation-related technologies developed and transferred in the past two decades include (1) simple water control strategies for rice cultivation, (2) simple water control structures (earth bunds) dyke to harvest stream water for irrigation, and (3) standardized roof rainwater harvesting technology.

v. **Poultry, Fisheries, Ruminants and Other Livestock Technologies**

Ghana's agriculture is natural resource-based, with extensive livestock production systems, hunting, and fish from natural water bodies. However, the sector is saddled with numerous challenges such as limited number of livestock specialists including veterinarians, breeders, and meat scientists; low quality livestock breeds; and lack of interventions that effectively address problems of lack of feed and water, particularly in the dry season. The practice of bush burning for crop production is a source of loss of fodder for livestock during the critical dry season period. Furthermore, livestock, especially rural poultry, is characterised by high mortality rates because of diseases and poor management practices. Overall, there is little adoption of improved livestock management systems, including proper housing, feeding and health care. Livestock production is a major feature in Ghana's agriculture and contributes largely towards meeting food needs, providing draught power, manure to maintain soil fertility and structure and cash income for farmers. The livestock sector contributes in direct products about 7 percent of agricultural GDP (MOFA, 2001), excluding manure and draught power that is provided to the crop sector. In relation to fisheries, there is inadequate infrastructure for landing and hygienic handling of fish and pre-shipment storage of fish and other fresh produce at the ports. In addition, supply of hatcheries, ponds and cages for aquaculture is limited.

Addressing these problems require science, technology and innovative solutions, which Ghana's researchers have focused on in the past two decades. The poultry-related technologies that were developed and transferred include (1) combine starter and finisher diet for broilers of chicken, (2) regime for Newcastle disease vaccine, (3) improved brooding management of local guinea fowl, (4) improved vaccination schedule for control of Gumboro disease, (5) a three-stage feeding regime for broiler production in Ghana. Ruminants and other food animal-related technologies include (1) controlling round worms in sheep and cattle, (2) ensiled brewer's spent malt for pig feeding, (3) feed pellets for grasscutter, (4) feeding package for growing finisher cattle, (5) husbandry package for small ruminant production, (6) simple on farm fodder conservation, and (7) snail farming. These poultry and ruminants technologies were largely developed by the CSIR Animal Research Institute. Six technologies related to fisheries were identified and they are (1) improved Akosombo strain of Nile Tilapia (Oreochromis niloticus), (2) a protocol for production of mudfish fingerlings, (3) formulated feed for growing tilapia in ponds, (4) integration of fish with broilers and/ or layers of chicken, (5) polyculture of mudfish and tilapia (Clarias gariepenus/hetero brandus longifilis and Oreochromis niloticus), and (6) polyculture of Tilapia and Catfish.

vi. Agro/Food Processing Food Engineering-related Technologies

Agro-processing is one of the critical sectors of Ghana's economy due to its enormous contributions to employment creation, reduction in postharvest losses, foreign exchange earnings, and shelf life extension among others. Agro-processing ensures constant availability of food in various forms and facilitates product distribution and growth of the national economy. Due to its importance to the growth of Ghana's economy, agro-processing features prominently in Ghana's policies such as the Food and Agriculture Sector Development Policy I and II (FASDEP I & II), METASIP, national trade policy, and Growth and Poverty Reduction Strategy (GPRS II). Food processing in particular is important especially at the micro-level where 95% of the actors are women (MOFA 2001). Already, the limited knowledge in post-harvest management, particularly of perishable produce results in high post-harvest losses of about 20%-50% for fruits, vegetables, roots and tubers, and about 20%- 30% for cereals and legumes (MOFA, 2007). This is further worsened by inefficient agro-processing technologies and equipment, and inadequate delivery of extension services to women in particular. Agro-processing contributes tremendously to value addition, which is vital for increasing competitiveness and acceptability of locally produced products both at the domestic and international markets. All over the world more value is being placed on value-added products while the prices of primary and raw commodities continue to decline on the world market. The fall in prices negatively affect the economy of Ghana in terms of foreign exchange earnings and consequently the country's developmental activities are slowed down.

These notwithstanding, agro-processing sector has over the years been confronted with challenges such as inadequate supply of raw materials, low quality raw materials, lack of appropriate processing and packaging technologies, lack of state-of-the-art equipment and lack of knowledge in good manufacturing and handling practices all of which negatively impact quality, value and consumer acceptability. Technology is an important determinant of productivity hence low or inappropriate technology limits the scope for competitive production. There is therefore the need to improve the development, availability and appropriate use of agro-processing technologies to increase competitiveness and market potential of Ghana's products in both local and world markets.

In the past two decades research and development institutions have devoted considerable attention to the agro-processing sector and this has resulted in the development of various value-added, shelf-stable and convenience products from locally produced primary agricultural products. Among the technologies developed and transferred are technology for producing various convenience foods such as fufu flours, bambara flour, banku mix, and breakfast cereals. Other technologies were the production of composite flours, dehydrated fermented maize meal, high quality cassava flour, peanut-cowpea milk, virgin coconut oil, sugar-free chocolate (ASPIRE), and glucose syrup. To enable the production of these products, various processing equipment have also been develop and transferred. These include solar dryer for vegetables, integrated cassava processing plant, mechanized palm kernel and shell separator technology, soybean oil refining plant, groundnut processing equipment, hammer mills, honey centrifuge extractor, industrial pressure cookers, and rice parboiling vessel. Most of these technologies were developed by the CSIR-Food Research Institute, CSIR-Industrial Research Institute, and the Nutrition and Food Science Department of University of Ghana.

vii. Other Agricultural Technologies

Other agricultural-related technologies that have been developed and transferred include biogas technology, soilless rooting medium technology, mushroom cultivation and seedlings development, methods for rehabilitating degraded forests and mined sites, and production of liquid soap from agriculture and industrial waste.

Agricultural Innovations: Case Studies

Innovation is the process of application of new or existing knowledge in new ways and contexts to do something better. It is a process that transforms ideas into outputs by replacing older established products, processes and services with new ones (KARI, 2013). This transformation may be in products, processes or services and can be incremental or radical and at various levels of the value chain. The Oslo manual for measuring innovation (OECD, 2005) defines four types of innovation namely, product innovation, process innovation, marketing innovation and organisational innovation. Product innovation refers to a good or service that is new or significantly improved. This includes significant improvements in technical specifications, components and materials, software in the product, user friendliness or other functional characteristics. Process innovation refers to a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. Marketing innovation implies a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. Organisational innovation refers to a new organisational method in business practices, workplace organisation or external relations. Innovation consists of three basic elements; (i) technology including new varieties or breeds and soil or water management practices; (ii) organizational in terms of organizing and delivering knowledge in new ways; and (iii) institutional in terms of rules, cultures, values, norms, behaviour, policies and laws (KARI, 2013).

The definitions of innovation presented here presupposed that not all the 270 technologies can be classified as innovations because they were at different stages of development, transfer and applications. On that basis, seven technologies have been selected to depict technologies that were already innovations and those that had the potential of becoming innovations. They are as follows:

i. Improved soybean variety Jenguma,
ii. Technology for the production of high quality cassava flour,
iii. Technology for mushroom cultivation,
iv. Rice parboiling vessel technology,
v. Utilization of Azolla as manure in lowland rice cultivation
vi. Husbandry package for small ruminant production,
vii. Improved Nile tilapia.

The cases have been organized into six sections, namely, introduction, characteristics of the innovation and how it works, funding and collaborations, dissemination and adoption of the innovation, impact of the innovation on beneficiaries, and challenges and opportunities.

i. Improved Soybean Variety Jenguma

Soybean is gaining prominence in northern Ghana because of its multipurpose 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 on time, leading to loss in investment. Thus, for individuals and oil mills to maintain sustainable and high soybean production, Jenguma variety was developed.

Characteristics of the innovation and how it works

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 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. It also acts as a trap-crop against Striga hermonthica, which causes yield losses in cereal crops in Africa. Jenguma is suited to Ghana's varied agro-ecology and tolerates the specific stresses of climatic conditions of the region. 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 variety—which is suitable for cultivation throughout Ghana, and indeed, the whole of West Africa—the National Varietal Release Committee approved its release.

Funding and collaborations

Jenguma was developed by Savana Agricultural Research Institute of CSIR (CSIR-SARI), in response to farmers' requests through the Research and Extension Linkage Committee for a solution to the early shattering problem in soybean. Other collaborators were 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 its nutritional qualities. CSIR-SARI introduced early generations of the variety from IITA and advanced them through several generations, identifying suitable lines selection for yield, shattering resistance and stability of yield through genotype-environment interaction studies. On-site evaluation, varietal selection, and testing were conducted using CRI data at four SARI stations—Nyankpala, Damongo, Yendi, and Manga. 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.

Dissemination and adoption of the innovation

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 programme, 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. Some farmers indicated that they previously cultivated Salintuya II variety, which was associated with shattering; hence, they were happy with Jenguma.

In 2009, a farmer-based organization (FBO) received financial support from the Millennium Development Authority (MiDA) to cultivate Jenguma, which was recommended to them by the Ghana Seeds Company. The variety has been highly adopted in Tibale area since it was the recommended variety from Ghana Seeds 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 to its 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.

Impact of the innovation on beneficiaries

Farmers confirmed that Jenguma can be stored for four and a half months without shattering, which was very good for the type of farming practised in the area. 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. Other benefits of farmers derived from Jenguma were its fast growth and ability to be used in various food applications (e.g. for local foods such as kooshe and tubani).

Challenges and opportunities

In total, it took CSIR-SARI 12 years (from 1991 to 2003) to develop this variety due to breaks in funding of the research process and for due diligence in generating the relevant scientific data to support its release. The lead scientist involved in its development stated that testing could have been done faster but was delayed due to lack of funds. A seed and chemical dealer in West Gonja District of Northern Region revealed that soybeans are no longer produced by commercial farmers in the district because of recent surpluses in the area. Jenguma was reported to be labour-intensive and relies on the use of chemicals to eliminate pests. Besides, 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).

ii. Technology for the production of high quality cassava flour (HQCF)

Cassava is strategically important as a food source and famine reserve, combining high calorific efficiency with versatile low cost/input, reliable and flexible production, but is now seen as a means of improving incomes of the rural poor; especially smallholder farmers. Ghana is the second largest cassava growing country in Africa and many people derive their income from growing cassava or processing it into popular traditional foods such as gari, fufu and agbelima. Cassava roots have a short shelf-life and are either consumed immediately after harvest or have to be processed into shelf stable products, such as gari. Cassava roots are processed into various products at household and cottage levels in the rural areas. Processing at these levels involves mainly the production of cassava chips and flour from fermented or unfermented roots. The processing of cassava roots into flour is done by traditional methods. The process typically involves peeling, cutting into pieces, sun drying, milling, sieving and packaging. To improve the traditional processing method and flour quality, the technology for producing HQCF was developed. This technology has particularly respond ended to the needs of a growing number of rural-based bakeries who partially substitute wheat flour with HQCF.

Characteristics of the technology and how it works

The high quality cassava flour (HQCF) is intermediate cassava flour which could be used for adhesives in the plywood industry, for the formulation of composite flours in the bakery industry, and for the production of cassava glucose syrup for use in the confectionery industry. The technology involves the use of mechanical chipping/grating techniques, fermentation, solar and mechanical drying to produce HQCF. It costs at least $360 to produce 1 tonne of HQCF, as compared to $490 for wheat flour.

Freshly harvested mature and healthy cassava roots are peeled and washed thoroughly. Washed roots, which should be very clean, free from any dirt and impurities, are grated. The grated cassava mash is packed into a clean bag or sack for pressing or dewatering. Pressing is done using a screw or hydraulic presser. The pressed cassava mash is spread thinly on a clean black plastic sheet raised off the floor for sun drying. The product quality is much improved when more efficient drying methods, such as the use of improved solar and mechanical dryers are employed. The dried cassava mash is milled and sieved (to remove fibrous materials and any lumps) to produce fine flour. The sifted cassava flour is packed in airtight moisture-proof lined sacks. To ensure high quality product, the production process of HQCF from harvesting to drying must be completed in a day.

Funding and collaborations

Under a collaborative project between six organizations- Food Research Institute, Forest Research Institute of Ghana, National Board for Small-Scale Industries (NBSSI), Department of Nutrition and Food Science (University of Ghana), Ministry of Food and Agriculture and the Natural Resources Institute of the UK- a value addition for cassava was carried out to produce High Quality Cassava Flour (HQCF). The Department of International Development (DFID) of UK funded the project, including the publication of training manuals on the production of HQCF and cassava-based bakery products. Together, the collaborating organizations demonstrated that HQCF could be produced at an economic price, and incorporated in common snack food items such as biscuits and cakes. The project also demonstrated that products containing cassava flour would be acceptable to a wide range of consumers. Market acceptability studies in Greater Accra showed that consumers would accept substitution levels of 35% cassava flour in soft dough biscuits and 60% cassava flour in hard dough biscuits (Ababio 1998). A cost/ benefit analysis for 18 pastry products showed that it is more profitable to use cassava-wheat composite flour than wheat flour in the preparation of a number of pastry products with profit margins ranging from 163% and 137% to 10% and 1% (Dziedzoave et al., 2002).

Dissemination and adoption of the innovation

The HQCF technology has been transferred to small scale processors, SMEs like Cassacoxa, Bredi, AMASA and St Bassah as well as large scale processors such as Caltech Ventures. Horizontal linkages within HQCF processors and vertical integration among HQCF processors and other end-users have been strengthened under the C:AVA project (Cassava: Adding Value to Africa). Cassava farmer groups are linked to SMEs who in turn are linked to larger firms. Community based processors are linked to end-users like educational institutions, hospitals and hotels as well as other SMEs for bulking and onward supplies to industries. The C:AVA phase II, which commenced in 2014 and being funded by Bill & Melinda Gates foundation, will continue to operate in the Brong Ahafo and Volta Regions of Ghana, and also expand to Ashanti, Central and Eastern Regions depending on the preferred location of the identified investors in larger scale cassava processing. It is expected that incomes from sales of fresh roots and processing by smallholders in Ghana will generate at least USD 6 million for rural communities by the end of five years. The Ministry of Food and Agriculture (MOFA), Food Research Institute and the Root and Tuber Development

Programme (RTIP) made some initiatives to promote the use of high quality cassava flour in composite flour for the bakery and pastry industry as a result, recipe books were developed and disseminated. The Women in Agricultural Development (WIAD) Directorate of MOFA under the RTIP trained several bakers, caterers, school matrons and domestic bursars, home science teachers and students in vocational institutes in all the regions of Ghana. Additionally, WIAD has organized several exhibitions in collaboration with other organization showcasing products prepared from composite flour.

Impact of innovation on beneficiaries

A group of cassava farmers in Northern Ghana who were struggling to produce high enough yields to feed their family, have seen their farms flourish under the CAVA project. The Vanakpor Farmers' Association, located at Dzolokpuita in the Ho municipality of the Volta Region, Ghana, has 15 members. Before the C:AVA intervention they were deeply rooted in traditional methods of farming, good agronomic practices were not observed, and planting of low-yielding local planting materials was the norm. The Associates for Sustainable Rural Development (ASRuD), a rural development organisation in Ghana, began to support the group with help from C:AVA in 2009. The cassava farmers were given training in the business of cassava farming, and entrepreneurship development, and more women were encouraged to get involved. They were also trained in good agronomic practices, good farm management practices, and relationship building. They were then linked to input dealers and the HQCF processor 'Marbet Enterprise'. A smallholder farmer in the Brong Ahafo Region of Ghana, Mr Osei Kwadwo, won the 'best cassava farmer' award for the farming season of 2009-2010, when his first cassava crop was harvested following C:AVA project interventions. Mr Osei Kwadwo is the chairman for the Cassava Farmers and Processors group at Bompa and was the interim chairman for the micro-processors association on the CAARD/C:AVA project. Within two years of its association with the C:AVA project in Ghana, Cassacoxa Limited has become the proud winner of the Sunyani Municipality 'best processor award'. Cassacoxa was identified by the C:AVA project in 2008 when owners of the company decided to invest in a cassava processing enterprise as their contribution to the development of the community. They created a market for the farmers who faced challenges accessing reliable markets for their produce.

Challenges and opportunities

Small scale processors of HQCF have challenges with high quality specifications particularly with the production of HQCF for the food industry. A major challenge facing HQCF industry is lack of policy support for uptake of HQCF in the flour industries. Another challenge is the lack of credit support for processors to access efficient drying and sifting technologies. The HQCF value chain presents a number of opportunities including foreign exchange savings when HQCF substitute wheat flour, alternative raw material for plywood and bakery industry, expanded and organised markets which generate additional income for farmers and processors. There are significant market opportunities for HQCF which has not been fully exploited because of processing constraints and pricing issues. Root price, drying costs and product recovery rates are key to improving price competitiveness and increase market access of processed cassava products. Building a market around large processing enterprises is a more effective way of driving the HQCF value chain and ensuring sustainability. Attracting investors in large scale cassava processing is a key challenge. High Quality Cassava Flour has proven to have both the technical and economic potentials to succeed in Ghana as a partial substitute for wheat flour in food products in particular. Potential users include processors in the informal sector, household users, catering services and as industrial raw material in the industrial sector. HQCF could be import substitute for wheat flour, alternative raw material for plywood and paperboard and bakery industry, expanded and organised markets which generate additional incomes for farmers and processors. However, the lack of an enabling national policy environment on composite flour production and promotion in particular has led to limited success in the adoption of the technology. The Ministry of Science Technology and Innovation in collaboration with other stakeholders is currently developing a national policy on composite flour production and usage in Ghana.

iii. Technology for Mushroom Cultivation

Mushroom has high nutritive and medicinal value. Edible mushrooms contain 26.9% protein, 0.3% fat and 4.4% carbohydrate. Mushrooms are healthy food sources for diabetics and over-weights due to its low caloric content. Gradually, there is a shift from overdependence on consumption of wild mushrooms to the consumption of cultivated mushrooms in Ghana. The National Mushroom Development Project in Ghana was launched in 1990. The Project aimed at providing alternative sources of income to both the rural and urban poor as well as improving food security in Ghana. The launch of the National Mushroom Development Project in 1990 to produce exotic mushrooms such as Pleurotus species brought about small scale mushroom farms mostly for the urban unemployed and as supplementary income sources. With the introduction of the plastic bag method in 1990, edible and medicinal mushrooms could be produced all year round on substrates like sawdust and other agricultural waste. CSIR-FRI is involved in cultivation of different kinds of mushroom, spawn multiplication as well as maintenance of the National Mycelium bank.

Characteristics of the technology and how it works

There are four different methods of mushroom cultivation in Ghana. These include (i) traditional method, (ii) the high bed method, (iii) the low bed method for cultivation of the oil palm mushroom, and (iv) the plastic bag method, which is used in the cultivation of the oyster, woodear and the monkey seat mushrooms. CSIR-FRI is promoting the use of the plastic bag method for mushroom cultivation. Generally, sawdust from 'wawa' Triplochiton scleroxylon or other soft woods is used as the substrate for the plastic bag method. Sawdust compost is packed in heat resistant polypropylene high density bags and steam sterilized for 2-3 hours. The cooled substrate is later inoculated with sorghum grain spawn and incubated in semi-dark conditions. Exposing the colonised bags to a high relative humidity (85-95%) in a cropping house or wooden box induces fruiting. In Ghana, inoculated compost bags are either sourced from Food Research Institute or trained commercial mushroom growers.

Funding and collaboration

The main source of funding was the National Mushroom Development Project which was introduced in 1990 to champion the production of exotic mushrooms such as the Pleurotus species, which includes one of the most widely eaten mushrooms in Ghana. Under the project small scale mushroom farms were established mostly for the urban unemployed with the help of CSIR-FRI.

Dissemination and adoption of the innovation

The Mushroom project organizes training workshops on cultivation of edible mushrooms. So far, about 4,500 farmers, extension officers, church groups, NGOs and the general public have been trained. The long-term objective of the project is to introduce techniques for the cultivation and processing of local and exotic mushrooms for domestic and export markets. Fresh and dried mushrooms are currently sold in major supermarkets and open-air grocery outlets in Accra and some regional capitals. To mobilize producers for the enhancement of their operations for the export market, a National Mushroom Growers Association has been formed with the CSIR-FRI staff as key players. FRI trains mushroom growers in compost bag production for sale. The CSIR’s Forestry Research Institute of Ghana (FORIG) has also begun the production of spawns of *Pleurotus sajor-caju* and *Volvariella volvacea* to meet the increasing demand especially in the Brong Ahafo and Ashanti Regions of Ghana. Target users of the technology include commercial mushroom growers, farmer and processor groups and those interested in growing mushrooms for export.

Impact of innovation on beneficiaries

A beneficiary, John Yaw Asubonteng, has his mushroom farm located at Kodie-Mowire, in the Kwabre West District of the Ashanti Region where he produces mushrooms for the local market including hotels, restaurant and supermarkets. According to him, the production of mushrooms has lots of advantages as compared to other farming activities and it is paying off because of the awareness on its nutritional values created among consumers through interventions from mainly NGOs and other organizations. Cultivation of mushrooms needs to be encouraged because the materials for its production such as sawdust, cassava and plantain peels are affordable or can be obtained free of charge from either 'chop bar' operators or households. This also makes it possible for mushrooms to be produced all year round. The CSIR-FRI, testified that the rate at which Ghanaians have shown interest in the eating of mushrooms is very encouraging. Most Ghanaians have cultivated the habit of eating mushrooms and therefore the CSIR-FRI, which was the sole producer and distributor of spawns-the seeds for growing mushrooms- used for the cultivation of mushroom throughout the country, is usually unable to meet the demand. Farmers often troop to CSIR-FRI every day to purchase the spawns. The technology for the cultivation of mushroom species could be easily adopted by individuals, families, in the rural and urban centres without difficulties. One advantage of mushroom production is that it is always produced from waste without the use of chemicals and it is safe.

Challenges and opportunities

The main challenges mushroom farmers encounter are low yield due to little technical know-how by farmers and inaccessibility to viable spawns, lack of adequate financing as banks consider the sector too risky to invest, and inability to access the international marketing. Moreover, mushrooms are highly perishable hence the lack of adequate storage facilities makes it difficult to venture into. The mushroom sector has several opportunities including growing demand for value added organic products especially in the food services industry like hotels and restaurants, opportunities for public-private partnerships in establishing large mushroom farms, decreasing availability of wild mushrooms which encourages cultivation of mushrooms and export opportunities. Some challenges in the mushroom industry are cultural perceptions associated with cultivated mushrooms, food quality and safety standards particularly for export markets as well as limited marketing networks to take advantage of demand opportunities, high perishable nature of mushrooms and lack of storage and processing facilities.

iv. Rice Parboiling Vessel Technology

Rice is the second most important cereal crop after maize in Ghana and its consumption keeps increasing as a result of urbanization, population growth and changes in consumer habits. Ghana’s per capita rice consumption is 35kg with urban areas accounting for 76% of total rice consumption. Unfortunately, just about 20% of local rice is consumed in urban areas in particular because of consumers’ preferences for long grain aromatic rice, which is principally imported. Close to 60% of rice produced in Ghana comes from the northern sector of the country and the paddy more often than not has less than 12% moisture content at harvest due to untimely harvest and harsh weather conditions. As a result, a high percentage of broken grains are obtained if the paddy is milled raw. Consequently, the bulk of the rice that is locally produced is parboiled (Tomlins et al, 2005). This is carried out almost entirely by women and their families as a major income generating activity using very simple equipment and resources like cooking pots, open fires, and earth drying floors Traditional parboiling is time-consuming and involves a lot of drudgery. Large quantities of firewood and water are utilized and profit margins are generally low. The quality of the milled parboiled rice is variable and does not often compare favourably with imported milled rice. The variation in quality of the milled parboiled rice is partly due to the equipment used and lack of effective control over some of the critical unit operations in the parboiling process which are largely identical in the different parts of northern Ghana. The Food Research Institute of Ghana has therefore developed an improved parboiling vessel and parboiling process which improves quality of parboiled rice and increases efficiency of parboiled operations.

Characteristics of the technology and how it works

Rice parboiling is a hydro-thermal process (that means it uses water and heat) applied to paddy rice to improve the quality of milled rice. The traditional method of parboiling is very time-consuming and laborious allowing for only parboiling of about 30 kg of paddy per batch. There are differences in the unit operations among women parboilers contributing to the varying quality of parboiled rice in Ghana. Some of the problems associated with the traditional parboiling include poor quality of products and the process being inefficient. The CSIR-FRI improved parboiling vessel allows for batches of up to 100kg to be parboiled at a time and produce more control over the process. Additionally the use of the vessel presents the following advantages:

- Less firewood is used (about half of the amount used in the traditional method);
- Discolouration that results when truncated oil drums are used is avoided;
- Drudgery in the process is greatly reduced (there are a few unit operations involved in the use of the parboiling vessel and presence of the drain-pipe eliminates draining with strainers);
- The presence of the separating mesh ensures that no paddy is in direct contact with water during the steaming process; and
- Less water is consumed while using the parboiling vessel.

Parboiling is done to improve the nutritional status of the rice. During the process of parboiling, water soluble vitamins and minerals in the bran layer of paddy rice penetrates the grain and make them available on consumption. Parboiling is also done to reduce breakages upon milling because in the process the cracks in the rice kernel are effectively sealed by starch gelatinization making the grain much harder and resilient in the milling process. Parboiled rice is also less sticky than raw-milled rice. Parboiled rice has a firmer, nuttier texture than raw-milled rice and the grains remain separate upon cooking. It also has a characteristic aroma on cooking which is preferred by most parboiled rice consumers.

Dissemination and adoption of the innovation

Target users of the technology include rice processing groups, NGOs supporting rice value chain actors to improve the quality of locally produced rice, Ministry of Food and Agriculture (MOFA) projects targeting rice quality improvement systems and market competiveness. The improved parboiling vessel has been transferred to women processors in Northern Ghana (Upper East, Upper West and Northern Regions) some parts of the Brong Ahafo Region) where the climatic conditions creates over-drying of the grain on the field resulting in severely cracked grain. The CSIR-FRI has tested both the parboiling equipment and the improved processing among some women processors in the Northern Ghana. Due to the enhanced efficiency of this innovation the World Food Programme (WFP) has between 2013 and 2014 procured 24 parboiling vessels for 24 women Groups in Northern Ghana. CSIR-FRI has subsequently trained these women on the use of the vessels and improved processes to achieve better quality of parboiled rice. A training manual on the use of parboiling vessel has been produced under the Rice Sector Support Project (RSSP) project for training rice processors in Ghana on quality improvement issues. The Rice Sector Support Project (RSSP) is part of the bilateral co-operation between the Government of Ghana (Ministry of Food Agriculture) and Agence Française de Développement. The RSSP purposes to increase rice productivity and household incomes through the adoption of appropriate technologies by low-income and/or resource poor farm households, rice processors, marketers. Through a DFID sponsored rice programme training manuals of efficient parboiling have been produced in collaboration with partners. These are:

i. Improving the quality of Ghanaian parboiled rice: the role of the millers;
ii. Improving the quality of Ghanaian parboiled rice: the role of parboilers;
iii. Improving the quality of Ghanaian parboiled rice: the role of farmers;
iv. Improving the quality of Ghanaian parboiled rice: the role of markets.

Impact on users

Through various projects such as, Agricultural Development and Value Chain Enhancement Program (ADVANCE) and World Food Programme (WFP), parboiling vessels have been procured for beneficiaries who have also been trained on the proper use of the vessels. As a result parboiling in Northern Ghana is more efficient. This has improved product quality and marketing efficiencies of the rice value chain. Promotional strategies were embarked on to introduce suitable technologies and practical solutions for the improvement of locally parboiled rice refined and developed, with a view to increasing the income of all stakeholders in the production chain and improving product quality and safety. The processors found the capacity of the vessel to be consistent with current batch size, provides superior product quality, saves fuel, and reduces drudgery associated with the traditional system. The vessel is however expensive, only a limited number is available and has a few technical problems.

Challenges and opportunities

Generally, constraints in the rice parboiling processing system in Ghana include lack of incentive for quality processing, poor quality of paddy, seasonality and irregular supply of paddy. Opportunities in the rice industry in Ghana include growing demand for rice and increasing availability of improved milling facilities. In Ghana, rice consumption increased by about 56% from 2000 to 2010 due to population growth, urbanization and changes in eating habits. With an average self-sufficiency level of 33%, the rice market in Ghana is predominantly supplied by imports with high income consumers putting more emphasis on brand and quality than price. The material used in constructing the parboiling vessel is aluminium and specific welding skills are required to weld this material. Most local welders do not have aluminium welding skills. This is major barrier to the mass production of the vessel. Another barrier to the widespread adoption of the vessel is the difficulty in the processors obtaining credit to purchase it. Opportunities however exist for increased use of the vessel due to local demand for quality parboiled rice over white rice.

v. Utilization of Azolla as Manure in Lowland Rice Cultivation on the Vertisols of the Accra Plains

Nitrogen is one of the major constraints in the production of rice grown under irrigation on the vertisols of the Accra Plains. Although the rice plant has a high nitrogen requirement, the inherent fertility of the soil and nitrogen recovery are low. This low fertility could be attributed to low levels of organic matter in the soils. Other factors such as bush fires, leaching, denitrification, volatilization and runoff reduce soil fertility. This technology was thus developed to enhance the fertility of the soil for increased rice productivity.

Characteristics of the innovation and how it works

The innovation involves the development of techniques by which Azolla could be utilized as green manure in rice fields. Azolla is a fern, which grows on the surface of water in ponds and also along the lower Volta Lake at Kpong and Asutsuare. It fixes nitrogen through symbiotic association with *Anabaena azollae* (alga) and in this way Azolla provides nitrogen to the rice crop. Consequently, it helps farmers to reduce the cost of rice production. Azolla serves as the host plant while the alga fixes nitrogen using atmospheric nitrogen. The fixed nitrogen is used by the Azolla for growth, but is released when the fern dies and decomposes. Apart from providing nitrogen to the growing rice crop, azolla grows profusely and adds organic matter to the soil. In the long term, organic matter exhibits greater efficiency as nutrients are retained and released slowly. It has a property of rejuvenating both the physical and chemical properties of the soil, but the quality of the organic matter determines the level of rejuvenating. The use of azolla green manure in rice cultivation would help to minimize the physical and chemical deterioration of soil used for rice cultivation under irrigated condition on the Vertisol. This would lead to improved rice yields. The use of azolla will reduce the dependence on inorganic fertilizers and consequently eliminate most of the undesirable effects of chemical fertilizers, particularly soil acidification and environmental pollution. Inorganic fertilizers are efficient in the short term, but because of their high solubility and high mobility of nutrients, this property results in loss of nutrients from the soil. The innovation involves the development of azolla nursery. The azolla is then incorporated into the rice fields before and after transplanting rice. The innovation was developed because of the high cost of inorganic fertilizers, declining soil fertility, growing demand for organically produced foods. Fortunately azolla can easily be grown and multiplied and the best season to cultivate azolla is the wet season (from May to November). The fern is however very sensitive to harsh weather conditions therefore it dies soon after the rainy season. The innovation can be replicated in other parts of the country provided the weather is wet to support the growth of the fern.

Funding and collaborations

The innovation was developed by the Kpong Agricultural Research Centre of the University of Ghana in collaboration with the Ecological Laboratory and the soil Science Department all of the University of Ghana. The collaboration was to enable the researchers to pool expertise available in the University to undertake the research. The scientists were also involved in packaging the information for publication in a scientific journals. The project was funded by Agricultural Services Sub-sector Investment Programme (AgSSIP) with some support from the Kpong Irrigation Project. The experimental cost was totally borne by AgSSIP whilst the organization of farmers' forum was funded by the Kpong Irrigation Project. The funding for the project was neither sufficient nor timely.

Dissemination and adoption of the innovation

The innovation was initially developed for use by rice farmers at the Kpong Irrigation Project site at Akuse and Asutsuare. About 2500 to 2600 farmers in the project area could benefit from the innovation. About 200 farmers have already been sensitized about the innovation at farmers' forum. The innovation can be transferred to other rice growing areas of the country. The only method used for dissemination of the innovation was farmers' forum. The transfer was done by demonstrating the use of the innovation to farmers at farmers' forum. However, the dissemination of innovation has been limited to farmers who directly participated in the experiments and others who showed interest at the farmers' forum. This means that the dissemination process has been limited in scope and needs to be extended to cover many farmers.

Impact of innovation on beneficiaries

The use of azolla as green manure can help rejuvenate many of the poor agricultural lands. The innovation holds promise for farmers engaged in rice production. Many practices like burning of vegetation and non-application of organic matter to farmlands have contributed to the depletion of the organic content of soils. By introducing the green manure, production by the majority of farmers will be increased and this will contribute to food security and improved farm incomes. The incorporation of azolla enhanced the nitrogen content of the soil and brought about a 21% savings in organic fertilizer use. In order to have the full benefit of the innovation, practices like bush and rice straw burning would have to be minimized. Azolla is recommended for areas that are waterlogged most of the time.

Challenges and opportunities

The main challenge was the unavailability of funds to complete the dissemination of the innovation. Moreover, azolla is not available all year round due to intense heat (from January to April), azolla growth slows down and they tend to die off. The involvement of the Extension Services of Ministry of Food and Agriculture (MOFA) in the dissemination of this innovation has been minimal. This calls for the strengthening of the relationship between research and the extension linkages to ensure innovations reach the extended target group. The use of green manure does not entail much cost, consequently rice farmers can easily adopt this innovation if it is well disseminated. The Agricultural Research Centre at Kpong has over the years researched into sustainable practices in rice production and has been involved in the transfer of information to farmers hence once they are resourced financially, they can achieve results.

vi. Husbandry Package for Small Ruminant Production

The ruminant industry is composed largely of small-scale enterprises involved in the rearing of cattle, sheep, and goats. Ruminant livestock play a major role in the socio-cultural life of the farming communities as a partial determinant of wealth, payment of dowry, and act as a bank and insurance in times of difficulty. Sheep and goats are particularly valuable in developing countries because of their ability to utilize scarce grazing and tolerate unfavourable climates. Ghana has no major pastoral or transhumant population relying on extensive cattle and small stock production. The main production system is based mainly on extensive grazing or free range among smallholder farmers with only a few commercial farmers operating mainly in the Coastal Savannah zone. The growth of the domestic ruminant livestock industry has been impeded by several constraints such as lack of improved breeding stock, disease, poor nutrition, inadequate stock water, poor marketing, lack of capital, high interest rate on loans and lack of a grassland policy. Notwithstanding this, recent developments show that the country has the potential to increase the off-take of livestock and produce good quality meat and milk to satisfy a greater part of the nation's animal protein requirements. The husbandry package for small ruminants is an innovation that seeks to improve the production of small ruminants in Ghana.

Characteristics of the innovation and how it works

The husbandry package, which started in 2000, aims to help the small farmer or stock owner to improve production, resulting in greater availability of protein and higher incomes. The emphasis of the innovation is on the improvement of indigenous production systems and to breeds within their own environments. The main feature of this innovation is that it helps to improve small ruminant productivity especially in rural areas. The reasoning behind the name is that it is a package which involves mainly the application of the following steps to improve on the traditional husbandry practices. Firstly, to go into the communities and to look at what the farmers are doing regarding their small ruminants and to interact with them. It is thus participatory. Secondly, the type and nature of the housing of the small ruminants are also examined, and thirdly a check on the health status of the animals, their nutrition and general management are carried out. The innovation introduced (shelters, anthelmintic drenching and flock grazing/ strategic feed supplementation), which are simple and could be easily adopted by farmers. Leguminous forage fodder crop- *Gliricidia sepium* and *Cajanos cajan* are cultivated near human settlements as fodder banks and these are harvested and fed as supplement to sheep and goat, especially towards the end of the dry season and also two to three times during the rainy season. These are described as feed gardens. They are harvested and fed to the animals as a source of protein. The innovation ensures the supply of food to small ruminants during the dry season. Secondly it helps farmers during the farming season. Thirdly the innovation ensures the provision of decent housing thereby leading to improved animal productivity and a reduction in mortality through improvement in the health status of the animals.

The innovation involves the use of the fodder bank or feed garden to help feed the animals, provision of housing and deworming packages. Due to the availability of only a few extension officers in the country, farmers depend on drug peddlers who sell fake veterinary drugs to them especially in the villages. Thus this innovation ensures the introduction of the recommended drugs. One way to get the farmers to accept the innovation was that, initial vaccinations were carried out free of charge which eventually led to the situation where the farmers were paying for the vaccinations.

Funding and collaborations

This project was a collaborative work between the CSIR- Animal Research Institute (CSIR-ARI) and MOFAS, AgSSIP, Semi-Arid Food Grain Research and Development (SAFGRAD) as sponsors, Farmers, Chiefs, Opinion leaders (described as motivators) and the District Agriculture Development Unit (DADU) as facilitators. The collaborations were fostered by an initial SAFGRAD advertisement to which the CSIR-ARI applied and brought on board the other collaborating institutions. Initial contact with the farmers through the research- extension-farmer linkage at the community level and stakeholder meetings led to the identification of these myriad of problems this innovation sought to resolve through the MOFA. The CSIR-ARI provided the planting materials for the fodder banks, while the farmers provided the land on which the planting took place with the drugs obtained through sponsors such as AgSSIP. SAFGRAD provided funds totaling $11,000.00 for the first two years of the implementation of the project. After the second year, AgSSIP came in with $6000 every three months for two years through a competitive grant. Funding for the project was not sufficient as it did not meet the requirements thus requiring a lot of sacrifice on the part of researchers.

Dissemination and adoption of the innovation

Dissemination of the innovation was done through MOFA and DADU onward to the motivators and the farmers. The motivators were trained to promote, demonstrate and guide the development of sheep and/or goat farming in village-based smallholder production systems. These activities were carried out with emphasis on practical training of the target group of farmers and closely monitored demonstration farms are a key component. Some level of success has been registered in the transfer of the innovation to farmers within the target areas. The agencies responsible are CSIR-ARI in collaboration with MOFA and the other agencies. Training of farmers through on-farm demonstration programmes at CSIR-ARI is another cornerstone of the institute's innovation transfer for the husbandry package. Training aids have been produced to support some of these activities including guidelines for specific elements of sheep and goat improvement. The potential end-users of this innovation are the farmers. In the initial phase, the project was able to reach a total of 23 farmers. However, small ruminant farmers across the country will benefit from the innovation. Resources for the adoption and use of this innovation are locally available and indeed the innovation can be easily replicated.

Impact of the innovation on beneficiaries

The practical problem solved by the innovation is the provision of small ruminants with good quality fodder throughout the year. During periods of prolonged droughts the mortality rate is well checked. The fodder banks serve as a protein supplement to complement the carbohydrates obtained from cassava peels. Mortality was reduced by 30% while growth rate increased 30% and in some cases the herds were doubled. Thus the innovation has significantly impacted small ruminant production in the country because of their ability to survive and produce in poor environments on low-cost feeds; their particular adaptability to arid conditions; and their suitability for the small, capital scarce family farms in developing countries. This has led to greater protein availability in the country as well as higher incomes for farmers and stock owners with its attendant impact on poverty reduction especially in village based smallholder production systems.

Challenges and opportunities

The first major challenge was funding, which was quiet inconsistent and thus limited the success of the project. Another challenge was that because most of the partners were illiterates it affected the initial uptake of the innovation. At some of the villages there were no veterinary doctors which posed some challenges for the transfer and diffusion of this innovation since the deworming regime was a key component of the package. There were also problems with accessibility, as villages were far away from motorable roads. Finally veterinary shops were not available nearby for farmers to access and there was also the problem of packaging of veterinary drugs for small ruminants. The major factors limiting a meaningful and sustainable improvement in small ruminant production in the country are: seasonally related low levels of nutrition, high levels of pre-weaning mortality resulting from parasites and infectious diseases, and bad management. These constraints are interactive and are often aggravated in traditional husbandry systems by lack of flock management. The introduction of the husbandry package small ruminant production is meant to address these constraints farmers and flock owners (end-users) encounter on a regular basis. In terms of the policy environment there is the need for the government to scale up within the Departments of Animal Husbandry and Veterinary Services, Small Ruminant Extension Units (SREU). Staff from these units will need to work closely with sheep and goat farmers to help them improve housing, feeding and disease control measures. Moreover, the government is required to encourage or assist research institutions to study vigorously the improvement of sheep and goat husbandry and their disease control and make available their results to the SREU for implementation. Also, government should encourage or assist in the timely provision of vaccines such as PPR, acaricides and anthelmintics for the control of sheep and goat diseases. Finally, government needs to provide coordination for all the agencies dealing with some aspects of sheep and goat production and disease control.

Despites these challenges there also are opportunities. The CSIR-ARI is well positioned to promote this innovation especially with a sustainable funding regime. At the national level, there is the need to improve on the provision of extension services for livestock farmers as well as the supply of veterinary services and this will go a long way to enhance the dissemination of the innovation. Some of the farmers in the beneficiary communities are using the innovation. Through this project, the CSIR-ARI was able to breed its current small ruminants which serve as a training centre for the farmers. Opportunities exist for CSIR-ARI to ensure effective dissemination of this innovation with the land available and animals at the institute. If applied diligently, the innovation could be used to positively impact the small ruminant production in the country which is currently low, leading to higher incomes for farmers.

vii. Improved Nile Tilapia (Akosombo Strain of *Oreochromis niloticus*)

In Ghana fish farming is done through two basic systems: monoculture of tilapia and polyculture of tilapias and catfishes. The main species of tilapia grown in fish ponds in Ghana is the Nile tilapia, Oreochromis niloticus. A major constrain to its culture in the country include unavailability of certified fast-growing fingerlings to stock fish ponds at the right time in order to make the aquaculture industry viable and profitable and contribute its quota to help solve the problem of protein imbalance and alleviate poverty among the population. To solve the problem of slow growth and survival of the Nile tilapia in Ghana, the “Akosombo Strain” was developed by the CSIR-Water Research Institute first in 1997 with improvements between 2001 and 2006.

Characteristics of the innovation and how it works

The innovation was developed at the Water Research Institute-Aquatic Research and Development Centre (WRI-ARDEC) located at Akosombo hence the name “Akosombo Strain”. Fingerlings produced using the Akosombo Strain of Nile tilapia grow at least 25% faster than those collected from the wild. The Akosombo strain of Nile tilapia was established in 3 stages:

- *Stage 1: by collection and evaluation of stocks* O. niloticus (Guinea savanna), Yeji (YE) (Transitional Zone) and Kpando (KP) (semi-deciduous forest). A fourth stock (FS) was collected from a farmer’s pond. The four stocks of O. niloticus were evaluated for growth rate reproductive capacity and survival. NA had the highest growth rate while "YE" had the highest reproductive capacity.

- *Stage 2: interbreeding of stocks*: The four stocks were interbred [Diallele Cross Experiment]. Results from evaluation of progeny of the crosses in three culture experiments (extensive, semi-intensive and intensive. Showed that the purebreds performed better than the crossbreds Heterosis (hybrids vigor) was low.
- *Stage 3: breeding and selection* (2003-2007). The best genetic materials from the crossbreeding evaluation experiment were selected to form the base population from which a faster growing strain of O. niloticus known as the Akosombo Strain has been developed. The breeding and selection process has not stopped. It is on-going. Every year, the best materials are selected to become the parents for the next generation thus, the growth rate of Akosombo Strain of Nile tilapia is increased through the process of application of selective breeding techniques.

The Fish breeding Center (where the Akosombo Strain is developed) is located at WRI-ARDEC, Akosombo. The most current generation of fast growing O. *niloticus* could be obtained from this Centre. Certified male and female broodstock (parents) are supplied to minor multiplication centers (private hatcheries) e.g. Tropo Farms, Fishreit, Crystal Lake Ltd. who produce two types of fingerlings (i.e. mixed-sex Nile tilapia fingerlings and All-made tilapia fingerlings) for sale to fish farmers. Farmers who have prepared their ponds or cages for stocking with fingerlings could either purchase them from the private hatcheries or directly from WRI-ARDEC. The fingerlings are fed on pelleted fish feed till they reach maturity (table size).

Funding and collaborations

The project is a collaborative work between the water Research Institute and the WorldFish Centre (formerly International Centre for Living Aquatic Resource Management-ICLARM) for the past ten years. Funding was provided by UNDP and the European Union through the WorldFish. The technology used in developing the Akosombo Strain is very high and this requires high level research scientists at The WorldFish Centre have also acted as advisors to the project. Collaborators are fish farmers whose ponds and cages are used in on-farm trials to test the growth of the improved strain of Nile tilapia. Funding for the project was provided by the following agencies:

a. The Ghana Government through the World Bank Sponsored Projects-NARP and AgSSIP. (20%) (1999-2003);
b. UNDP through the World Fish Center (40%) 2001-2003; and
c. European Union through the World Fish Center (40%) 2005-2009.

Dissemination and adoption of the innovation

The potential end-users of this technology are fish farmers across Ghana and within the West-African Sub-region. As indicated above, NGOs from Burkina Faso have already collected breeders and mixed-sex fry of the fast growing Akosombo Strain for ARDEC for use in their country. Other potential end-users are tilapia hatchery operators who use the brood stock to produce fry and fingerlings for the farmers. Women fish traders who deal in table-size fish will benefit indirectly through their trading activities. The Akosombo Strain of *O. niloticus* has been populated and transferred to potential users through workshops, conferences (local and international) and seminars. By conducting on-farm trials in farmers' ponds, they were convinced of the increased yields that they would achieve when they use fingerlings from the Akosombo Strain of *O. niloticus.* Basically, a lot of information about the positive performance of this strain has been circulated through farmer to farmer contacts. Through an international workshop, "Pioneering Fish Genetic Resource Management and Seed Dissemination Programmes for Africa: Adapting Principles of Selective Breeding to the Improvement of Aquaculture in the Volta Basin" in 2007, an organization in Burkina Faso, Project d'elevage Piscicole (PEP) has purchased 10,000 mixed-sex fingerlings and 220 breeds of the Akosombo strain from WRI-ARDEC in 2008. Further purchases were made for brood stock in subsequent years. African countries have been introduced to the Akosombo strain through a new project which coordinated by FAO and funded by the Spanish Development Agency-Mentum through the European Union. An FAO sponsored project "Aquaculture Investments for poverty reduction in the Volta-Basin: Creating Opportunities for Low-Income African Fish Farmers through Improved Management of Tilapia Genetic Resources" was inaugurated in 2009 at Abidjan, La Cote d'Ivoire. This project helped to promote the use of Akosombo strain amongst six countries within the Volta Basin i.e. Benin, Burkina Faso, Ghana, Cote d'Ivoire, Mali and Togo. Adoption of their technology by farmers in these six countries has increased production of Nile tilapia in Ghana. The supply of certified fast-growing fingerlings to fish farmers is more reliable and created a chain of employment opportunities. T.V. documentaries and published papers were also sources of popularizing the innovation.

Impact of the innovation on beneficiaries

The Aquaculture industry in the country previously experienced low yield after harvesting the fish due to the slow growth rate of fingerlings stocked. By using the Akosombo strain which has a superior growth rate compared to Nile tilapia from the wild, farmers are able to harvest more fish per year, the time it takes to harvest more fish per year, the time it takes to grow the fish to maturity is reduced and this translates into more money in the pockets of farmers. Increase in yield would result in more protein being made available to the population and this result in reduction in poverty, unstable income and food insecurity. This technology has addressed a major problem that was a set back to the sector. Without a reliable supply of fast growing fingerlings, the fishery industry cannot survive. The technique and methodology could be used to improve catfish (*Clarias gariepinus* and *Heterobranchus* spp.) which follows the Nile tilapia in order of importance in Ghana. The benefits that this innovation brings are numerous. The innovation has generated a chain of employment for the youth as producers, farmers, exporters, processors and entrepreneurs involved in various levels of the fish value chain.

Challenges and opportunities

The main challenge is the sustainability of the research activities at the nucleus breeding centre at WRI-ARDEC in Akosombo. Improvement of the growth rate of the Akosombo Strain is not a onetime activity: it is continuous from one generation to the next. The process is expensive and involves inputs that have to be exported (e.g. PIT tags for identification of different families and individuals' tag readers, anaesthetizes, among others. A contract and reliable source of funding is required. Brood stock management and multiplication centres should be established by the government whiles existing facilities should be upgraded. These stations will be the first to collect the latest generation of "Akosombo Strain" development at the nucleus station, multiply them, using approved techniques that ensure their quality; and distribute them to minor multiplication centres and fish farmers. Adoption of this procedure will ensure that reliable certified feed is supplied to fish farmers at all times. Increased production through application of this technology could be sustained by strengthening of fish farmers' association at local, district, regional and national levels while provision of sustainable credit facilities to farmers to initiate and expand their operations will enable them contribute significantly to the economy of Ghana. The Aquaculture Research and Development Centre is well positioned to develop and promote the use Akosombo Strain of *O. niloticus* in Ghana and within the West African sub-region. Development of the strain using breeding and selection methods requires a high level of expertise. Research and technical staff involved in the project have been well trained and most of them have doctorate degrees in their field of study. At the national level, the Government and international research collaborators (e.g., the Worldfish Centre) have continued to support the project through provision of infrastructure and funding for minor equipment such as ponds, cages, and concrete tanks. Currently, the WRI-ARDEC is the leading institution in West Africa which has a nucleus breeding centre and this has positioned it strategically to disseminate the Akosombo strain of Nile tilapia to procedures within the sub-region.

SYNTHESIS AND LESSONS

There is a growing emphasis on innovation in current development thinking. The reason is simply that, innovation underpins improvement in all socio-economic activities. The challenge confronting all nations can only be effectively addressed through science, technology and innovation. In the market place especially, innovation gives competitive edge to the innovating enterprises. In this regard, no society can afford to down play the issues constraining innovation for its socioeconomic activates. The traditional roles of agriculture include provision of food security, supply of raw materials for industry, creation of employment and generation of foreign exchange earnings. Beyond these, agriculture is also recognised to have a greater impact on poverty reduction than other sectors. Other roles are social stabilisation, buffer during economic shocks, support to environmental sustainability, and cultural values associated with farming. Indeed agriculture is the backbone of this country hence it is necessary to pay attention to the drivers of innovation taking place to improve the sector.

The situation analysis presented in this report highlights important issues that need policy decisions to enhance innovation generation, transfer and adoption in Ghana. The following discussion focuses on the key issues arising from the seven case studies of agricultural innovations:

- Relevance of innovation
- Research and development institutions
- Funding and collaborations
- Dissemination and adoption of the innovation
- Impact of the innovation on beneficiaries
- Challenges and opportunities

i. Relevance of innovations

The innovations identified in this study clearly demonstrate that Ghana's researchers are involved in applied and demand-driven research with the aim of solving problems in the agricultural sector and the nation as a whole. Although some domains such as crop variety improvement received much attention, essentially relevant domains and issues have been given some attention. The challenges of Ghana's agricultural sector such as poor soil conditions, low and poor distribution of rainfall, diseases and pests, limited access to planting materials, seed and livestock breeds, poor livestock management practices, limited appropriate technologies for processing, handling and storage, limited knowledge in post-harvest management, and low adoption of existing technologies are all being addressed by Ghana's R&D institutions.

ii. Research and development institutions

Most of the technologies were developed by the various institutes of Council for Scientific and Industrial Research (CSIR). The CSIR is the foremost national science and technology institution in Ghana and it is mandated to carry out scientific and technological research for national development. The involvement of CSIR institutes in the generation and dissemination of the innovations is this in line with their core mandate. The CSIR institutions that were involved in the generation of the technologies and innovations are as follows:

- Animal Research Institute
- Crops Research Institute
- Food Research Institute
- Forestry Research Institute of Ghana
- Institute of Industrial Research
- Oil Palm Research Institute
- Plant Genetic Resources Institute
- Savanna Agricultural Research Institute
- Soil Research Institute
- Water Research Institute

Other institutions that generated technologies and innovations are departments in the universities as follows:

- Department of Crop Science, Faculty of Agriculture, University of Development Studies, Tamale
- Department of Crop Science, Faculty of Agriculture, KNUST, Kumasi
- Department of Crop Science, Faculty of Agriculture, University of Ghana, Legon
- Agricultural Research Centre, University of Ghana, Kpong
- Animal Science Department, University for Development Studies, Tamale
- Animal Science Department, KNUST, Kumasi
- Department of Nutrition & Food Science, University of Ghana, Legon
- College of Agriculture Education, University of Education, Winneba.
- Department of Horticulture, Faculty of Agriculture, KNUST, Kumasi.

iii. Collaborations and funding

The development and dissemination of the innovations involved a number of collaborations. A good level of collaboration was observed among CSIR institutes, especially CSIR-CRI and CSIR-SARI which are all involved in crops research. These institutions also collaborated with the CSIR-FRI where the innovations involved post-harvest issues and product quality improvement. Collaboration was also observed between the research institutes, universities and MOFA, which clearly demonstrates a good linkage between research and extension. Collaborations were also seen between researchers and existing projects such as the Food Crops Development Project and the National Mushroom Development Project. Other collaborators were National Board for Small Scale Industries, local and international NGOs, International Institute of Tropical Agriculture (IITA), Natural Resources Institute of the UK, and World Fish Centre. The development and dissemination of the innovation were largely project-based and funded by various development partners and agencies. The funders include the Ghana government, African Development Bank, Department of International Development (DFID) of UK, Bill & Melinda Gates Foundation, AgSSIP, Semi-Arid Food Grain Research and Development Programme, UNDP, and the European Union. In most Funds were not sufficient as it did not meet the requirements including innovation, generation, dissemination and monitoring and evaluation.

iv. Dissemination and adoption of the innovation

The innovations for high quality cassava flour and mushroom production, rice parboiling vessel, improved soybean variety- Jenguma, and improved Nile tilapia have been extensively disseminated. All these technologies have been adopted and are being applied in various ways. The dissemination process either formed part of the innovation development or as a component of other projects. The dissemination of the parboiling vessels technology, for example, was enabled by other projects such as World Food Programme (WFP), Rice Sector Support Project, Agence Française de Développement, and ADVANCE. Evidently, the success of these innovations stemmed from the extensive support provided by Ghana government and its agencies such as MOFA and Ghana Seeds Company, and donor agencies, development partners and NGOs. There have been limited dissemination and adoption of the innovations for utilizing Azolla as manure in lowland rice cultivation and the development of husbandry package for small ruminant largely due to unavailability of funds. This findings clearly demonstrate that extensive collaboration among various stakeholders is necessary for converting research efforts into socioeconomic developments. This suggests that in designing projects with development objectives, there is the need to integrate methods and resources for dissemination and adoption into the design. For example, supplying improved soybean seeds to farmers, procuring parboiling vessels for women groups and training them on their operations and maintenance demonstrates effective ways of disseminating innovations and ensuring adoption. This is where the innovation platform concept becomes relevant. The concept was developed by Forum for Agricultural Research in Africa (FARA) to address most barriers to technology development, dissemination and adoption in Africa, which the previous linear methods of technology transfer failed to tackle. The innovation platform approach is effective in strengthening the linkages not only between researchers and farmers but also among policy makers and several stakeholders along the commodity value chain.

v. Impact of the innovation on beneficiaries

All the innovations were developed with socioeconomic development objectives and to solve specific problems hence their impacts on the beneficiaries are enormous. The impacts were however greater where there was an effective dissemination coupled with the supply of inputs and other resources, capacity building and monitoring.

vi. Challenges and opportunities

The challenges identified can be classified into research and development-related challenges and challenges associated with the use of the innovations. The major challenge in the development and dissemination of the innovations is funding, which was either inadequate or delayed. A reliable funding source is required, for example, to sustain research activities at the nucleus breeding centre at WRI-ARDEC in Akosombo to generate more innovations. The other challenge is poor infrastructure, such as bad roads, some of which are not motorable, hence hampering dissemination activities. Weak research-extension linkage was also identified as a challenge especially with regard to the innovations involving the use of Azolla as manure and the development of husbandry package for ruminants. In some cases lack of promotion and national policy limits dissemination and adoption. An example is the use of high quality cassava flour as a wheat flour substitute, which has no policy backing as against mushroom cultivation and the use of soybean variety Jenguma that were actively promoted by the National Mushroom Development Project and Ghana Seeds Company respectively. In relation to challenges associated with the use of the innovations, beneficiaries often have limited access to finance to enable them acquire and apply the innovations. Even when the use the innovations, they are often confronted with limited access to markets. This has happened in the case of soybeans and mushroom production. These suggests that technology development, transfer and application need to be tackled holistically by involving all relevant stakeholders so as to remove most barriers.

Despite these challenges, opportunities exist for the generation of useful innovations. The CSIR is well positioned to conduct research and develop technologies that will address Ghana’s socioeconomic challenges. Although government’s funding for research is insufficient, researchers from the CSIR, universities and other institutions are capable of writing proposals to compete for funding from international sources. In fact, this has been the major source of funding for its research and development activities. Increasingly, awareness is being created about the various technologies and innovations that researchers have developed in Ghana and programmes such as the

COTVET technology transfer project is helping bridge the gap between research and industry. There is also increasing local and international demand for quality and value-added products, which creates opportunities for more innovations in quality product development. There is however the need to link marketing issues to all technologies being developed to ensure the attainment of increased economic benefits from innovations. The CSIR and all research institutions under the Ministry of Environment, Science, Technology and Innovation (MESTI) are enjoying increasing positive political influence, which has enabled the drafting of a composite flour and biogas policies together with their implementation plans. With these policies in place, it is expected that more research and promotional activities will be carried out to realize maximum socioeconomic benefits from high quality cassava flour and biogas innovations.

STUDY TWO

Inventory and Characterization of Innovation Platforms

INTRODUCTION

Innovation platforms (IPs) are important vehicles to stimulate stakeholder actions for innovations. In the agricultural sector, IPs are considered crucial for improving productive activities in the identifiable components of the value chain. The use of IPs is the result of the systemic thinking of innovation with emphasis on promoting positive interaction among stakeholders in the agricultural innovation system (AIS). In Ghana, there have been efforts at establishing IPs in the agricultural sector to promote innovations, to enhance agricultural productivity. There is the implementation of the Integrated Agricultural Research for Development (IAR4D), which is an IP concept advanced by FARA. The specific case of Dissemination of New Agricultural Technology in Africa (DONATA), which is led by the Crops Research Institute of the CSIR, holds out some experiences worthy of analysis. There are also the IP cases of the Convergence of Science – Strengthening Innovation Systems (COS-SIS), which bring in lessons from other dimensions of IPs.

Clearly, the diversity of IP cases coming from different conceptual perspectives provide a rationale for conducting a study to review and appraise the experiences in the various cases. Generally, IPs are instruments for promoting innovations in specific domains and localities. The systemic approach to innovation has given credence to the use of IPs, especially in the agriculture sector. However, there is the fundamental question of how to implement a given IP concept in order to enhance its effectiveness and impact. It is against this backdrop that the Programme for Accompanying Research and Innovation (PARI) project, in collaboration with 12 national agricultural research institutes in Africa, has formulated this scoping study of existing agricultural innovation platforms. In Ghana, this study is being conducted by the Science and Technology Policy Research Institute of the Council for Scientific and Industrial Research. The basic question this study attempts to answer is: What lessons are there to guide and enhance the experiences in the IP implementation in Ghana in the past one decade? The study will address specific questions such as:

- What are the IP cases and experiences in Ghana?
- How were they executed and what are the outcomes?
- What are the key lessons to enhance the IP implementation in Ghana?

METHODOLOGY

The study began with desk research given that a lot of literature has been generated on the implementation of the IP concept in Ghana. There was extensive search for reports and publications of literature on IP cases in Ghana. The internet was a useful tool in accessing information and literature on IP experiences in Ghana. There were also consultations with some of the leaders of IP projects in Ghana to gather more information and views on the IP cases. The consultations were based on some of the issues that arose in analyzing the information gathered from the literature review.

Efforts towards transforming agriculture with a view to reducing poverty, increasing food and nutrition security, and reducing environmental degradation started in the 1950s, when the linear transfer of technology model was introduced (KARI, 2013). The linear approach looks at knowledge development/production and application as separate activities, carried out by researchers and farmers (Nederlof et al., 2011). Researchers are in charge of producing knowledge. Extension agents are expected to transfer the knowledge to farmers, who are expected to adopt it. In the 1970s, the farming systems perspective emerged, which was aimed at understanding constraints faced by the farmer, while the scientific input was interdisciplinary and the work was conducted on-farm. Farmers were consulted, but scientists remained as the key source of knowledge and innovation. In the mid-1980s, more participatory approaches where introduced with more emphasis on farmers with the goal of developing technologies suitable for small-scale, resource poor farmers and ensure adoption to increase farm productivity and income (Selener, 1997). Thus, the concept of 'Farmer First' was introduced, which involved approaches such as 'Farmer-back-to-Farmer', 'Farmer First and Last', 'Farmer Participatory Research', and 'Participatory Technology Development' (Mulema, 2012). Farmers were involved in the process of generating, testing and evaluating technologies to promote sustainable agricultural production. Farmer participatory research approaches (FPR) were launched in the 1990s, when scientists and farmers were considered as co-creators of new knowledge that was directly relevant to the farmers' livelihoods. This new approach recognized the importance of farmer engagement in the knowledge development process, but failed to fully recognize institutional constraints and the usefulness of multiple actors besides the necessity to engage all key stakeholders (KARI, 2013). Towards the end of the 1990s, the innovation systems approach and its actualization through innovation platforms (IP) was introduced. This approach recognizes the enabling role played by institutions, multi-stakeholder engagement, as well as policies towards innovation, social learning and the adoption of improved methods (Hounkonnou et al., 2012).

An innovation is the process of application of new or existing knowledge in new ways and contexts to do something better. It is a process that transforms ideas into outputs by replacing older established products, processes and services with new ones (KARI, 2013). This transformation may be in products, processes or services, and can be incremental or radical and at various levels of the value chain. The Oslo Manual for measuring innovation (OECD, 2005) defines four types of innovation, namely: product innovation, process innovation, marketing innovation and organizational innovation. Product innovation refers to a good or service that is new or significantly improved.

This includes significant improvements in technical specifications, components and materials, software in the product, user friendliness or other functional characteristics. Process innovation refers to a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. Marketing innovation implies a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. Organizational innovation refers to a new organizational method in business practices, workplace organization or external relations. Innovation consists of three basic elements: (i) technology, including new varieties or breeds and soil or water management practices; (ii) organizational, in terms of organizing and delivering knowledge in new ways; and (iii) institutional, in terms of rules, cultures, values, norms, behaviour, policies and laws (KARI, 2013).

Innovation system

Innovation system refers to dynamic network of agents interacting in a specific economic/industrial area, under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology (Adekunle and Fatunbi, 2012). The innovation system approach emerged through policy discussions on the nature and analytical framework for industrial growth in 1980s (Agwu et al., 2008). The concept extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways (World Bank, 2006). The innovation systems framework sees innovation in a more systematic, interactive and evolutionary way, whereby networks or organizations, together with the institutions and policies that influence their innovative behaviours and performance, bring new products and processes into economic and social use (Hall, 2005). In the innovation system, more emphasis is placed on fostering active interactions among diverse stakeholders and enhancing human capacity to continuously innovate to be able to adapt to changing socio-economic and environmental conditions. This is further enhanced by favourable policies that stimulate and support innovation, and utilization of new innovation.

In the sphere of agricultural research and development, innovation system depicts a dynamic network of stakeholders interacting and learning together towards the generation, dissemination and continuous adoption of a technological output. Lately, it has found prominence among the policy makers and it is being explored as an approach for achieving sustainable development in agriculture and rural development (KARI, 2013). It has been applied to agriculture in developing countries only recently, but it appears to offer exciting opportunities for understanding how a country's agricultural sector can make better use of new knowledge and for designing interventions that go beyond research system investments. The last 40 years have witnessed substantial debate over the best way for science and technology (S&T) to foster innovation. The first view to emerge regarded scientific research as the main driver of innovation, whereby research created new knowledge and technology that could be transferred and adapted to different situations. This view is usually termed the "linear" or "transfer of technology" model (World Bank 2008). The second and later view was termed the "agricultural knowledge and information system" (AKIS) concept in the 1990s and, more recently, the "agricultural innovation systems" (AIS) concept. An AIS has five main elements namely: education, research, enterprise, demand and intermediary domains, as well as supports structures as shown in figure 1 with linkages among the various components and the institutions and policies that constitute the enabling environment for innovation.

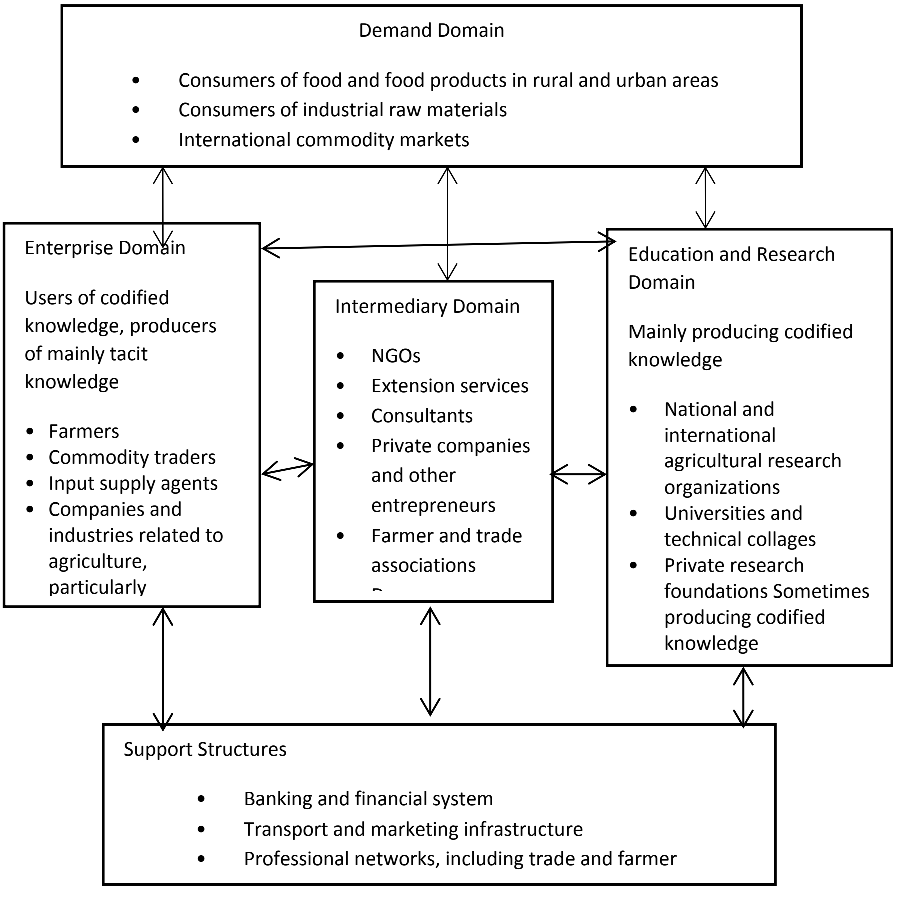

Figure 1. Elements of an agricultural innovation system
Source: World Bank 2008 as adapted from Arnold and Bell 2001: 292

The Concept of Innovation Platform

An innovation platform (IP) derives its roots from the innovation systems theory. An IP is described as a forum established to foster interaction among a group of relevant stakeholders around a shared interest (KARI, 2013). It serves as the platform for diagnosing problems, exploring opportunities and investigating solutions. Essentially, an IP is the framework which brings stakeholders along the value chain together for continuous interaction and lesson learning through action research to ensure that technology generation, dissemination and adoption takes place on targeted commodities or systems for the economic benefit of stakeholders (Adekunle and Fatunbi, 2012). The stakeholders in this case perform different but complementary roles in the development, dissemination and adoption of knowledge for socio-economic benefit. These roles could be new ideas, methodologies, procedures, concepts or technologies developed or adapted from other locations. Innovation platforms seek to harness innovations related to technology processes, institutional and social organizational arrangements. To promote these innovations, partnerships along and beyond agricultural value chains must be fostered to bring on board actors with a special mix of skills (World Bank, 2011). Value chain comprises an entire system of production, processing and marketing, from inception to the finished product. It consists of a series of value chain actors, including farmers, traders, processors, wholesalers, retailers and consumers linked together by flows of products, finance, information and services. Value chain supporters such as government regulators, financial institutions, research institutions, extension agencies and transporters provide various services to the chain and enable it to function (Birachi et al., 2013).

In constituting the IP members, key obstacles that could hinder the accomplishment of developmental goals are considered. Every member of the platform is considered to have something unique to contribute and to benefit, thus making it a win-win collaborative mechanism. The stakeholders interact to jointly identify problems and opportunities, seek and apply solutions, learn, reflect and source more solutions for the innovation process to continue (Adekunle et al., 2010). Innovation platforms have to strategically engage researchers for continual contribution to the development of technologies, new products, increased productivity, natural resource management, policy, markets development and gender. In a typical agricultural value chain, IPs are used as a mechanism to organize stakeholders (including farmers, pastoralists, rural communities, researchers, extension agents, development specialists, traders and processors, wholesalers and retailers, policy makers, regulators and consumers) who then identify research issues, problems, needs and opportunities in their respective localities and generate strategies to address them (FARA, 2007). Thus, an IP facilitates integration of perspectives, knowledge and actions of different stakeholders around a common issue and foster learning through interaction (Hawkins et al., 2009). Typically, IP creates interdependences among stakeholders, promote social learning, and build confidence and joint action (Röling 2002). It also identifies bottlenecks and opportunities in production, marketing and the policy environment. This process is galvanized through discussions on market requirements (such as quantity, quality, and the timing of sales), followed by an analysis of existing production strategies. The IP then identifies and implements technologies to improve production to fulfil market demand.

The IP is a fluid entity with an evolving membership that draws on relevant expertise depending on the problem being addressed. The central partners, often consisting of those with the most at stake, such as producers and buyers, provide insight on technology and information challenges in production and marketing, and articulate market requirements. Together, the most feasible solutions to be tested and implemented are chosen. By bringing together the various stakeholders and providing them with a stage to voice their various needs/requirements, the IP generates site-specific solutions to align production with market requirements, which will ensure better prices for smallholder producers (ICRISAT). For an IP to sustain its mission, it must continuously innovate and replace existing products, processes, and services with more effective ones. Focusing on innovation as a continuous process acknowledges the effect that learning has on knowledge creation within the IP. Learning how to innovate effectively entails managing knowledge within the platform and offers the potential to enhance the way it innovates. Thus, while we may define innovation as the process of making changes to something established by introducing something new, it is important to add that the introduction has to add value for the customers (IP members) and also contribute to the knowledge store of the IP, which is partially synonymous with the concept of organizational learning (KARI, 2013).

The International Livestock Research Institute (ILRI, (2013) identifies three types of platforms that deal with value chains. The first type is the farmer-based IP, which helps farmers market their produce. It involves members from the value chain, such as buyers and processors, along with service providers such as financial organizations. It may deliberately avoid certain groups or individuals, such as traders, who the farmers think exploit them. A goal of such a platform may be to enable the farmers to sell directly to larger urban buyers. Such platforms may facilitate negotiations on behalf of the farmers, arrange deals and coordinate production and trading. The second type is the value-chain-based IP, which focuses on the value chain as a whole. It may be established by a research or development organization, or perhaps by a leading actor in the value chain, such as a processor or supermarket chain. It aims to identify and overcome bottlenecks in the chain and find ways to make the chain more efficient. The third type is the accidental IP, which starts by accident. Such platforms are established to deal with another topic, such as animal feeding or crop production, but when members realize that market development is an issue then they shift at least part of the platform's attention to deal with it.

Nederlof et al. (2011) also delineated four types of innovation platforms: (1) The learning and research-oriented IP includes the platforms for which the foremost aim is learning on how innovation emerges and is sustained, and in which research organizations play a prominent role. (2) Development and research-oriented IP relates to the platforms primarily aimed at local economic development, where research plays a prominent role. (3) Development and non-research oriented IP includes the platforms aimed at achieving local economic development, but in which research does not play a prominent role. (4) Learning and non-research oriented IP may include platforms that are supported by the AgriProFocus (www.agriprofocus.nl) and Prolinnova networks (www.prolinnova.net).

Critical Actors in Innovation Platforms

In the innovation literature, emphasis has always been on the role of critical actors. In the agricultural sector, Nederlof et al. (2011) indicates that innovation platforms generally involve five stakeholder groups, namely: (1) smallholder farmers; (2) input dealers, agro-food processors and traders; (3) private and public providers of technical (research and extension) and managerial (business development) services; (4) financial services (banks and microfinance institutions); and (5) regulatory bodies (which define standards and rules). The government can be part of groups 3, 4 and 5. Non-governmental organizations (NGOs) are normally part of group 3, filling in gaps left by poor public-service provision. Typically, the role of farmers, agricultural extension officers, researchers and policy makers is crucial for successful outcomes. Figure 1 also shows critical actors of an agricultural innovation system, which include researchers and other knowledge producers, farmers, industries and other knowledge users, private sector, NGOs, donors, farmer and trade associations, consumers and policy makers, banking and financial system, transport and marketing infrastructure and professional networks.

Membership of an innovation platform is dynamic. Therefore in some instances, actors will be invited over time, and some actors who initially participate will leave the platform. When the platform better defines its objectives and scope of work, its members may well realize that they miss the presence of important organisations or individuals. As the focus of the platform changes over time, its composition may also change to adapt to the new focus. The roles of participating individuals and organizations may also change, not only as a result of a change in the platform's objectives or strategies, but also as a result of internal reflection and learning. However, as time goes by, and the platform's functioning demands different skills, others may be well placed to take up the challenge of brokering, facilitating, coordinating or representing the platform.

Getting multiple partners to work, learn, and innovate together often requires a broker, champion or a catalyst. An innovation platform broker or champion (who may be an individual or an organization) is responsible for connecting the local partners for operational purposes and linking them with platforms at higher levels. Platforms at higher levels, e.g., regional or national platforms, are tilted more towards strategic rather than operational matters. The broker also provides guidance and where this is an outsider, gradually facilitates takeover of this role by local stakeholders in form of a local broker or a local steering committee stakeholder. Brokering involves a number of functions that include facilitation. Innovation brokers are those who act as a catalyst of interaction between two or more parties (Nederlof et al., 2011). Their purposes are to build appropriate linkages and multi-stakeholder interaction (Klerkx et al., 2009). Typically, functions of brokers include:

- Facilitation (e.g., facilitating meetings between parties)
- Linking and strategic networking (e.g., mobilizing resources and linking the platform to resource persons such as legal, financial advisors and thematic specialists),
- Technical backstopping (e.g., providing technical information or linking the platform to those who can provide the information),
- Mediation (devising strategies to address conflicts),
- Advocacy (e.g,. informing policy makers and calling for policy change),
- Capacity building (e.g., providing training or linking members to training institutes),
- Management, which may include financial management, reporting and communication with the donor. This enables the brokers to have an overview of funding issues, but the disadvantage is that the broker may sometimes also be looked upon as a donor in disguise (Klerkx et al., 2009; Tennyson, 2005);
- Documenting learning (e.g., stimulating reflection on the experiences of the platform, sharing findings)

Some persons who are neither platform members nor brokers sometimes play monitoring roles. These persons can be referred to as champions. These are typically highly motivated stakeholders within the innovation platform. Champions motivate peers from their group, promote contacts between the platform members and their respective constituencies, and often set an example. Champions often also take care of day-to-day platform management issues, training and mobilization when the broker cannot do it. Though undoubtedly useful and important, champions do not always have a legitimate brokering position or the ability to enhance overall capacity of the platform for reflection on vision and goals (Nederlof et al., 2011).

IP Approaches

Innovation platforms can be formed at least at three levels - operational (local), intermediary/regional and national levels. All platforms however deal with common problems found in a specific sector or sub-sector, for which identification and application of solutions depend on more than one actor (KARI, 2013). Stakeholders may have different interests yet share a common objective and depend on one another in responding to the challenges and opportunities encountered.

At the community level, platforms often look for opportunities or practical solutions to a local problem, by linking local farmers to markets and other stakeholders. In so doing, they provide evidence for realistic policies and policy areas which could be taken up at the higher level. Higher level platforms inform policy makers, who in turn formulate policies that will have an influence on local level activities. Platforms can operate at several levels, with local, provincial and national level bodies. This multi-layered structure is of great advantage. Local-level platforms have the potential to provide evidence on how new ideas work on the ground, which can then feed into higher-level policy dialogue. In addition, they can be used to get the opinions of key stakeholders on a particular issue. Local-level platforms can be better used if they are considered innovation platforms in their own right. As such, they also go through a participatory process of decision making and agenda setting, focusing on their members' immediate interests and concerns.

Formation of IPs

Most innovation platforms follow a number of steps to be initiated. These include: (1) scoping, to figure out where a platform fits; (2) analysis of stakeholders and of promising entry points, and (3 planning (Nederlof, 2011). KARI (2013) also identifies four broad phases of IP formation as follows:

1. Initiation and visioning (this includes engagement with stakeholders and setting vision for the group);
2. Establishment (which includes planning and stakeholder engagement);
3. Management (including facilitation, learning, assessing), and
4. Sustainability (which includes the application of lessons from assessment in developing sustainability measures)

1. **Initiation phase.** This phase includes site selection, determination of the agenda and entry points. This first step comprises a scoping study or process to determine and understand the compelling challenges of the value chains of selected commodities or systems. The process is accomplished by an initiator or broker who convenes a meeting of diverse, all-inclusive stakeholders to discuss and articulate the challenges that limit performance of the value chains of selected commodities or systems. The initiator here could be an individual or a team or even an organisation in either the public or private sector. They could be researchers, farmers, development workers or private sector players covering the inputs or output markets or policy makers. The product from this phase may include a general description of the system or the value chains coupled with a privatization of the entry points.

2. **Establishment phase.** Selected entry points influence this phase, particularly the kind of stakeholders to be engaged. Stakeholder analysis is conducted to enable the initiator to identify stakeholders willing to join the platform and their capacities to play expected roles on the platform. The narrowing of the platform topic, understanding of the context, visioning and action planning is undertaken in this phase. After gaining the general understanding of the challenges in the initiation phase, the stakeholders relevant to the topic are selected and engaged. Through the relevant stakeholders, the IP agenda is refined.

3. **Management of IP phase**. This is where the management of the process takes place, including learning and innovation.

4. **Sustainability of an IP.** This is where stakeholder dynamism occurs as issues are solved and new issues arise, old stakeholders leave and new ones join as need arises. These new issues can be championed by an individual or organization with the expertise in that new area or has knowledge to bring relevant interventions to solve the new challenges. Learning and innovation continues in this stage. "Sustainability is concerned with measuring whether the benefits of an activity are likely to continue after donor funding has been withdrawn" (OECD, 1991). While an IP is not meant to survive through generations, it is critical that it remains active only while it fulfils a need and responds to an opportunity, or ceases to function or transforms itself into a renewed platform with a new objective (Nederlof et al., 2011).

Institutionalization (scaling up and out)

Convincing organizations of the need for such platforms – or, in fact, for such approaches– and having it actively supporting them, is here referred to as 'institutionalization'. By institutionalization we mean incorporating an idea or approach, or its principles into an organizational culture, policy and activities. The result of such institutionalization is not only that more platforms are established but, more importantly, that the principles behind the work of such platforms (and in this case, of agricultural innovation systems) are well understood and acknowledged, and therefore become the accepted pillars for the organization's activities. In other words, this means that organizations adopting, participating in, and possibly initiating stakeholder dialogue through innovation platforms or similar mechanisms, become part of their way of working. Policy makers may, for example, change the way agricultural research and development's priorities are set, by using the platforms to do so, or by making such platforms part of their policy on development of value chains in a certain area of the country. Farmers' organizations, on the other hand, may institutionalize the approach by deciding to systematically improve their capacities to work with other organizations and do so more frequently.

Scaling out refers to the duplication or replication of: a. innovation platforms themselves, and b. results, solutions and findings obtained through joint action by the platforms (i.e., the immediate outcomes). In the case of scaling out the platforms themselves, there is a risk that innovation platforms be considered solutions in and of themselves, rather than a mechanism that can be applied to enhance innovation in certain contexts.

RESULTS

Some innovation platforms have been established in Ghana in the last 10 years and this section presents a list of these innovation platforms. Also included in this section are key characteristics of the IPs, such as the entry point or value chain, location, participating communities, date of establishment, institutions setting up the IP, funding agents, facilitators, opportunities addressed, achievements made, challenges and sustainability issues. In total, ten IPs were identified, and these include: DONATA Cassava Innovation Platform (which has three sub-IPs), Nyame Na Aye Crop-Small Ruminants IP, COS-SIS Oil Palm Innovation Platform, Climate Change Agriculture and Food Security (CCAFS) Platforms and Wulugu Innovation Platform.

Table 1A-J: List and characteristics of IPs in Ghana

A. IP Name	*Donata Cassava Innovation platform*
Entry Point or VC	1. Producer access to improved cassava varieties 2. Enhanced soil fertility management and use of herbicides to control perennial weeds in cassava 3. Cassava product development and processing 4. Market and information access.
Location (name and GPS coordinates in UTM or degrees)	Amponsakrom, Ayigbe, Nkonsia, Wenchi and Wurompo (All in the Brong Ahafo Region)
IP webpage:	NA
Participating villages	Amponsakrom, Ayigbe, Nkonsia, Wenchi and Wurompo (All in the Brong Ahafo Region)
Date of IP establishment	Amponsakrom, Ayigbe, Nkonsia, Wenchi and Wurompo (All in the Brong Ahafo Region)
Institutions setting up the IP	CSIR-CRI
Funding agents	AfDB
Number of years of activities on the ground	3 years
Facilitators (names and contacts)	Wenchi Municipal Director of Agriculture (MoFA)
IP members (regrouped by VC actors and sectors)	IPTA Focal Person / Organization Farmers/Farmers' group s Agri-businesses Public/private extension Research institution Policymakers Media
Opportunities addressed	• Improve income of smallholder cassava producers, processors and marketers.

	• Sensitize policy institutions/organizations on the Integrated Agricultural Research for Development (IAR4D) concept • Transfer and disseminate improved cost effective technologies along the cassava chain • Exchange and share indigenous knowledge and practices among various stakeholders • Enhance skills and knowledge • Strengthen linkages and encourage peer learning • Scale-out and up of adapted technologies through the media
Achievements to date	• Farmers have access to new improved cassava varieties • Improved method of cassava cuttings • Cassava yield increased by 186%. • Establishment of Good Practice Centre (GPC) • Personal contribution of $1249 (kind and cash) by Ayigbe platform members • Enhanced interactions and participation through farmer –led field visits, Peer learning and mentoring.
Challenges	• Limited skills and competence in setting up a functional IP. • Setting up of effective governance for sustainability of IP. • Effective integration of M&E into platform activities • Changing mind-set of research & extension facilitators and other actors • Irregular internet services
Sustainability issues	• Sensitization Directors of CSIR and National Directors of MoFA on IAR4D concept and DONATA activities to ensure buy-in • Adoption of innovation platform approach of technology dissemination for WAAPP II.
Phase in IP process	Phase 2 (exploiting commercial opportunities)

B. IP Name	*Volta Basin Two Project Innovation Platform*
Entry Point or VC	• Increasing crop and livestock productivity through identifying, evaluating and disseminating best-fit rainwater management strategies • Improving water productivity at farm level • Increasing the capacity of actors through innovation platforms to access and use relevant knowledge on rainwater management.
Location (name and GPS coordinates in UTM or degrees)	Digu and Golinga in Tolon-Kumbungu district of the Northern region and Naburinye and Orbilli in Lawra district of the Upper West Region.
IP webpage:	NA
Participating villages	Digu, Golinga, Naburinye and Orbilli
Date of IP establishment	2011

Institutions setting up the IP	Council for Scientific and Industrial Research-Animal Research Institute (CSIR-ARI) of Ghana, Agricultural and Environmental Research Institute (INERA), University of Wageningen - Plant Production Systems (WUR-PPS)
Funding agents	Netherlands Development Organization (SNV)
Number of years of activities on the ground	4 years
Facilitators (names and contacts)	SNV, Ghana
IP members (regrouped by VC actors and sectors)	Input dealers, agricultural producers (farmers), intermediaries (livestock dealers in particular), rural small-scale, as well as urban recognized traders and processors. Other stakeholders include research institutes, donors, rural based or agricultural oriented financial institutions, government offices working on agricultural development (such as district cooperative offices and ministries of food and agriculture), and other organizers
Opportunities addressed	• Identifying how stakeholders can work together in various capacities and competencies to support value chains along the Volta Basin • Identifying opportunities, constraints and develop strategies for addressing challenges and promoting the value chains • Identifying initial steps and modalities of ensuring a dynamic and responsive innovation platforms
Achievements to date	• Increased interactions, information flow and understanding among different actors • Enhanced knowledge sharing and joint planning. • Enhanced capacity to improve on what actors have, know and are doing • Improved productivity and efficiency. • Improved access to market and input information • Establishing new trade partnerships •Increased use of best practices
Challenges	• Lack of good and reliable market opportunities • Inadequate transport services • Inadequate input supply • Prevalence of insects (pests) • Low prices of agricultural products • Shortage of processing equipment • Inadequate water for processing • Shortage of funds for facilitators to organize platforms members.
Sustainability issues	IP in Tolon-Kumbungu district registered as a cooperative
Phase in IP process	Phase 2 (engaged in commercial activities)

C. IP Name	*Nyame Na AyeCrop-Small Ruminants IP*
Entry Point or VC	• Introduction of the dual purpose legumes as the global entry point • Improved fodder production and animal health as community entry points based on the fact that scarcity of fodder and poor fodder quality were the fundamental challenge in the system. Improving fodder production and animal health will require improved crop productivity and yields, low cost of inputs, access to credit, low incidence of pest and diseases, among others.
Location (name and GPS coordinates in UTM or degrees)	Atebubu/Amantin District of Brong Ahafo
IP webpage:	NA
Participating villages	Amantin
Date of IP establishment	2011
Institutions setting up the IP	CSIR-CRI
Funding agents	Department of Foreign Affairs, Australia through CORAF/WECARD
Number of years activities on the ground	3 years
Facilitators (names and contacts)	Research institutions, professional organization, extension ageneies
IP members (regrouped by VC actors and sectors)	Farmers (crops and livestock), extension officers, researchers, local authorities
Opportunities addressed	• Crop production constraints were insects, disease, labour, cost of chemicals and interest on credit. • Livestock constraints were theft, financial difficulties, poor housing, pest and disease and low price. • Existence of indigenous knowledge which needed effective evaluation and promotion complement with improved technologies to strengthen and further develop the crop small ruminant system through intensification. • Existence of major markets like Amantin, Atebubu and Ejura provided an opportunity for marketing value added products
Achievements to date	• Tractor service delivery organized • Formal seed system established (Am &Ag) • Community livestock health workers introduced (Wu) • IP accesses low cost of borrowing • Multi-nutritional blocks and saltlicks produced at 30%-50% of market price

	• Improved seeds being produced and sold for the first time in IP communities and beyond • IP brokered peace between nomadic herdsmen and crop farmers • Selected IP trained and became community livestock health workers • IP members trained and became registered seed growers • IP members began to mobilize their own resources and bought land • Mind-set change beginning
Challenges	• Reward system for researchers restricts involvement • Some researchers have perception that IAR4D is for extension and adaptive research with limitations for basic research • Need for better ME&L, documentation • How to upscale and out-scale innovations • Short duration of support for IPs
Sustainability issues	• Raising the level of individual and collective vision • Provision of critical equipment and infrastructure is useful in out scaling • Need for coordination of different IP initiatives within a nation • Need for buy in from agricultural research and extension policy makers at all levels
Phase in IP process	Phase 2 (engaged in commercialization of activities)

D. IP Name	*Convergence of Sciences: Strengthening Agricultural Innovation Systems (COS-SIS): Oil Palm Innovation Platform*
Entry Point or VC	Inability to access a remunerative market for their palm oil because of its poor quality.
Location (name and GPS coordinates in UTM or degrees)	Kwaebibirem District
IP webpage:	NA
Participating villages	
Date of IP establishment	2008
Institutions setting up the IP	COS-SIS Programme, collaboration among University of Ghana, Legon, universities in Mali and Benin, Wageningen University and Research Centre in the Netherlands, and KIT and Agriterra, which are Dutch NGO partners of the programme.
Funding agents	Wageningen University and Research Centre
Number of years of activities on the ground	2008-2013 (5 years)

Facilitators (names and contacts)	A research associate facilitated the higher level platform; and a PhD researcher facilitated the local level platform.
IP members (regrouped by VC actors and sectors)	Smallholder oil palm producers, oil palm processors and mill owners, public sector advisors and regulatory bodies, research and extension agents, equipment suppliers, policy makers
Opportunities addressed	• There is an increasing demand for palm oil both in the domestic and international market, thus opening opportunities for smallholders to improve their incomes. • During an initial stakeholders' workshop, processors, mill owners, mill workers, scientists and extension agents from the Ministry of Food and Agriculture (MoFA) prioritized the poor quality of crude palm oil, seasonal high moisture and low oil content of palm fruit mesocarp during the peak rainy season, environmental hazards resulting from poor processing practices, and lack of access to markets as major constraints, which the platform sought to address.
Achievements to date	• Processors have now understood the causes of poor oil quality • Knowledge generation • Enhanced interest, capacities and confidence of women to participate in the decision-making process of the district has been enhanced • Improved articulation of needs • Conflict resolution • Problem solving ability enhanced at both levels
Challenges	• Lack of commitment from some members due to lack of financial reward • Work schedules of most of the representatives sometimes conflicting with platform activities. • Frequent changing of institutional representatives • How to continuing facilitation and platform activities when CoS-SIS programme ends • Lack of facilitation skill among technical scientists and extensionists
Sustainability issues	• Formation of a higher level platform with people from different organizations that promote the principles further • Already farmers are applying their newly acquired knowledge by experimenting on their own and sharing knowledge
Phase in IP process	Phase 2 (engaged in commercialization of activities)

E. IP Name	*Climate Change Agriculture and Food Security (CCAFS) Platforms*
Entry Point or VC	Strengthening climate change adaptive capacity and fostering dialogue among farmers, researchers, local governments, NGOs and policy makers, and using the outcomes to inform decision making at both the local and national levels on specific climate change issues.
Location (name and GPS coordinates in UTM or degrees)	National, regional and district levels, e.g. Sub-National Level Climate Change Science-Policy Platforms in the Lawra, Jirapa and Nandom Districts in the Upper West region of Ghana
IP webpage:	NA
Participating villages	Several, nationwide
Date of IP establishment	2012
Institutions setting up the IP	CSIR-Animal Research Institute.
Funding agents	Various
Number of years of activities on the ground	2012- to date (3 years)
Facilitators (names and contacts)	Dr. Naaminong Karbo, CSIR-Animal Research Institute.
IP members (regrouped by VC actors and sectors)	farmers, researchers, local governments, NGOs and policy makers
Opportunities addressed	• Enabling all stakeholders to access needed knowledge (formal & informal) • Learn about the effectiveness of CCA implementation approaches • Determine good practices for climate smart development actions at the community level • Creating linkages and coordination between actors • Facilitating networking and information sharing between actors at various levels • Facilitate consultation on priorities to guide research policy consultation (better insight of local gaps and strengths) • Validation by all stakeholders of various reports (i.e., Ghana's CC vulnerability analysis)
Achievements to date	• Baseline on Climate Change Adaptation done in two districts in the CCAFS sites • Six partners identified and engaged in community-based adaptation • A Climate Change Adaptation Committee established at the Lawra-Jirapa district site • Policy level outputs/outcomes

	• Validated Ghana Climate Change Vulnerability document for Cancun conference • Research policy consultation (better insight of local gaps and strengths) • CCA Platform launched with support from 3 ministers and 2 MDA directors-general • Information shared on CCA at the national level, informing: – Policy – Research and Development – Good practices (climate smart practices) at the community level
Challenges	• Using an integrated systems approach • Identifying market opportunities • Balancing endogenous versus exogenous development • Community CCAFS scenarios development • Creating institutional incentives for policy learning and strengthening capacity • Information and communication technology (weather forecasting, pricing tracking, etc) • Mainstreaming gender
Sustainability issues	• Not-for-profit organisation legally recognized and operating in Ghana • WAAPP phase 2 is mainstreaming climate change into its activities. • Attraction of funds through proposal development • Transparency, trust building and team work • Registration as independent not for profit organization • Partnership with key stakeholder organizations
Phase in IP process	Phase 2 (engaged in policy activities)

F. IP Name	*Wulugu Crop-Small Ruminant Innovation Platform*
Entry Point or VC	• To address poverty in the community through an improvement of IP members' capacities and utilization of best practices in crop and livestock production to enhance productivity. • To address the constraint of low crop productivity and high small ruminant mortalities and develop and strengthen value chains of the target crops and animals products.
Location (name and GPS coordinates in UTM or degrees)	Wulugu in West Mamprusi District in the Northern Region
IP webpage:	NA

Participating villages	Wulugu
Date of IP establishment	July 2011
Institutions setting up the IP	Agricultural Extension Agent, CSIR Researchers
Funding agents	Funded under the Sustainable Intensification of Integrated Crop-Small Ruminant (SIIC-SR) Project in West Africa. Other funding sources to ensure sustainability are: • Registration fees and monthly dues payment • Own contributions in the form of levies • Plans to establish a crop and livestock farm. • Plans to register IP as a seed producing company.
Number of years of activities on the ground	2011- to date (4 years)
Facilitators (names and contacts)	Agricultural Extension Agent, CSIR Researchers
IP members (regrouped by VC actors and sectors)	Scientists and technical officers from CSIR Crop Research Institute (CRI), CSIR Animal Research Institute (ARI), CSIR Savanna Research Institute (SARI), Ministry of Food and Agriculture (MoFA) district officers, crop and small ruminant farmers, the social welfare department, financial institutions, local government
Opportunities addressed	• Inadequate veterinary services, • Weeds • Lack of credit facilities • Low crops' yields • Improper use of agro-chemicals • Difficulty in accessing tractor services • Improper use of agro-chemicals and its residual effects on farmers and farm animals • Difficulties in carting crop residue (as feed for livestock) • High rate of mortality among small ruminants in many farmers' flock • Lack of regular access to quality seeds • Poor rainfall pattern and moisture level determination for decision making in farming • Technical support on crops and livestock production practices
Achievements to date	• Training on the use of improved seed, appropriate planting and fertilizer application methods. • Initiated engagement policy makers • Training of community-based animal health workers as auxiliary veterinary service providers • Financial institutions sensitized IP members on credit facilities

Challenges	• Inadequate capacity to address policy-related constraints • Lack of credit facilities for inputs, initial capital for farming and trading. • Mutual distrust between the farmers and some micro credit institutions
Sustainability issues	IP members agreed to source for funding to ensure sustainability
Phase in IP process	Phase 2 (engaged in commercialization of activities)

G. IP NAME	National Agricultural Research and Extension (NARE) Innovation Platforms
Entry Point or VC	• Implementation of 'Sustainable intensification of integrated crop-small ruminant production systems in West Africa project' through the establishment of eight community innovation platforms (IPs) in Ghana and Benin in the sub-humid agro-ecology and The Gambia and Mali in the semi-arid agro-ecology of West Africa. • To improve the productivity of cereal/legume–sheep/goats farming systems in targeted project areas. Introduction of dual purpose legumes was the global entry point. Each innovation platform selected its entry point based on prioritized constraints and opportunities within the global entry point.
Location (name and GPS coordinates in UTM or degrees)	Several in West Africa
IP webpage:	NA
Participating villages	Several
Date of IP establishment	2011
Institutions setting up the IP	Researchers and Extension Officers
Funding agents	DFAT/CORAF
Number of years activities on the ground	2011- March 2015 (4 years)
Facilitators (names and contacts)	Agricultural Extension Agent, CSIR Researchers
IP members (regrouped by VC actors and sectors)	Development partners, agricultural extension officers, farmers, other value chain actors such as security personnel, researchers, credit providers and the media
Opportunities addressed	• Inadequate veterinary services, • Weeds • Lack of credit facilities • Low crops' yields • Improper use of agro-chemicals

	• Difficulty in accessing tractor services • Improper use of agro-chemicals and its residual effects on farmers and farm animals • Difficulties in carting crop residue (as feed for livestock) • High rate of mortality among small ruminant in many farmers' flock • Lack of regular access to quality seeds • Poor rainfall pattern and moisture level determination for decision making in farming • Technical support on crops and livestock production practices
Achievements to date	• Contributed to changing mindset among IPs to take charge of their farming and agribusiness. • Establishment of legume seed system • Improving the capacity of the animal health management systems • Policy intervention to improve marketing
Challenges	• The limited soft skills to deal with many partners within the IAR4D; • Proper choice of entry point; • Resource challenges of time, funding and capacity; • Poor documentation, synthesis and use of IP information; • How to upscale and out-scale from community level to national coverage.
Sustainability issues	• IPs are getting the mindset of "learning to fish rather than asking for fish" • Raising entrepreneurial skills market opportunities, and creating innovations with attractive market and economic benefits, • Strategies to integrate the IAR4D concept into the national agricultural research.
Phase in IP process	Phase 2 (engaged in the formation of more IPs)

H. IP NAME	*Soybean Cluster*
Entry Point or VC	Soybean value chain
Location (name and GPS coordinates in UTM or degrees)	Wenchi- Techiman
IP webpage:	NA
Participating villages	Wenchi and Techiman, Brong Ahafo Region
Date of IP establishment	2006
Institutions setting up the IP	International Centre for Soil Fertility and Agricultural Development (IFDC)
Funding agents	International Centre for Soil Fertility and Agricultural Development (IFDC)

Number of years activities on the ground	9 years
Facilitators (names and contacts)	• Methodist University College, Faculty of Agriculture • An external consultant (cluster advisor) was hired directly by IFDC to coach the cluster facilitator.
IP members (regrouped by VC actors and sectors)	Farmers' groups, input suppliers, traders, processors; usiness development bservices
Opportunities addressed	• Shattering of soybeans • Increasing processing of soybeans in to oil and cake
Achievements to date	• Cluster members learned from working together about technologies and how to operate as part of a value chain through sharing of information and complementary efforts. • New modalities through which farming credits could easily be accessed by farmer groups were explored with the rural banks and cooperative credit unions. • Intensification of soybean production with the introduction of non-shattering soybean varieties and improved cultural practices • Average yields have increased from 960 kg/ha in 2006 to 2500 kg/ha by 2010. • Grain quality has also increased for most, raising the purchase price from GHS 0.20 in 2006 to GHS 0.35 per kilogram in 2010. • Increased number of participating farmer groups. • Many farmers who participate have changed their mindset about agriculture and now think beyond subsistence and see their farms as profit-making ventures. • Some farmers now have mutual savings that they can use as collateral for bank loans. • Farmers and input dealers have discussed the use of inputs as well as the possibilities to buy on credit. • The Methodist University College and the NGOs support farmers making bulk purchases while addressing issues of input adulteration.
Challenges	• A major challenge for the cluster has been the phenomenon of "side selling". This occurs when farmers do not honour a contract or agreement they had with a buyer, and sell their products to a competing buyer (for example, because of a better price). This poses problems, especially when it comes to scaling up activities, because the mutual dependency along the value chain depends on trust between the collaborating parties. • Finding new funding for cluster members for their organizational and capacity building activities. • Incentives to meet regularly since the IFDC project that spanned from 2006 to 2011 was the major incentive for meeting.

	• Training was targeted more at individuals, making it difficult to assure the involvement of their whole organization in future.
Sustainability issues	Many farmers who participate have changed their mindset about agriculture and now think beyond subsistence and see their farms as profit-making ventures and willing to invest.
Phase in IP process	Phase 2 (Independent and commercializing activities)

I. IP NAME	*West African Agricultural Productivity Programme (WAAPP) Innovation Platform*
Entry Point or VC	The WAAPP IPs were established with the following objectives: • To create awareness among WAAPP key stakeholders/decision making bodies on IAR4D – IPs • Train facilitators and key commodity value chain actors on the innovation platform(s) • Mentor and coach facilitators and actors on the platform • Develop extension/technology transfer materials to facilitate the scaling up processes • Facilitate technology dissemination processes. The IPs focus on the following as entry points: • Cassava, cocoyam and yam value chains • Production • Processing • Marketing
Location (name and GPS coordinates in UTM or degrees)	5 Regions (Volta-3 IPs, Ashanti- 4 IPs, Eastern- 5 IPs, Brong Ahafo- 2 IPs, Northern- 2 IPs) 8 Districts covered in all 16 Sites/locations
IP webpage:	NA
Participating villages	16 communities in the regions mentioned above
Date of IP establishment	2014 (pilot)
Institutions setting up the IP	Council for Scientific and Industrial Research
Funding agents	WAAPP funders
Number of years activities on the ground	1+ year
Facilitators (names and contacts)	• Local/District: (Director of Agriculture, MIS Officer, District Development Officer, Agric. Extension Agent, Farmer Organization Leaders)

	• Regional/Area: (National Facilitation Team Member, Research Extension Linkage Committees [RELC] Coordinators, Assistant RELC Coordinators, Potential Actors on the IPs)
IP members (regrouped by VC actors and sectors)	RELC Coordinators Assistant RELC Coordinators Regional & District Directors Scientists &Technicians (Research Institutions) Group /Community Leaders Ministry of Food and Agriculture Farmers' groups, input suppliers, traders, processors; business development services
Opportunities addressed	Production, processing and marketing
Achievements to date	• Developed technologies for dissemination, e.g., for yam, minisett techniques, vine trailing techniques, good agronomic practices. For cassava, the introduction of 2 new cassava varieties, planting material harvesting techniques, safe handling of cuttings, weed management practices, and other good agronomic practices. For cocoyam, 3 improved varieties, time of harvesting and soil fertility management • Stakeholder needs assessment. • Increased farmer participation • Technical training • Established learning fields and planting material sites • Women encouraged to go into commercialization of yam planting material production • Emerging platform facilitators • Enhanced farmer –to- farmer learning • Building confidence of actors along commodity value chain
Challenges	• Current institutional structures do not allow for effective interaction in a dynamic way among institutions • In adequate skill in IP facilitation
Sustainability issues	• Re-grouping/zoning as follows: Northern Sectors: (North, Upper East, Upper West) Mid – Sector: (Eastern, Ashanti, Brong Ahafo) Southern Sector: (Greater Accra, Volta, Central, Western) • Capacity building: (1) Farmer – to – farmer learning through learning visits, field and study tours using the learning fields/good practice centres. (2) Training of IP facilitators • Increase institutional participation • Focus more also on: -Communication skills - IP facilitation skills - Mentoring and coaching - Sustainability issues -Governance

	• Increase technical training for staff of the Department of Agriculture, key value chain actors (production, value addition & marketing) and service providers
Phase in IP process	Phase 2 (Some are independent and commercializing activities, others are still at the initial stage because they were established at different times)

J. IP NAME	*Ghana Aflatoxin Management Innovation Platform*
Entry Point or VC	The objectives of the Ghana Aflatoxin Management Innovation Platform are as follows: • To increase awareness on aflatoxin problem in Ghana • To identify and disseminate proven mitigation strategies • To develop alternative uses for contaminated produce to remove them from the food system. • To enhance stakeholders capacities in the management of aflatoxin • To facilitate domestic, regional and international trade in aflatoxin-safe food products • To strengthen partnerships for aflatoxin control in Ghana • To advocate for policies and legislation on aflatoxin control in Ghana The IPs focus on the following as entry points: • Maize and groundnut value chains • Production of aflatoxin-safe grains • Post-harvest technologies and handling techniques to produce and maintain aflatoxin-safe grains and processed products • Marketing strategies to promote the demand and sale of aflatoxin-safe maize and groundnut products
Location (name and GPS coordinates in UTM or degrees)	Techimanand Nkoranza (Brong Ahafo region) Ejura (Ashanti Region) Gomoa Abaasa (Central Region
IP webpage:	NA
Participating villages	Techiman and Nkoranza (Brong Ahafo region) Ejura (Ashanti Region) Gomoa Abaasa (Central Region
Date of IP establishment	2015
Institutions setting up the IP	Forum for Agricultural Research in Africa (FARA)
Funding agents	FARA
Number of years activities on the ground	Less than 1year

Facilitators (names and contacts)	Ghana Federation of Agricultural Producers; Science and Technology Policy Research Institute (CSIR-STEPRI)
IP members (regrouped by VC actors and sectors)	Researchers, farmers, traders, group/community leaders, Ministry of Food and Agriculture, input suppliers, processors, business development services, caterers
Opportunities addressed	• To establish innovation platforms in each of the three pilot locations • To identify proven mitigation strategies, develop training materials and train trainers: • To facilitate the adoption and implementation of mitigation measures • Create awareness among the general public on aflatoxin problem and its control • Increase demand and supply of aflatoxin-safe maize and groundnut products • To develop and implement monitoring and evaluation systems
Achievements to date	• Stakeholder sensitization workshop organized with the participation of the chairman of the Parliamentary Select Committee on Agriculture • Location of IPs identified and actors being mobilized • Situational analysis being conducted to understand the extent of the aflatoxin problem and other relevant issues in the selected locations • A business proposal (for the establishment of the IP) has been developed and submitted to FARA for funding
Challenges	• Identifying interested and committed actors (stakeholders) to actively participate in the IP • Facilitators have inadequate skills in IP facilitation
Sustainability issues	• Increased awareness creation using evidence-based data to show the health impact of consuming aflatoxin contaminated foods, which will enable people to choose aflatoxin-safe products even if the price is higher. • With good agricultural practices, food safety and quality management strategies in place, farmers' production levels are likely to increase, while losses will be minimized. Thus, gains might be made and farmers will remain in business.
Phase in IP process	Phase 1 (still at the initial stages)

Case Studies of IP Implementation in Ghana

There have been some interesting developments in Ghana with respect to IPs. Various stakeholder organizations such as R&D organisations, development partners, NGOs, farmers' associations and communities have collaborated to use the IP platform to accelerate innovation in specific localities and agro-industrial domains. This chapter reviews some of these cases, highlighting the context, the formation and operation of the IP platforms, the outcomes and achievements and the policy lessons. The IPs selected for review are as follows:

1. The Volta Basin Two Project Innovation Platform
2. Dissemination of New Agricultural Technology in Africa (DONATA)
3. Convergence of Sciences: Strengthening Agricultural Innovation Systems (COS-SIS): Oil Palm Innovation Platform
4. Sustainable Intensification of Integrated Crop-Small Ruminant (SIIC-SR) Project in West Africa

Case Study 1: Volta Basin Two Project Innovation Platform

The Volta Basin Two (Volta2) Project for Integrated Management of Rainwater for Crop- Livestock Agro-Ecosystems, under the Volta Basin Development Challenge (VBDC) was initiated in 2010. The project has the overall goal of improving rainwater and small reservoir management in Burkina Faso and Northern Ghana, to contribute to poverty reduction and improved livelihoods resilience, while taking into account the downstream and upstream water users, including ecosystem services (CPWF, 2010). The project aimed at achieving three specific objectives: 1) increasing crop and livestock productivity through identifying, evaluating and disseminating best-fit rainwater management strategies, 2) improving water productivity at farm level, and 3) increasing the capacity of actors through innovation platforms to access and use relevant knowledge on rainwater management.

The project was implemented by a consortium of partners, namely: International Water Management Institute (IWMI), Council for Scientific and Industrial Research-Animal Research Institute (CSIR-ARI) of Ghana, Agricultural and Environmental Research Institute (INERA), University of Wageningen - Plant Production Systems (WUR-PPS), and Netherlands Development Organization (SNV) (CPWF 2010). The innovation platforms set up by the Volta2 project in both Burkina Faso and Ghana started off by facilitating the farmers' uptake of irrigation and production techniques that would help them manage their water resources better (CPWF In press). These were key activities to reach other development outcomes of the project, but farmers also gained a regular marketable surplus which engendered a need for improved marketing and value chain coordination. In Ghana, the project has been implemented in four communities, namely: Digu and Golinga in Tolon-Kumbungu District of the Northern Region, and Naburinye and Orbilli in Lawra District of the Upper West Region. At the beginning, four IPs were established (one IP in each community) through the facilitation of SNV Ghana.

Organization and formation of the IP

As part of achieving the above objectives, SNV Ghana facilitated the establishment of four innovation platforms in the selected communities. This initiative was part of a development intervention targeting the communities along the Volta River Basin. Thus, One Crop-Livestock Value Chain Innovation Platform was formed in each of the four communities with the following objectives:

- Identifying how stakeholders can work together in various capacities and competencies to support value chains along the Volta Basin.
- Identifying opportunities, constraints and develop strategies for addressing challenges and promoting the value chains.
- Identifying initial steps and modalities of ensuring a dynamic and responsive innovation platform.

To understand and agree on the entry points or priority areas, meetings were held in each of the communities to identify constraints, opportunities and strategies to improve the crop and livestock value chains. The first IP meetings in the Tolon-Kumbungu District took place on the 14^{th} and 15^{th} of July 2011 in Digu and Golinga communities, and were attended by 29 and 58 participants, respectively (SNV Ghana 2011). Out of the total number of participants, 28 were women. These participants represented farmers' groups (producers), input dealers, processors, traders, farmers' representatives, a representative from the traditional rulers, representatives from the Ministry of Food and Agriculture (MoFA), Veterinary Services Department, Animal Research Institute, Irrigation Development Authority, Savanna Research Institute, University for Development Studies, Masara N'arziki marketing company and NGOs (IFDC, World Vision International). In Lawra district, the first IP meetings were held on the 26^{th} and 27^{th} of July 2011, in Naburinye and Orbilli communities, and were attended by 45 and 50 participants, respectively. Out of the total number of participants, 24 were women. These participants represented farmers, input dealers, tractor service providers, community chiefs, arepresentative from MoFA, Veterinary Services Department, Animal Research Institute, Irrigation Development Authority, NBSSI, Department of Cooperatives, Nandom Rural Bank and NGOs (OXFAM, Plan Ghana, YARO, ACDEP, SEND-Ghana, LACERD, JICA).

In the subsequent IP meetings, the number of IP members were reduced and the total number of IPs was also reduced to two by merging the set of communities in each district and, hence, leaving one IP per district (SNV Ghana 2011). There are about 20 participants per IP in the current Volta2 IP project in Ghana. Some of the traders, processors and other stakeholders are from nearby towns and others are small-scale rural-based operators. Rural farmers are those settled in the rural communities of the respective districts. These rural farmers constitute more than 80% of the IP membership. Although the types of actors within the platforms did not significantly change overtime, the exact numbers of members for the two IPs is not known. What is certainly known is that there are 16 farmers in each platform, whose membership did not change since the beginning. The 16 are involved in technology adoption through PAR, which might be an explanation for their commitment because of the direct benefits associated with it. The organizers recently invited a few more farmers who have been participating in local meetings and on-farm demonstrations. These new farmers started attending general IP meetings and trainings since March 2013.

Since its formation in July 2011, the platform members have been conducting quarterly meetings on a regular basis to discuss their matters and exchange ideas to design better solutions to the various bottlenecks. The platforms also organized a couple of trainings on issues such as improving crop and livestock production, rainwater harvesting techniques, post-harvest management and marketing.

Facilitators, actors and their roles

The IPs are composed of various actors. In both platforms alike, there are various value chain actors as well as other supportive stakeholders (which are either facilitating the meetings and trainings, cover the funding requirements or are involved in policymaking and, hence, support members, etc.). The Lawra IP is working mainly towards maize value chains development, while Tolon-Kumbungu focuses on maize, rice, yam and small ruminants at the same time. The lack of focus on livestock value chain in Lawra was witnessed when the IP meeting of June 2013 started with a recap of the previous meeting in which they mentioned that they have agreed to work on the maize value chain through majority voting against the option of small ruminants.

The value chain actors are mainly composed of input dealers, agricultural producers (farmers), intermediaries (livestock dealers in particular), rural small-scale, as well as urban-based traders and processors. Other stakeholders include research institutes, donors, rural- based or agricultural-oriented financial institutions, government offices working on agricultural development (such as district cooperative offices and ministries of food and agriculture) and other organizers. There is no visible difference between the compositions of the two platforms in terms of the nature of activities participants are engaged in. This is also mainly because of the fact that the platforms are being implemented under the same project, with common objectives. Participants recognized as traders in the platforms participate in a number of value chain associations, while the producers (farmers) are involved in producing crops and livestock in the villages. Most of the platform member farmers are small-scale producers with little business orientation. They depend to some extent on agricultural inputs provided through the PAR project. The farmers' group is also the most stable in terms of membership.

In addition to the value chain actors, there are other stakeholders who are not directly involved in the value chain activity. These other stakeholders deal with organizing/facilitating of the meetings, trainings and workshops, funding, staffing, research and similar issues, rather than direct involvement in the marketing activities in the value chain. The research institutes, for example, are engaged only in doing practical research through the Participatory Action Research (PAR), to assist the farmers in improving productivity and natural resource management (such as soil and water conservation). In the third year of the project, the innovation platform meetings facilitated by the project team led to an explicit request for some capacity development on value chains management and analysis.

Due to the interventions from the V2 project, farmers in particular had increased their crop and livestock productions and had been experimenting in improving their market access. However, they lacked adequate skills and resources for engaging with traders hence their constraints shifted from managing their crop and livestock production enterprises to accessing credit and creating linkages with markets (e.g., logistics, coordination, communication, capacity to locate and use new knowledge). Consequently, a trainer (not a facilitator) was engaged who developed the training curriculum, which was entirely based on the sharing of prior knowledge by the participants. This learning process was based on the innovation systems perspective, which is the interaction between the different stakeholders who contribute their own knowledge and experience, leading to knowledge sharing and capacity development (Cadilhon, 2013). The external facilitation played an essential role in the learning process, because it also added the trainer's expertise that may not have been available locally.

This change of focus by the stakeholders is already an indication that the innovation platform tool had led to an increased capacity to innovate. The platform members were able to look beyond the original aim of the platform; they were addressing evolving challenges and seizing emerging opportunities.

Achievements

The Volta2 IPs in Ghana have so far brought certain benefits for its members. These include:

- Increased interactions and understanding among different actors,
- Enhanced information flow among various stakeholders for knowledge sharing and joint planning. This in turn enabled producers, traders and processors to gain better access to markets (Adane et al., 2013) and farmers to improve their crop and livestock productivity (Téno et al., 2013).

- Enhanced capacity to improve on what actors have, know and are doing
- Improved productivity and efficiency.
- Improved access to market and input information (e.g., availability of fertilizer)
- Establishing new trade partnerships through contacting new people at meetings and trainings
- Increased communication among platform members to share information and knowledge
- Increased use of best practices such as use of weighing scales, opening bank accounts, and weed control

Challenges and opportunities

The main challenges faced by the members of the platform include:

- Lack of good and reliable market opportunities
- Inadequate transport services to convey products to the market;
- Inadequate input supply such as tractors during peak season and lack of credit options to buy inputs;
- Prevalence of insects (pests) which affect the quality of products and hence disturb the value chain process;
- Low prices of agricultural products and shortage of processing equipment (grinding mill for example) for value addition.
- Inadequate water for processing (rice in particular)

The platform facilitators are also constrained by a shortage of funds to adequately organize the platforms and to increase the number of members. These challenges might negatively affect the sustainability of the groups. Although the challenges are still prevalent, the participants believe that the IPs have created many future opportunities to better design strategies and overcome the challenges. Some of the opportunities mentioned include:

- The existence of various stakeholders in the IPs and different market players to share experiences and information,
- A culture of being organized as a group to share information among the producers;
- The existence of various communication means because of changing technology and the availability of local materials for constructing warehouses for storage facilities and shelter for livestock.
- The existence of research institutes and other support organizations which give information on agricultural intensification, weed control, better management of land and water resources and product marketing;

- Cooperation of different value chain actors and other stakeholders to share knowledge on processing and information for better prices have been mentioned.

Sustainability

To strengthen legitimacy and scope of action, the platforms have been striving to be registered as a formal multi-stakeholder organization, with defined rules and regulations. During an interview, the northern region's deputy leader of the Farmers Organization Network of Ghana declared that the IP in Tolon-Kumbungu District got recognition from the national government and was registered as a cooperative by the end of May 2013. They are registered as "innovation platform for crop and livestock value chains" with an index of the district's name and will be governed by the nation's cooperative law. The Lawra IP is also in a similar process. One of the topics on the agenda of the meeting attended in Lawra on 27th June 2013 was on how to form viable cooperative associations. The legal recognition of the platforms and their congruence with cooperative structures strengthens the assertion that IPs organized on value chains development fit to hybrid forms because of their intermediate attributes. However, until recently, the IP structures have been mainly used as interaction/discussion forums among the members to deliberate on issues of common interest rather than governance of actual market transactions among them. Because the platform members have grasped the power of the innovation platform tool to facilitate such multi-stakeholder learning around value chain development, they are eager to keep facilitating the discussions themselves without the help of the project.

Case Study 2: Dissemination of New Agricultural Technology in Africa (DONATA) Innovation Platform

Dissemination of New Agriculture Technology in Africa (DONATA) is a component of the Promotion of Science and Technology for Agricultural Development in Africa (PSTAD). The PSTAD is funded by the African Development Bank (AfDB) and implemented by the sub-regional organizations (ASARECA, CORAF/WECARD and CCADESA) under the coordination of the Forum for Agricultural Research in Africa (FARA). DONATA is an initiative aimed at catalyzing the widespread adoption and use of new and proven technologies. This is to enhance agricultural productivity and growth for increased food security and poverty reduction on the African continent. DONATA established the Innovation Platforms for Technology Adoption (IPTAs) to facilitate the widespread adoption and utilization of proven agricultural technologies and innovations. The Innovation Platforms for Technology Adoption is a multi-stakeholder innovation platform comprising representative farmers and farmers' organizations, extension workers, agro-processors, marketers, agribusiness actors, transporters and researchers and, in some cases, media practitioners and credit-services providers. The IPTAs are facilitated by DONATA focal persons and assisted by other leaders selected by the stakeholders on the innovation platform.

At the sub-regional level, DONATA is managed by the sub-regional organizations, namely ASARECA, CORAF/WECARD and CCARDESA, while their respective NARS implement the project activities on the ground. The IPTAs include researchers, primary producers, extension workers, NGOs, government policymakers, equipment manufacturers and suppliers, traders, processors and others. All of these stakeholders are organized into a coherent platform, with each participant (individual or corporate) contributing to the attainment of its goals. The IPTA is a mechanism or a tool to support the development and maintenance of a value chain. It is a strategy for improved dissemination of innovations horizontally (to primary stakeholders) and vertically (stakeholders across the various divides), or more effective service delivery to value chain actors. The IPTA is a demand-driven participatory approach that can adopt any or a combination of the participatory methodologies, such as participatory learning and action (PLA), participatory community planning (PCP), farmers field school (FFS), demonstrations, among others.

DONATA project in Ghana: Cassava value chain

Under the Dissemination of New Agricultural Technology in Africa (DONATA) programme, Ghana launched a project in 2011 entitled "DONATA Innovation Platform along cassava value chain". The innovation platforms were established with the goal of catalysing agricultural innovation along cassava value chains in Ghana. An IP each was set-up for cassava value chain in five communities in the Wenchi municipal assembly of the Brong Ahafo Region, namely: Wenchi, Amponsakrom, Nkonsia, Wurompo and Ayigbe. This was done in collaboration with the CSIR- Crops Research Institute, Ministry of Food and Agriculture (MOFA), African Agricultural Women in Development (AAWID) and CSIR-INSTI RAILS Project.

Cassava (*Manihot esculenta* Crantz) is one of the food security crops that can enhance growth in income and also reduce income variability in Ghana, besides being the second highest cropped in terms of acreages. It is a major staple crop consumed in various forms, with an AGDP of 22%, and also an emerging raw material source (starch and flour) for the pharmaceutical, bakery, furniture and livestock industries. Wenchi Municipal has the second largest agricultural active labour force of 69% (M=51%; F=49%) and a rural farm population of 63% (GSS, based on 2000 census population). Wenchi is 37.1km from Techiman, which is a major convergence market hub in Ghana. The Wenchi Municipal is located in the western part of Brong Ahafo Region, and situated northeast of Sunyani (Regional Capital). Wenchi Municipal covers a land area of 3,494 sq kilometres. A greater proportion of the Wenchi Municipal falls under the savannah ochrosol, with some lithosols. The land is generally low lying and most of the soils are sandy loam and, in the valleys, loamy soil exists. The soils are fairly rich in nutrients and are suitable for the cultivation of crops such as maize, yam, cocoyam and cassava. The soil generally supports the cultivation of savannah, transitional and forest crops. The annual rainfall of 1140 – 1270mm spreads over 4 months in a year, and can support cereal and other seasonal crops such as yam and tomato, with proper management practices. The municipal offers various opportunities for investment in agriculture. For example, the municipal has vast tracks of uncultivated agricultural land for crops and livestock farming, hence land acquisition is not difficult. Currently, about 81.3% of all farmers acquire their land through inheritance or farm on family lands. The rest who have various forms of shared tenancy arrangements are mostly settler farmers. The municipal has also agricultural-related institutions such as the Farm Institute and Research Station that train people for middle income jobs and research in agricultural disciplines, respectively. The major economic activities in the municipality are agriculture, animal and forestry, employing about 75% of the working population. The major crops grown in the municipality include:

a) Root and tuber (yam, cassava and cocoyam)
b) Cereals and legumes (maize, groundnut, cowpea, soybean, bambara and sorghum)
c) Vegetable (okra, pepper, garden eggs, tomato, water melon)
d) Cash crop (cashew, mango, cocoa, citrus and oil palm)
e) Other crops such as plantain

Total averages under cultivation for the major crops have increased steadily over the years. In terms of yield estimates, cassava yields were the highest (21 metric tons/hectare). In 2006, cassava yielded 199,920 metric tons, followed by yam with 115,584 metric tons. Despite these opportunities, the municipal faces challenges in implementing its agricultural plans. These include:

- Low agricultural extension agents (AEA) – farmer ratio, which is currently 1:1000 and, hence, as much as 75% of the farmers do not receive any technical support from the extension service department.
- Late release of funds to implement activities
- Poor state of feeder roads
- Farmers’ failure to repay their credit given to them
- Soil fertility and productivity have reduced considerably with resultant declining crop yield.

- Storage and post-harvest management problems have resulted in high losses in roots and tubers and cereals, mostly due to absence of storage facilities and value addition. Post-harvest loses is conservatively estimated between 15% and 30% for both perishables and imperishable, of which the former is mostly higher
- Processing of agricultural produce is limited and there is the need to encourage more processing of produce through credit provision.
- Marketing of agricultural produce has been slow due to the limited availability of capital, while there is a lack of business orientation and unstable producer price for farm produce.
- Women in the municipality have only limited access to agriculture extension, credit and education, although their contribution in agriculture is very enormous. They are all involved in all agricultural activities from land preparation to harvest and post-production activities.

With specific reference to cassava, farmers still grow low yielding landraces or minimal improved varieties, contend with inefficient production practices, indiscriminately use herbicides in an effort to control weeds and avoid the high manual cost of weed control. Farmers have minimal/limited access to market information and a dearth of information on fertilizer application and its effect on quality of cassava. Besides, usual manual processing of cassava by most small- scale farmers, a majority of women are constrained in their efforts to add value for a higher premium.

To address these challenges, there is a need to adopt a comprehensive strategy, hence the choice of an innovative platform approach- Dissemination of New Agricultural Technology in Africa (DONATA). The focus of DONATA, Ghana, is to improve income of smallholder cassava producers, processors and marketers. There was thus the urgent need for sound ideas and proof practices that work well for the actors along the cassava chain. Hence, the Ghana DONATA Cassava Innovation Platform (IP) launched in June 2011 was set up to:

- Sensitize policy institutions/organizations on the Integrated Agricultural Research for Development (IAR4D) concept
- Transfer and disseminate improved cost effective technologies along the cassava chain
- Exchange and share indigenous knowledge and practices among various stakeholders
- Enhance skills and knowledge
- Strengthen linkages and encourage peer learning
- Scale-out and up of adapted technologies through the media

Organization of IPs

The objectives of the IPs were fully explained and discussed at the regional launching of the DONATA Project in June 2011, where major drivers in agricultural research and development (R&D) were presented. Issues discussed included ensuring the sustainability of the IP after the exit of DONATA. The way forward proffered was to involve relevant stakeholders in the communities so that it could be easily integrated into formalized structures of R&D systems. To make sure the objectives were properly developed to deal with challenges that would be encountered in the implementation, the roles of the major stakeholders on the platforms were discussed and assigned.

The setting up of IPs

In setting up the IP, a pertinent question of relevancy to the community was posed to ensure that proposed interventions are the real felt needs of the community. To arrest this situation, the analysis of the problems and needs related to the innovations and knowledge to be shared or transferred were done together with all relevant beneficiaries, target groups and stakeholders. In Ghana, an IP defined by the community name, consists of farmers, processors, marketers (retailers), input dealers and transporters. A criterion for the selection of a community was based on secondary data and information gathered during a pre-survey relating to previous collaboration with research, NGOs and Ministry of Food and Agriculture (MoFA). The selected communities were each accessed through the Participatory Rural Appraisal (PAR) to identify challenges/constraints and needs in the cassava production chain (processing and marketing inclusive). The stakeholders included farmers, processors, retailers, input dealers, transporters, researchers, extensionists, NGOs and policy makers. The PRAs enabled the IP facilitators together with the stakeholders to draw entry points and thematic areas for dissemination of technologies and shared learning. Five IPs were established in 2011, after a SWOT analysis at Amponsakrom, Ayigbe, Nkonsia, Wenchi and Wurompo, based on 4 entry points listed below:

1. Producer access to improved cassava varieties
2. Enhanced soil fertility management and use of herbicides to control perennial weeds in cassava
3. Cassava product development and processing
4. Market and information access.

The above entry points were couched from the listed constraints/challenges: a) Declining soil fertility, b) Drudgery in manually processing cassava, c) Poor marketing of produce and products, d) Ineffective weed control/land preparation practices, e) Inadequate access to improved planting materials, and f) Bulkiness in transporting cassava cuttings. Experience has shown that most farmers expected monetary reward for taking part in project activities, thus the objectives of the DONATA IP was fully explained and discussed. Hence, actors along the chain were selected based on willingness to participate.

The summary of the IP formation process is as follows:

- Technology / best-bet practice scaling-up and out
- Stakeholder analysis including roles and responsibilities
- Determining challenges/opportunities to be addressed
- Selecting critical technology/best-bet practice to be promoted along segments of the value chain
- Determining ecology/area to be covered
- Establishing platforms on priority segments as entry points of the value chain, and agree on role of actors for each segment
- Assessing changes on actors behaviour and or impact

The Innovation Platform for Technology Adoption (IPTA) included: (1) farmers/rural communities, (2) agric-business/processors, (3) policymakers, (4) advisory services, and (5) research institutions. The process was facilitated by CSIR-CRI, MOFA, AAWID. The cassava value chain was divided into four segments, namely: planting material acquisition, production, processing and marketing. In terms of the planting material acquisition stage, IPs were formed to participate in the multiplication of planting materials and the key actors in the IP were farmers, research institutions, extension agencies and agribusinesses. Specifically, this segment involved five farmers with the aims of increasing farmers' access to improved varieties for domestic and industrial use, and ability to distinguish and multiply varieties. At the production segment, the IPs were involved in weed control and soil fertility management. At this stage, the key actors driving the IP process were farmers, research institutions, extension agencies, input dealers and tractor operators. In total, eighteen farmers participated in this segment, which involved: (a) use of improved weed and soil management practices, (b) adoption of row planting, and (c) proper application of herbicides and handling of knapsack machine. At the processing segment of the cassava value chain, the IPs were involved in establishing a cassava processing centre and the key actors driving the IP were equipment fabricators, agribusinesses, extension agencies and Environmental Protection Agency (EPA). Seven farmers participated in the segment, which sought to: (a) provide improved processing equipment and (b) construct processing sheds. The final segment, which involves marketing, was mainly driven by IP actors including contract purchasers, agribusinesses and service deliverers. The main activity for the IP was to identify and form market linkages and enhance information access. Here, five farmers were involved in the IP process to: (a) link producers to contract purchasers and agribusiness, and (b) facilitate access to market information.

In total, 35 farmers (including 11 women) participated in the cassava value chain IP. The platform served as a knowledge hub that helped in building confidence and the abilities of farmers for sustainable adoption of technologies and best practices. The IP process strengthened the capacity of actors and, thus, helped in the development of strong linkages and trust among the value chain actors. The roles of the key IP actors are detailed in table 2.

Table 2. Key actors and their roles in the cassava value chain Innovation Platform for Technology Adoption (IPTA)

Stakeholders	*Key role*	***IPTA 1*** *Planting material*	***IPTA 2*** *Production*	***IPTA 3*** *Processing*	***IPTA 4*** *Marketing*
IPTA Focal Person / Organization	Coordinating, facilitating, provision of technical backstopping, monitoring and evaluation of activities. Development and distribution of technology transfer material. Feeding RAILS with technology dissemination/promotional activities.	Facilitate the supply of farmer preferred improved cassava planting materials.	Provision of resources and resource persons for weed and soil management technology transfer.	Procure small or medium scale processing equipment to process large volume of cassava to avoid post-harvest loses.	Facilitate and strengthen existing linkages between technical support providers and farmers/farmer group.
Farmer /farmers' group	Provision of local resources (land, labour, inputs, capital) for production, processing and marketing of produce. Be available for training and technology transfer activities.	Provision of site for multiplication and demonstration. Provision of available planting material.	Storage and maintenance of spraying equipment and agrochemicals.	Provide site for processing centre Contribute in kind and cash for development of centre. Own and maintain facilities at centre.	Developing and honouring of sales and purchasing contract. Develop and maintain market linkages.
Agri-businesses	Collaborate with focal institute, NGOs, MoFA, training institute and other stakeholders in sourcing for appropriate materials, equipment or services. Be available for training and upgrading.	Negotiate and honour agreed prices for input and services.	Provision/respond to the needs of actors.	Develop and maintain quality standards of products and produce. Developing and honouring of sales and purchasing contract. Develop and maintain supply of raw materials and products.	Sustain market outlet and fair prices. Collection and delivery of inputs and products at agreed prices.
Public private extension	Strengthen and maintain the capacity of farmers/farmers' group for sustainability. Prepare platform for technology delivery. Provision of advisory/technical services.	Link farmers/farmers' group to source of planting material	Provision of technical support for weed and soil management.	Liaise and link to source of raw materials and markets.	Link farmers/processors to available markets.

		Training of farmers and coppicing gangs.	Linkage to sources of information, acquisition and use of agrochemicals.		Build business and marketing skills of actors.
Research	Training of public/private advisory /technical providers. Provision of technical materials. Monitoring and evaluation. Provision of technical backstopping.	Facilitate the identification of improved varieties and their attributes.	Facilitate verification trials and demonstrations.	Provide criteria for quality /environmental standards. Provision of improved processing technologies/facilities.	Conduct market studies. Provision and linkage of farmers to sources of market information.
Policy	Translate, monitor and ensure compliance of agricultural policies and its implications.	Ensure farmers understand and conform to policy issues related to planting material development and distribution.	Monitoring input dealers to ensure sale of certified products.	Monitoring and ensuring production in healthy environment. Ensure establishment of processing facility conform to set standard.	Periodic monitoring sale of quality product.
Media	Promoting dissemination of available cassava technologies under DONATA. Publicize, activities, successes and challenges of various actors along the value chain. Enhancing information sharing among IPTA actors in the 4 communities and environs through the print and electronic.				

Source: Bolfrey-Arku et al. (2011)

Table 3. Other Stakeholders and their roles in the cassava value chain

Stakeholder	Key Roles
Focal organization/person	Coordination and facilitation of IPs through provision of needed and unavailable resources (human and material), management and accounting of funds and linkage with RAILS
Farmer/farmer-based organization	Provision of local resources (land, labour, inputs, capital), record keeping, available for knowledge sharing, upgrading and technology transfer activities, disseminate acquired knowledge from IP to other beneficiaries
Agro-input dealers	Assist various actors in sourcing for appropriate products, equipment or services
Research	Provide technical backstopping
Ministry of Food and Agriculture (MoFA)	Prepare platform for technology delivery, provision of advisory/technical personnel and services; monitor IPs and send feedback reports to FP to collaborate with research
NGO – Association of African Women in Development (AAWID)	Form and make operational farmers' groups, link to available and appropriate markets and services. Strengthen and maintain group dynamics
Policy	Translate, monitor and ensure compliance of agricultural policies
Media/RAILS	Promote, publicize and disseminate available cassava technologies, activities and success stories, enhance information sharing among IPTA actors and other non IPTA actors.
Retailers	Provide information on consumer preferred varieties
Financial institution	Support access to affordable credit
Local assembly	Lobby for support for development of rural infrastructure to sustain local industries.
Traditional leader	Provide information on socio-cultural issues along the chain in the Wenchi Municipal; support release of land
Business Advisory Center (BAC) of Ministry of Trade & Industry	Provide training on record keeping, group dynamics, costing and pricing of produce. Advice on business development and link to market sources, financial institutions and registration of enterprise.
Fabricators	Fabricate and maintain equipment, provide training to equipment operators,
Processors	Purchase raw produce, develop quality products
Transporters	Facilitate the collection and delivery of cassava roots and products
Harvesters/loaders	Ensure proper harvesting of cassava roots to minimize bruises or injury
Women in Agric. Development (WIAD) of MoFA	Quality assurance and training on preparation and utilization of cassava for value addition

Facilitation of IP and stakeholders' interactions

The 5 platforms identified were coordinated by the DONATA focal person (CSIR-Crops Research Institute), who is the research extension linkage coordinator (RELC) for the region. However, within the Wenchi Municipality, where the 5 IPs are located, the Municipal Director of Agriculture (MoFA) is the Local lead Facilitator, supported by 2 other facilitators for each platform. Activities on each platform is monitored by the local extension officer in the community in conjunction with AAWID (NGO) for the Ayigbe Platform and BAC (Ministry of Trade and Industry) for Amponsakrom, Nkonsia, Wenchi and Wurompo platforms for ease of facilitation. Included in the facilitation are local representatives of each platform and a local radio as partner. The assembly member, chiefs, media, producers, processors, marketers, transporters, input dealers, together with the research institutions and extension agencies periodically meet in a multi-stakeholder forum to review activities and discuss real and perceived problems among them. The farmers' groups within the platforms meet once a month to discuss issues affecting them. The farmers' groups in the Ayigbe, Nkonsia and Wenchi platforms have their own executives. Amponsakrom Platform, with the support of BAC has been mobilized into a group with a constitution and a bank account. The 5 platforms do not have a formalized governance structure presently, but is managed by the structures discussed above. It is hoped that before the exit of the project, the various stakeholders would elect a rep each to constitute the municipal governance.

Information sharing and knowledge management

Extension agents and researchers provided technical backstopping to actors on the platform. Varied dissemination strategies as setting up field demonstration plots, skills and hands on training, field visits, peer learning and local radio were used. Farmer-led field visits/tours were organized to expose stakeholders to activities within and among the platforms. Actors actively discussed, asked questions and shared knowledge on observations on demonstration, learning and farmers plots farmer mentors. Farmers on each IP mentored 2 other farmers in year 1. Farmers were taken through hands on practice in the preparation of healthy planting materials (3-node stem cutting and pre sprouting techniques), herbicide application and soil fertility management. Monitoring and evaluation tours were organized for farmers in the IP, while processors had exposure visits to Good Practice Centre (GPC). To introduce cost effective technologies in building processing or storage facilities, experts from the Building and Road Research Institute (CSIR-BRRI) trained local artisans and platform actors in the use of pozzolana cement as composite in building. Training programmes were held for spraying and coppicing gangs, while capacity building workshops were organized for extension staff. Linkages between and among actors for products and services in the municipality was by brokering done through stakeholder fora and phone calls. Feedback on strengths and weaknesses of the IPs, which was reviewed quarterly by the facilitation team, was used to improve the running of the IPs and also to include more stakeholders. To promote trust, actors were encouraged to be transparent and maintain regular communication. Thus, accessibility to the IP members, especially the facilitation team, was both formal and informal.

The media, a major actor of the platform, assisted in disseminating adapted technologies through the local radio station –Royals FM. The CSIR facilitated the filming of DONATA field activities for the World Science Project on the role of communication and new information and communication technologies by a team from Louisiana State University (Sociology) and University of Ghana. Platform activities were fed to RAILS. There was collaboration with AusAid to sensitize directors of CSIR and national directors of MoFA on the IAR4D concept and DONATA activities to ensure buy-in and adoption of the innovation system of technology dissemination for WAAPP II.

Changes observed in the IPS

The platforms initially started with production, but stakeholder's enthusiasm gradually moved it to a real IP with producers, processors and marketers as major stakeholders. Agro input dealers have shown a real interest by demanding for a list of EPA-certified agro input dealers and linkage to ensure sustainability and affordable pricing. The IP started with a total of 35 farmers in four platforms (communities), but now has 122 actors (59 M, 63 F) and 5 platforms. Guided by limitations of the research and extension team on the conduct of IP and also the intent of being a more result-based IP, the Ghana team tried to restrict the number of actors on the platform. Through constant sensitization on sustainability, the Ayigbe Platform members contributed $1249.00 (cash and kind) towards the construction of GPC. Nkonsia and Wurompo platforms are recording an increase in the number of processors, while the Amponsakrom platform (mainly processors) are demanding cassava planting materials to plant on their fields. Demand for information on channels/facilities for enhanced market, value addition of cassava products, capacity building and skills training from actors is on the ascendency.

Key achievements

Key achievements of the IPs under the entry points are as follows:

Producer access to improved cassava varieties and enhanced soil fertility management

- Farmers now have access to 5 other (Nkabom, Ampong, Bronibankye, Esambankye and Otuhia) improved cassava varieties, in addition to Bankyehemaa and IFAD. One hundred and three direct beneficiaries (41 m, 62 F) planted 34.7 ha of 4 improved cassava varieties; there were also 111 indirect beneficiaries. Eleven platform members have adopted Bankyehemaa on their own fields on a total of 8 Ha.

- Improved methods of preparing cassava cuttings have increased planting material base of farmers to a ratio of 1:3. (60% reduction in quantity of planting material required per Ha).
- Cassava yield increased by 186%. PRA results indicated yield of 12 -16 t/ha, but below the IP yield of 42 t/ha.

Use of herbicides to control perennial weeds in cassava

- Promotion of row planting for ease of weed control as a way of increasing yield increased cassava population by 47% over the conventional farmer's practice of random planting.
- Use of herbicide nozzle and training on herbicide application reduced glyphosate application by 50% (10L/Ha to 4-5L/Ha). Cost of weed control has reduced by 30 – 50%.

Product development and market access

- Establishment of Good Practice Centre (85% completed) soon to be launched.
- Personal contribution of $1249 (kind and cash) by Ayigbe platform members towards building of GPC to encourage ownership.
- Motorizing an existing manual cassava chipping machine
- Mobilization of Amponsahkrom Platform to a functional group with a constitution, elected executives and a bank account.
- Input dealer on Ayigbe Platform has realized the need for expansion of his enterprise and to maintain integrity has requested for direct linkage to registered companies for supply of inputs.
- Enhanced interactions and participation through farmer–led field visits/tours, peer learning and mentoring.

Challenges and resolutions

- Limited skills and competence in setting up a functional IP. Challenge resolved through training in multi-stakeholder processes and value chain approach, and learning visits in 2012 to Burkina Faso and Gambia IPs, respectively.
- Setting up of effective governance for sustainability of IP.
- Effective integration of M&E on platform activities
- Presenting a result-based M&E report
- Changing mindset of research and extension facilitators and other actors
- Irregular internet services

Expected impact of the IPs

- The adoption of IP for WAAPP Phase II technology dissemination. Established IP can be a potential learning platform for the intended integration of IAR4D systems. Possibility for up scaling of governance systems.
- The provision of GPC would lead to job creation. There is a potential for increased area of cassava production due to the innovation platforms system of dissemination. There could be emerged enterprises and leaders who may support value addition and post-harvest storage.
- Increased dissemination of improved technologies as a result of linkage to RAILS would enhance knowledge sharing and information.

Case Study 3: Convergence of Sciences: Strengthening Agricultural Innovation Systems (COS-SIS): Oil Palm Innovation Platform

The Convergence of Sciences: Strengthening Agricultural Innovation Systems in Benin, Ghana and Mali (CoS-SIS) programme aims to unlock the potential of smallholder farming in West Africa by creating enabling conditions for farmers to innovate. Since 2002, the programme has been experimenting with this approach, which takes a different track to mainstream research. Rather than focusing on technical innovations, CoS-SIS helps national, sub-regional and African agricultural research organisations, universities and other public and private sector agencies, including non-governmental organisations (NGOs), to strengthen their programmes. It supports university curriculum development and informs decision makers at district and national levels about ways to encourage smallholder innovation. The CoS-SIS has developed from a first phase (2001– 2006) that focused on participatory technology development. Work in the first phase showed that smallholders were unable to benefit fully from appropriate and desirable technologies because of their limited opportunities. So the researchers started to experiment with institutional change – the 'rules of the game' that govern smallholders' environments, constraints and opportunities. By demonstrating that such change is both important and feasible, the work inspired a second phase (2008–2013), which explored more full institutional changes.

The oil palm innovation platform is a learning and research-oriented platform setup under the CoS-SIS programme to improve the quality of palm oil and, as a result, access markets. An initial exploratory study pointed out that small farmers could not access remunerative markets due to the low quality of their palm oil. The platform includes actors in the palm oil value chain, from smallholder farmers and processors to the Ghana Standards Board and its Environmental Protection Agency. The platform is organized at the local level where experimentation takes place with small-scale processors, to improve their practices and to gather evidence and information to feed into the higher-level platform, which carries out lobbying for policy changes at the national level and to influence the behaviour of oil palm producers and processors.

The Kwaebibirem District is well known for its oil palm resources, which is processed into palm oil. Palm oil obtained from the mesocarp of palm fruits is an important domestic and industrial commodity in Ghana. This country currently produces about two million tonnes of fresh fruit bunches annually, of which about 60% is processed into crude palm oil by small-scale palm fruit processors, whose practices often result in the production of poor-quality oil, related to the free fatty acid content. High free fatty acid content incurs high oil losses during refining, and can therefore not be suitable for industrial processing or refining. Thus, in spite of the large quantity of crude palm oil produced in Ghana, the country still imports large quantities to meet its fat and oil requirements. At the same time, several small-scale processors find it difficult to market the crude palm oil they produce, especially during the peak fruit production period from February to May. Furthermore, the absence of policies regulating the activities of small-scale processors often results in environmentally unfriendly and unhealthy practices that also impede their entry into the industrial and export markets. These and other considerations went into the decision to create an oil palm innovation platform in Ghana.

The innovation platform was initiated as part of a larger research programme implemented by the University of Ghana, Legon, called the Convergence of Sciences-Strengthening Innovation Systems (CoS-SIS 2008-2013). This involves collaboration with other universities in Mali and Benin and technical backstopping by Wageningen University and Research Centre in the Netherlands. KIT and Agriterra are Dutch NGO partners of this programme. The CoS-SIS programme sought to find ways to improve opportunities for smallholder farmers and processors. During the first phase undertaken between 2002 and 2006, the programme tested the assumption that farming technologies that work effectively under smallholder conditions will improve their livelihoods. The research results suggested that developing these kinds of technologies can only make a marginal impact on smallholder livelihoods since they operate within very limited windows of opportunity. The technologies developed were highly appreciated and continue to be used for years after the programme has ended. However, the researchers came across institutional constraints for smallholders such as insecure access to land, lack of access to remunerative markets and exploitation (cheating by buyers - for example, using doctored scales when purchasing farmers' produce). This and other experiences informed the need for institutional change as a condition for smallholder development. Thus, the platform approach was adopted for use in negotiating an agreement on concerted actions among key actors.

The CoS-SIS programme in Ghana selected the oil palm as one of the priority domains for research on institutional innovation because of its wide geographical coverage (oil palm can be cultivated in six out of the ten administrative regions), as well as its role in poverty alleviation. An exploratory study (unpublished) carried out in the oil palm sector revealed that although small-scale palm fruit processors have access to the bulk of fresh fruit bunches produced by smallholder farmers, they are not able to access a remunerative market for their oil because of its poor quality. Meanwhile, there is an increasing demand for palm oil both in the domestic and international market, thus opening opportunities for smallholders to improve their incomes. During an initial stakeholders' workshop, processors, mill owners, mill workers, scientists and extension agents from the Ministry of Food and Agriculture (MoFA) prioritized the poor quality of crude palm oil, seasonal high moisture and low oil content of palm fruit mesocarp during the peak rainy season, environmental hazards resulting from poor processing practices, and lack of access to markets as major constraints. It therefore became necessary to create linkages between stakeholders, both at the local level (to encourage some changes in the current processing practices to be able to meet market standards for highly-priced quality oils), and at a higher district or national level (to work on developing the value chain by promoting standards enforced by bylaws and policies in support of the operations of smallholder processors and farmers).Thus, the objectives of the oil palm innovation platform were to improve the processing capacities of small-scale palm oil processors to be able to produce better quality crude palm oil for the export and industrial markets, as well as improving the opportunities of small-scale processors through institutional change (bylaws and policies).

Organisation of the IP

The oil palm platform membership comes from actors in the palm oil value chain. The platform actually consists of two sub-platforms: one operating at the local and one at a higher level. Each of this IPs have different members. The local level platform consists of two different groups, each having its own specific function. The first is the experimentation group that carries out participatory experimentation of processing practices (for example, storage period of palm fruits before processing) that will result in the production of good, quality crude palm oil to meet the standard of the export and industrial markets. This group includes smallholder farmers, small-scale processors, mill owners, mill workers with support from agricultural extension agents, and scientists from the Oil Palm Research Institute. The second is the stakeholder group**,** which operates at the district level. The stakeholder group consists of all stakeholders of the small-scale palm oil processing industry in the district. These include scientists from the Oil Palm Research Institute, palm fruit processors other than those involved in the experiment group, mill owners, mill workers, farmers, extension agents of the Ministry of Food and Agriculture and members of the District Assembly. This platform discusses and makes inputs to the entire project at different stages of the research process. The experiments are set by the stakeholders' group and carried out by the experimentation group. The platform is built on or draws from the innovativeness and entrepreneurial skills of the primary actors, which in this case are the farmers and processors. Its effectiveness is enhanced through sustained interaction among the stakeholders through joint learning, as a result of experimentation. Each of the stakeholders' (farmers, scientists, millers, processors) perspectives are taken into consideration during design and subsequent implementation of experiments.

The higher level platform is called the concertation and innovation group (CIG), which is a non-permanent platform of stakeholders who are expected to be able to change institutional conditions that determine the opportunities of smallholder palm oil processors. This group has become very effective through continuous interaction, lobbying efforts and respect for the different stakeholder perspectives during platform meetings. Negotiations within the platform are guided by its objectives and decisions are reached through consensus building. Both groups at the local level focus on technological innovations, with the aim of developing the capacity of processors so they can produce better quality crude palm oil within the context of R&D. The CIG is an institutional innovation platform that aims to contribute to changing institutional conditions that determine the opportunities of small-scale processors in the context of the innovation system.

Members of the experimentation group were selected by the district stakeholder group. Some of the actors along the chain are strategically excluded and included at different levels and stages of the groups, depending on the focus. Primary actors such as smallholder farmers and the small-scale processors are represented at all levels, as is the Ministry of Agriculture. Membership in the concertation and innovation group was based on selecting actors who can potentially make interdependent and complementary contributions towards improving the conditions of smallholders. Selection of the platform members to the CIG was carried out according to the following processes:

- Potential platform members were identified through stakeholder analysis by the facilitator and other stakeholders;
- The facilitator of the platform held discussions with some of the identified actors to explore their interest and willingness to participate;
- The initial core group of actors was then selected by the facilitator in consultation with the coordinator of the CoS-SIS programme after which they were sent an invitation letter to the first meeting; and
- Additional actors were brought in as and when necessary.

The IP formation process

CoS-SIS undertook lengthy and thorough exploratory and diagnostic scoping studies before the platforms were initiated. Researchers played a dominant role including a part in the studies before the platforms were established. Scoping was most important for the "learning and research-oriented" platforms, as they were the result of thorough studies that took a long time. Scoping refers to the initial effort to narrow down the platform's topic, and to better understand it, along with the context where the platform is to be inserted. In the oil palm platform, a high-level committee was requested to propose topics from the perspective of priorities in the national innovation system. This was followed by different exploratory and diagnostic studies. Analysis concerns both the initial stakeholder-mapping and selection and the identification of promising action entry-points in a specific value chain or thematic area. Platforms of all types carried out some kind of an analysis. Studies and consultation are common methods used, and contribute to defining the needs and problems and opportunities of specific platform topics, as well as the initial orientation and boundaries of the platform-to-be. A comprehensive joint analysis –often done in a workshop setting -- by invited platform members of the initial problems and opportunities allows for the different stakeholders' interests and needs to be put on the table. "What do they need and what do they want?" Through such analysis, participants define which concrete issues they would like to deal with. Such analyses ensure that the different actors are part and parcel of the decision making process within the platform and, eventually, lead to a jointly defined agenda. The "learning & research-oriented" platform types again require more time and effort for the preliminary studies and consultations, whilst the development-oriented types often carry out an analysis during the first stakeholder meeting. Planning also often takes place through (a series of) meetings and workshops. This process entails a further narrowing down of the main points raised from the joint analysis and a defining of a clear strategy for action, i.e., who must do what and when. The resulting joint action plan and agreed division of tasks may change again later on. Joint analyses and planning highlight the diverging interests of the stakeholders. In general, economic interests are the strongest drive to both national and local actors, although social and political interests may also be important factors. Members of the oil palm platform saw participation as a springboard for being able to better communicate to district-level authorities. In fact, in this case, two female processors – whose capacities and self-confidence were enhanced through their participation in the platforms' decision-making body – were recently elected to the District Assembly. The IP operated at the national and local level. At the local level, the focus was on experimentation, while at the national level, it was on concerted action for institutional change. Different levels were facilitated by different individuals. Lessons from the local level were used as evidence at the national level. Provisions were made for reimbursing participants' costs for attending meetings. In many platforms, attendance and commitment of platform members is a major challenge. Particularly, learning and research-oriented and "development and research-oriented platform types seemed to struggle with this. This stresses the importance of getting the right individuals from the key organizations to participate. In many platforms, attendance and commitment of platform members is a major challenge. Both the local and higher level platforms met once every three months to discuss results of assigned tasks and experiments, and to decide how to proceed further. The local-level experimentation group meets more regularly during experimentation, sharing results with the stakeholder group every three months. Members were provided with transport and lunch during platform meetings. The CoS-SiS programme financed platform activities and the training of the facilitators. The platform agreed on the budget for proposed activities to be carried out every quarter to be submitted to the programme management team through the programme coordinator for approval and release of funds.

Facilitators and actors

The oil palm innovation platforms were initiated by the CoS-SIS research programme, which also provides facilitators from its oil palm domain (a research associate for the higher level platform and a PhD researcher to facilitate the local level platform). Some actors along the value chain were strategically included or excluded at different stages of the platform, depending on the issues being dealt with at that specific moment in time. Table 4 shows the roles of facilitators and actors.

Key activities undertaken at the local-level platform included three experiments at the processing mills, which examine: (1) the effect of period of fruit storage before processing, on quality and quantity of palm oil produced; (2) seasonal analysis of oil content of fruits at the selected mills, and 3) seasonal ripeness assessment of fresh fruit bunches delivered to the mill. Scientists, farmers, processors, mill workers and owners were carrying out the joint experiments, comparing impact on oil yield and quality. Once the group members were selected, the higher-level platform identified the institutional changes needed in the activities of the processors. These included locating mills close to the residential areas, discontinuing the use of spent lorry tyres as sources of fuel for processing, and proper disposal of palm oil mill effluent. The institutions that needed to be changed were then worked on by the group's members. This was done by looking for information on the adverse effects of undesirable processing activities on the environment and health of people, lobbying key policy makers and traditional authorities to grant audience to the CIG, sensitizing policy makers on activities of processors that needed to be changed, and lobbying policy makers and traditional authorities to take action.

Table 4. Actors and their roles

<table>
<tr><th>Actors</th><th colspan="2">Role</th></tr>
<tr><td>Facilitators</td><td>Local level:
• organizes the processors for experimentation
• organizes the resources needed for the experimentation
• monitors the performance of the platform
• share results with a wide range of stakeholders beyond the experimentation group</td><td>Higher level:
• organizes meetings,
• takes minutes,
• coordinates activities,
• facilitates interaction among the members of the platform
• makes resources available for the operation of the CIG
• reminds members of their assigned tasks and makes sure that they carry them out on time,
• keeping the platform on track
• help the key actors to reach com- promise and reconciling opposing views, to come to decisions
• documentation about empirical processes and events that take place</td></tr>
<tr><td>Producers:</td><td colspan="2">• Smallholder farmers supply the small-scale processors with palm fruits which are the raw materials required for the processing of the palm oil.
• Producers participate in the experimentation group to determine the effect of harvesting season on oil yield and quality.</td></tr>
<tr><td>Processors and mill owners</td><td colspan="2">The processors in most cases do not own the milling facility but access such services from the owner of the mill for a fee. Both of them are represented at both the higher and lower level platforms.</td></tr>
<tr><td>Public sector advisors and regulatory bodies</td><td colspan="2">These are public sector organizations with expertise in areas of environment, standard setting and export of industrial commodities that provide support services to local industries (Environmental Protection Agency, Export Promotion Council and Ghana Standards Boards). The information they provide relate to small-scale palm oil processing, which is also used as empirical evidence to lobby for policy change within the sector.</td></tr>
<tr><td>Research and extension agents</td><td colspan="2">Major actors include the Ministry of Agriculture in the Kwaebibrim District, which coordinates all agriculture-related activities in the district, including extension services. The Ministry of Agriculture plays a major role in facilitating the platform both at the lower and higher levels; the Oil Palm Research Institute sits in the lower-level platform and assists with facilitation, providing laboratory space, an experimental field and materials (fruit).</td></tr>
<tr><td>Equipment suppliers</td><td colspan="2">Ghana Regional Appropriate Technology Industrial Service (GRATIS) designs and manufactures processing equipment for local industries. Its role in the platform is to provide and share information on best practices for small-scale palm oil processing.</td></tr>
<tr><td>Policy makers</td><td colspan="2">Representatives of the District Assembly and various policy makers participate in the innovation platform. Their role is to facilitate interaction between the higher-level platform and the executives of the assembly, as well as facilitating the General Assembly.</td></tr>
</table>

Achievements

The activities of the local and higher-level platforms are expected to result in the generation of knowledge in good processing practices, and enactment of rules and regulations governing processing practices. The immediate outcome of these processes will be the production of better quality oil which will enable processors to access better markets and will ultimately result in improved income and livelihoods for smallholder farmers and processors.

At the local level, initial results of one of the experiments investigating the effect of the period of fruit storage on oil yields and oil quality suggest that when the fruit are stored beyond one week before processing, the oil quality deteriorates very quickly; while oil yield decreases after storing them beyond two weeks, which is a common practice among processors. Processors have now understood that storing fruit for a longer period does not necessarily increase palm oil yield as perceived by most small-scale processors, but rather decreases yield and reduces oil quality. Knowledge generated from experiments carried out by the experimentation group is also shared with the concertation and innovation group, which includes other actors along the value chain.

At the higher level, the concertation and innovation group has contributed to three major achievements: First, two female processors became members of the District Assembly (the highest decision-making body of the district) at the beginning of the year. Their membership to participate in the decision-making process of the assembly was enhanced through their involvement in the platform activities. This has built their capacities and confidence, while at the same time enhancing the activities of the group. Second, the CIG has been able to engage the executive and other members of Kwaebibrim District Assembly in discussion on activities in the small-scale processing industry that prevent processors from accessing the export market. Although bylaws have not yet been enacted, the executives of the assembly are fully convinced of the need for them. Consequently, they have requested the group to make another presentation to the general assembly during their first sitting of the year, based on which an informed decision can be made. Since initiating the platforms, organizations such as the Oil Palm Research Institute and the Ministry of Agriculture now pay more attention to the activities of small-scale processors and oil palm farmers. The research institute has committed both human and material resources to the running of the lower-level platform activities and the ministry has begun organizing the small-scale processors into groups in order to streamline the lower-level platform activities into its extension activities.

On the whole there was: (1) Improved articulation of needs: in identifying palm oil quality (low free fatty acid) as a constraint for tapping the export market in Ghana. Experiments were simulated and the palm oil platform actors managed to respond effectively. (2) Conflict resolution: the innovation platform contributed to solving conflicts between millers using spent tires as fuel and, as a result, eased the suffering of surrounding communities from serious air pollution. (3) Problem solving: the oil palm platform in Ghana initiated specific research to improve processing practices and to investigate the reasons behind low oil recovery during the rainy season.

Challenges

The main challenge facing the platform (especially the concertation and innovation group) is the lack of commitment on the part of some members due to lack of financial reward for them. Members are only paid transport, lunch and sometimes accommodation when they attend meetings or carry out platform activities. Most of the representatives have busy work schedules which sometimes conflict with the activities. This situation has even resulted in the loss of members from the platform. The operation of the platform was also delayed by political and administrative changes at the district assembly, which affected the implementation of the platform activities. After the platform had lobbied the executives to grant audience to the concertation and innovation group, the district's chief executive of the assembly was removed, while the district coordinating director went into retirement. One other major challenge is how to continue the role of facilitator and platform activities once the CoS-SIS programme ends and funding stops. If the platform is to become institutionalized, it requires that research and extension take up a new role as interactive researchers and facilitators. Most technical scientists and extensionists, however, are handicapped in terms of adult learning and facilitation skills (Defoer, 2002).

Future plans and scaling up

The platform plans to mainstream its work into the formal research and extension system. Since the constraints faced by smallholders are multi-faceted, at different scales, and include technical as well as institutional issues, making the platform part of the research and extension system will effectively address these complex issues and find solutions that are well embedded in the needs and circumstances of smallholders. The involvement of local-level agricultural organizations such as the Oil Palm Research Institute and the Ministry of Agriculture, in the platform activities provides opportunities for it to be streamlined within the activities of these organizations. Nevertheless, funding and facilitation challenges exist.

Institutionalization seems to have been the most important tool for scaling up the innovation platforms. Particularly, the learning and research-oriented platform type have well-developed institutionalization strategies. Deliberate strategies designed from the initiation of a platform can be found in some cases. The oil palm platform saw the need for the formation of a reference group of people higher up in different stakeholder organizations (i.e., ministry, national research and university), which are then in the position to promote the principles further if they see the benefit. In the case of the oil palm platforms in Ghana, there is evidence that farmers are taking the lessons learnt from the experimentation groups further by experimenting on their own and sharing knowledge (for example, the effect of topography on fruit yield and moisture content).

Lessons learned

The concertation and innovation group currently consists of eight members (which consists of three women). Although two of the women involved in the platform have a low educational background, their continuous interactions with other stakeholders at a higher level have built up their confidence and empowered them to play advocacy roles in their community. As for example was the case in one of the communities where one of the women CIG members lives. A processor set up a mill within the residential area of the community. The activities of the processor generated a lot of smoke, which was disturbing the residents. The residents of the area complained to the processor about the pollution from his processing activities but to no avail. The woman platform member, who also lives in the same community, took up the matter and put a lot of pressure on the processor until the company installed chimneys at the mill to direct the smoke up into the atmosphere. The joint experimentation with the farmers, processors and mill workers has improved their confidence levels and their innovative capacities (remember the farmers' quote in the activities section). However, this activity requires good skills in adult learning and facilitation. Joint learning on platforms is also time-demanding for stakeholders. Although it is too early to assess the impact of the platform on poverty alleviation, indications are that choosing to divide tasks between different levels (including joint experimentation) and working towards improving institutional conditions will have a positive impact on the livelihoods of smallholder farmers and processors. Processors are now convinced of the need to process their fruit early to improve the oil quality and reduce oil losses.

Case Study 4: Sustainable Intensification of Integrated Crop-Small Ruminant (SIIC-SR) Project Innovation Platform

The SIIC-SR Project set up an IP in Wulugu in West Mamprusi District in the Northern Region. The Wulugu Innovation Platform was inaugurated in July 2011. The formation of the IPs in project communities was a main output under the project and this IPs were to serve as community level platforms for developing and strengthening value chains of the target crops and animal products in the project implementation sites. The project facilitated and provided support in the form of training facilitators for the formation of the IP, but the IP was run by the various actors on the platform, including an executive body. The agricultural extension agent for the area was influential in setting up of the IP, running it and served as the first facilitator of the IP.

No IPs existed in the area prior to the formation of this one. However, various groups existed in the community, whose members had an interest in crop and livestock production. The membership of the Wulugu IP was drawn from these groups. A few of these groups included the maize farmers association and the soybean farmers association. A group formed by the assistance of JICA also existed, which sought to assist farmers in rice production. The IP was a platform to address poverty in the community through an improvement of IP members' capacities and utilization of best practices in crop and livestock production to enhance productivity. An earlier baseline survey had established that low crop productivity and high small ruminant mortalities were key constraints to productivity and the IP members were to use the IP to address these issues (Konlan et al., 2015).

Challenges and constraints

Climate change is currently the major factor that affects the production system. The current level of precipitation is very poor. The rains delays in coming and, when it starts, it is very heavy and do not last over the production period of the major crops grown in the area. In addition to the above, inadequate income at the beginning of the major farming season is making the farmers not to be able to cultivate the area of cropland that they would have cultivated. Also, bush fires is the major constraint affecting farmers in the West Mamprusi District. This issue occurs as a result of hunting, smoking and cooking of food by farmers themselves on the farms. Other challenges affecting the production system is the cutting down of trees as fuel-wood and production of charcoal, coupled with lack of afforestation and leaving the area as a desert prone area.

Formation of the IP

The SIIC-SR Project team members are scientists and technical officers from the Council for Scientific and Industrial Research (CSIR) Crop Research Institute (CRI), CSIR Animal Research Institute (ARI), CSIR Savanna Research Institute (SARI) and Ministry of Food and Agriculture (MoFA) district officers. These professionals formed the innovation support team (IST) members for the IP. Their operations in the IP area were technical in nature, and include: capacity building of IP leaders and local facilitators, technological transfer through demonstrations and scientific investigations to address the identified constrains in the project base line study, and concerns of the IP to increase crops and livestock production and trade for livelihood improvement.

The establishment of the IP involved the invitation of key persons such as hardworking farmers (both crops and small ruminants), opinion leaders, and people with common interest in improving the livelihoods of the people of Wulugu and its environs. The issue of trust in the initial leadership of the IP to be effective in performing their duties was a critical consideration, as the leadership of the IP was determined to be effective as compared to other farmer organizations that had failed due to poor vision, lack of team building and cooperation.

Operation of the IP

- There were regular meetings, on-farm demonstrations on both crops and small ruminants' best production practices, periodic cleaning of the environment by the IP members Inadequate veterinary services,
- Weeds
- Lack of credit facilities
- Low crop yield
- Improper use of agro-chemicals
- Difficulty in accessing tractor services
- Improper use of agrochemicals and its residual effects on farmers and farm animals
- Difficulties in carting crop residue (as feed for livestock)
- High rate of mortality among small ruminants in many farmers' flock
- Lack of regular access to quality seeds
- Poor rainfall pattern and moisture level determination for decision making in farming
- Technical support on crops and livestock production practices and regular monitoring by the innovation support team (IST) members. Several challenges were identified as entry points that the IP wanted to work on, including:

The identification of these challenges leads to some major interventions such as the training of community animal health workers, seed production training, development of "chameleon" moisture metre, box bailing techniques, amongst others. Cultural norms and ways of doing things are shared values among the IP members. They had the same expectations and respected each other's views and suggestions that will help in improving the effectiveness of the IP. The members knew each other since they lived in the same community and there was cordial relationship among them. The IP had ties with key organizations such as MoFA, SARI, ARI, the social welfare department, financial institutions, local government, IST members, amongst others.

The IP membership is made up of people with interests in crop and livestock production and trade. An individual becomes an IP member by voluntary registration, payment of dues and attends IP meetings. Non-IP members can, however, participate in meetings as observers, or may be invited to carry out an activity alone or together with some IP members for the benefit of the IP.

The common interest of the IP members is to build their capacities in crops and livestock production and trade, and policy issues affecting these activities to generally improve their livelihoods. There were cordial relations between the IP and other farmers' groups in the area and they often share knowledge and experiences as well as farm inputs (like seeds, tools and equipment). The activity of the IP involves only the members of the group. These activities are usually related with their common interest. Members are also motivated by the structures available in addressing concerns of the various actors in the IP, which are unique as compared to other organizations or groups operating in Wulugu community.

Though there are other farmer-based organizations (FBOs) in the community, the relationship between the IP and the FBO's was found to be cordial. There are even some members of the IP who are members of other organizations. The members of other groups sometimes share their experiences with the IP members. The registered IP members enjoy the following rights and responsibilities:

- Right to take part in all IP activities
- Equal respect and dignity is accorded to all members
- Welfare of group members is paramount in the IP operations
- Executives are mandated to periodically render accounts to members
- If an individual fails to turn up for a meeting for two consecutive occasions, without reason, that individual pays a fine of about 5 Ghana cedis (1.6 USD).
- If a member defaults in the payment of monthly dues for up to three months, he/she will be expelled (dues are non-refundable)

The IP has a formal structure which consists of a chairperson, vice chair, secretary, treasurer, organizer (for both males and females), facilitators (crops/livestock) and the general membership. Even though the IP is yet to be registered, it has been recognized by various organizations and some opinion leaders. Some of this recognition has enabled the IP to carry out some of its activities in the West Mamprusi District. The IP is commonly called "kpangmangvella," which means "hard work pays," by the membership.

Achievements

As outlined earlier in this case study, the constraints to productivity were identified in the baseline study in 2012 (i.e., at the beginning of this project) and the measures taken to address them were previously discussed. Most of the constraints were related to agricultural productivity, and some were more effectively tackled than others as shown in table 4.

Table 4. Constraints identified and measures taken as a redress

Constraint	Measures taken
1. The high incidence of weeds and pest on crop fields of farmers	Training on the appropriate use of agro-chemicals and weeding regimes to control weed and pest
2. Deaths of small ruminants arising from polythene bag ingestion	Organization of weekly clean up exercise to pick up all polythene bags in the community to prevent animal ingestion.
3. Destruction of crops by Fulani herdsmen with their cattle herds.	This constrain was not tackled at the IP level, but communicated to the local authority for policy regulation enactment as a solution.
4. Low crop yields	Training of farmers on the use of improved seed, appropriate planting and fertilizer application methods.
5. High cost of fertilizer	Policy makers engagement initiated
6. High cost of technical inputs	Referred to policy makers
7. Inadequate veterinary service	Training of CAHWs as auxiliary veterinary service providers
8. Lack of credit facilities for IP members	Financial institutions were invited and they sensitized IP members on credit facilities availability and how to access the credit in their institutions

The key innovations produced from the IP activities and decisions were training of some farmers in the IP on seed production and linking them to registered seed producing company, with the full rights to produce seed for sale to the company as out-growers. Training of community-based animal health workers (CAHWs) to complement the services of the mainstream veterinary technicians in the IP area. By this training, CAHWs are equipped to attend to a range of disease conditions in animals and to assist mainstream veterinary staff in disease monitoring and surveillance. The IP members have also acquired the expertise to construct box balers, which are used in the compaction and transportation of crop residues to feed ruminant livestock. Feed storage methods to maintain quality in the dry season feed supplementation were emphasized.

Policy level outcomes

Constraints that were ultimately related to agriculture, but involved policy changes at the political level were more difficult to tackle. For example, though the incidence of destruction of crops by the cattle of Fulani herdsmen ranked quite high in the list of constraints, this constraint was not tackled by the IP due to inadequate capacity. The policy makers (district authorities) were informed about it, but no action has been taken till date. Another constraint was lack of credit facilities (which was related to the inability to afford the cost of inputs and initial capital for farming and trading, respectively). Though the IP invited representatives of financial institutions in the area for presentations on how to access micro credit, it was clear from the onset that some mutual distrust existed between the farmers and some microcredit institutions. The hope is that with their newly-acquired skills in seed production, the IP will eventually be registered as a seed producing company, capable of generating income from sale of seeds.

Sustainability

The IP members generally agree that the IP needs to continue to run after the project period has elapsed, and they understand that they need to put in place key measures such as having an overarching goal and establishing a source of funding to ensure sustainability. The IP currently has the ambition to acquire a tractor for the IP and they are thinking of some income generating activities (e.g., establishing IP farms for both crops and livestock, producing seeds for sale) that could help them secure the kind of funds they will need to finance their activities.

The IP strengths emanate from strong group cohesion, regular attendance of meetings and high commitment of some key members to the operations of the IP. The project has given the members an idea of how an IP should be run and this can be exploited to keep the IP alive after the project period has elapsed. Further training in IP facilitation will increase the effectiveness of the IP activities. The withdrawal of project funding may discourage attendance at meetings and the payment of dues to fully finance IP activities. Sources of funding for IP sustenance include:

- Registration fees and monthly dues
- Own contributions in the form of levies
- Plans to establish a crop and livestock farm.
- Plans to register IP as a seed producing company.

Other actions or relationships that will be important to sustain the IP are the development of a business plan to help the IP acquire a main source of income generation (tractor for operations) and maintenance of linkages between the IP and MoFA, agricultural extension agents and researchers in the area.

From the IP operations, three clear development impacts have been observed. There is an increase in the rate of adoption of improved technologies, yields and incomes. Improved technologies like the dual purpose legumes, improved maize, seed treatment and improved housing for small ruminants, fodder conservation, nutrient treatment, etc., have been adopted by IP members and other non-IP members. This has led to increase in yields and productivity of producers. Farm incomes of households as a result have increased, thus improving their livelihood. The end result will be an improvement in the rural economy and social wellbeing.

Development impacts from IP operation were achieved as a result of the approach used. The use of IAR4D through the innovative systems created synergies among the value chain actors, which influenced the spread of technology. Through this system, other non-production interventions were introduced to complement the production technologies. The role played by project management also contributed greatly to these impacts. Most especially, the leadership role by the regional coordinator in getting things going has been very instrumental. Project team members gave their best in delivering on the project objectives. The active participation of IP members in programmes and activities has been very important in achieving results. The role of extension in organizing members for activities played a lead role in achieving development impacts.

Future Innovations and Impact

The ultimate aim of the IP is to improve the food security and livelihoods of the nation. This will improve the IP members' income and livelihood to be able to contribute to socioeconomic development of the nation. The IP hopes to develop a strong crop and animal production system supported with the required capital for commercial production. To achieve this long-term impact will require sustaining IP activities and building a strong relation with policy and other service institutions like financial institutions and non-governmental organizations (NGOs). Raising the required capital requires change in the agricultural finance policy, where currently financial institutions shy away from agriculture. This is as a result of the high level of risk in the sector. Minimizing the risk will require mechanizing production and the introduction of irrigation systems. This goes beyond the IP and the required policy support from government and other organizations.

Research for Development Practice

Working with the IP has improved the appreciation of IAR4D approaches by the project team. It has given the team an opportunity to practically implement the concept and learn from it. Interactions with different stakeholders have deepened the researchers' understanding of some issues and also provided new opportunities for research. The research facilitator is now well equipped in IP facilitation and provides support to other projects. The project team members have become ambassadors for IAR4D and advocate for its institutionalization. The regional coordinator has been championing this institutionalization effort and has had discussions with the top hierarchy of the CSIR and MoFA.

To improve the outcomes of innovative platforms, it will be better to have more than one IP at the community level, depending on the entry point. The IP at community level should be built around change dominance to ensure that outcomes are not one-sided. Graduating IPs to district and national level IPs will be very important in getting certain critical policy changes. Policy changes are difficult to achieve at the community level, since decisions are taken at district and national levels. Establishing policy platforms at the district and national level will be vital in changing some policies and programmes to support the production systems and input and output market IPs. All change dominance IPs must be linked and should not work in isolation.

STUDY THREE

Investments in Innovations for Agricultural Development and Food and Nutrition Security

INTRODUCTION

This report presents a snapshot of the status of national and international support for innovation research for food, nutrition and agricultural development in Ghana. It aims at providing some insights into expenditure and investment patterns of innovation research in the agricultural sector of the country, as a way of exploring and presenting the state of knowledge and management of innovation research in Ghana, with the view of making good the country's deficiencies in innovation research, and to improve the competitiveness and sustainability of the country's knowledge base in science, technology and innovation (STI). Today, these concepts have become the bedrock of development, and many countries are plying the road of STI development-led economy (World Bank, 2006), especially in agriculture-based economies such as Ghana.

In Ghana, like in other developing countries, agriculture is the mainstay of the economy. The sector remains the single most important sector in terms of provision of employment and food security, among others. In 2007, it was reported that a third of the world's workers were employed in the agriculture sector, and production from the sector accounted for not less than 5% of the gross world product (International Labour Organization, 2007). Indeed, agriculture has and still plays a crucial role in the development of many nations. This is evident by the increasing demand for inventions, technologies and innovations used for cultivation, conservation and exchange of agricultural products. The development of agriculture, without doubt, has been directly connected with human development in many cases (World Bank, 2006).

Although declining in terms of its contribution to growth variables such as gross domestic product, the agricultural sector in Ghana still serves as the single most important sector in the economy. This sector provides food and bio-raw materials for the agribusiness industries. The agricultural sector is very important in terms of the provision of employment, revenue and as a survival mechanism for many households. Although agriculture in Ghana is mainly small-scale, with farmers cultivating less than 2 hectares of land per plot (MoFA, 1990), these farms provide occupation to millions of people, generate income and help to reduce poverty in the country.

Apart from the fact that agriculture's contribution to Ghana's GDP is declining, the incidence of poverty is highest among food crop farmers (MoFA, 2000). This has been attributed to the fact that this sector is characterized by basic technology and poor support from credit, inputs and other support services agencies. As a result of the growing world population, it is becoming obvious that the traditional technologies and way of doing things in the agricultural sector are no longer able to support the sector and the growing populations who need to be fed. This begs for modern technologies of science, technology and innovations. The use of machinery in the production process, the provision of many products like pesticides and fertilizer and the offering of innovative agri-business training for farmers and other value actors have helped to increase agricultural yield per unit of land, improve agricultural production and made more efficient agricultural systems of producing outputs.

In spite of this, the constantly increasing global demand for agricultural products demands more machineries and knowledge and advanced technologies for more intensive production. This has created opportunities for the advances in biotechnology and other technologies to enhance improvements in crop and animal production, among others. These developments suggests that not only does the sector provide the basic necessities such as food, employment and income, the agricultural sector also plays a key role for absorbing and developing other related industries. However, this requires involvement and support from research and development in innovations and favourable governmental policies, which all rely on investment from both international and national governments. Yet, the question that remains is related to the kind, form and quality of innovation investments that governments have and are ready to undertake.

This paper aims at improving our understanding of the status of innovation research in the country, and the role played by the state and international organizations in promoting agricultural and rural development innovations as a way of proposing pragmatic ways for which donors can relate with and engage with the state to yield better outcomes.

In spite of the increasing global wealth, some developing countries, especially in Asia and Africa, have people who go to bed hungry (FAO, 2015). Alongside this canker, is an increasing rate of poor people in the cities and rural communities, some of which are recent victims of the emerging climate change and growing populations in the midst of scarcity of resources and employment. As a way of circumventing the situation, some technologies have been developed and circulated among farmers and other food producers. Yet, the results have been discouraging, and this is evident by the current figures of poverty and food and nutrition insecure people of the world (FAO, 2015). These poor and negative situations have generated the desire among policy makers and governments to eliminate the pervasive hunger and malnutrition, particularly in Africa. The objective is to reduce the high food import outlays which has bedevilled the economies of some of these poor and developing countries in Africa and Asia.

The quest for achieving the above has become the driving force behind the urgency for which governments are adopting the Comprehensive Africa Agricultural Development Programme (CAADP) developed by heads of state and government in Africa. The CAADP programme is purposed to use agriculture-led development as a fundamental platform to reduce hunger, poverty and the burden of food imports, while generating economic growth and creating the way for the expansion of food exports. To achieve high results under the CAADP objectives, countries are in the process of identifying research and adoption priority mechanisms to disseminate agricultural research and development outputs for better outcomes. These priorities form the basis of the priorities of the Forum for Agricultural Research in Africa (FARA), the regional coordinating research body and other research and development organizations working in Africa.

The product is an agreement to concentrate on staples, but with the work on staples, concentrating on issues such as conservation, use and enhancement of genetic resources, integrated natural resource management, markets, institutions, information and up-scaling challenges, and improving livelihoods in unstable environments. For a rapid growth in African agriculture, especially those of the sub-Saharan region, such as Ghana, the need for enhanced capacity in agricultural innovation research and development has been underscored. Thus, the time is ripe for optimal coherence between principal actors in Africa's agricultural research and development organization, as well as extension organizations and other stakeholders or value chain actors through the adoption of an innovation platform to disseminate the outputs of research and development innovation.

Innovation has become one of the top priorities for many national economies and governments are doing their best encourage innovation processes in their countries, with the expectations that it will help support economic growth, and increase national competitiveness and social wellbeing of the populace. At present, agriculture seems a not so attractive business, as opposed to technologies like the ICT or the nanotechnology industries. Yet one thing remains, that the demand for food will constantly increase and people will always demand it. Thus the sector is expected to seek new opportunities, reachable through new technologies and the application of science, technologies and innovations.

While this is important, it has been often been observed that developing countries have often adapted and applied directly innovations from developed countries, even though the results have not always been encouraging. This is partly because certain characteristic factors peculiar to countries were not considered in appropriating such innovations. While these factors such as culture, poverty, unemployment, low-income and low-productivity, among others, cannot just be ignored, policy makers have neglected their importance in informing policy.

Agriculture innovations in Ghana

Ghana's agriculture is dominated by smallholder producers, who constitute about 90% of the farmers in the country, cultivating an average farm size of about 1.2 hectares, with a low application of improved technology generally. This has been observed to have resulted in yields generally below expectations. This suggests that there is significant potential for improvement. In general, reports about the sector have suggested that a major contributor to low yields is poor soil fertility (resulting from nutrient depletion), soil mining, low input use (resulting from the high prices of commercial fertilizers) and limited availability of high quality organic inputs (manure, crop residues, etc.) to complement the inorganic fertilizer. Another major factor of crop productivity is the use of improved seeds and planting materials that is suitable for the sociocultural environments within which the crop is cultivated. Yet, in spite of the agricultural sector's importance to the overall economy, fertilizer use in Ghana is about 7.2 kilograms per hectare (kg/ha), similar to the average rate in SSA, but significantly lower than in other developing countries. In Ghana, this has been observed to have moved up from 8 kg/ha in 2008 to 12kg.ha in 2012 (MoFA, 2009).

AGRICULTURAL SECTOR EXPENDITURE

Public spending on agriculture is crucial considering the size and the traditional role of agriculture, especially in a developing country like Ghana. Table 1 and figure 1 present the trends in agricultural expenditure and share of agricultural expenditure in total public expenditure. In monetary terms, government budget on the agricultural sector has consistently increased since 2004 except 2009 (column two of table 1). Percentage wise, the share of total agricultural expenditure in total government expenditure remained a little above 6% from 2001 to 2003, and then increased to 8.9% in 2004. This increase in expenditure share of agriculture is not surprising as it comes in the wake of the Maputo Declaration (2003), where African heads of state and governments urged member countries to commit at least 10% of their annual budgetary resources on agriculture, with the sole aim of ensuring agricultural growth of at least 6% annually. Since 2006, the expenditure share of agriculture in total public expenditure shows a rising trend, reaching the highest of 16% in 2010 and later falling to 11.2% in 2011. Following the Maputo Declaration, the share of agricultural expenditure in total government expenditure has been below the 10% target up to 2008. However, during the 2009 – 2011 period, the 10% target set out in CAADP was finally reached and even exceeded. On one hand, it can be said that Ghana has fared well in terms of meeting the target during the last years; but on the other hand, the question that must be put forward is has the desired growth of 6% materialized considering the recent growth in the agricultural sector, especially in 2011?

MoFA has the largest average share of agricultural sector expenditure, followed by COCOBOD and agricultural research (World Bank, 2013). It is not surprising that COCOBOD accounts for the second biggest share of the sector's expenditure considering the strategic position and importance of cocoa in the Ghanaian economy. Most of the expenditure incurred by the ministry go into the payment of salaries and other emoluments, and not for actual agricultural activities. There is currently a debate as to whether such expenditure should be counted as actual sectoral expenditure, since it does not go into actual investment in the sector.

Table 1. Agricultural expenditure and share of agricultural expenditure in public expenditure

Year	*Agricultural expenditure (in 2001 constant prices) GHS million*	*National expenditure (in 2001 constant prices) GHS million*	*Public agricultural expenditure as percent of total public expenditure*
2001	25	382	6.6
2002	32	524	6.1
2003	77	1177	6.5
2004	124	1402	8.9
2005	138	1444	9.6
2006	162	1937	8.4
2007	208	2504	9.1
2008	265	3324	9.9
2009	254	2620	10.3
2010	268	1670	16.0
2011	303	2693	11.2

Source: SRID/MoFA (2013)

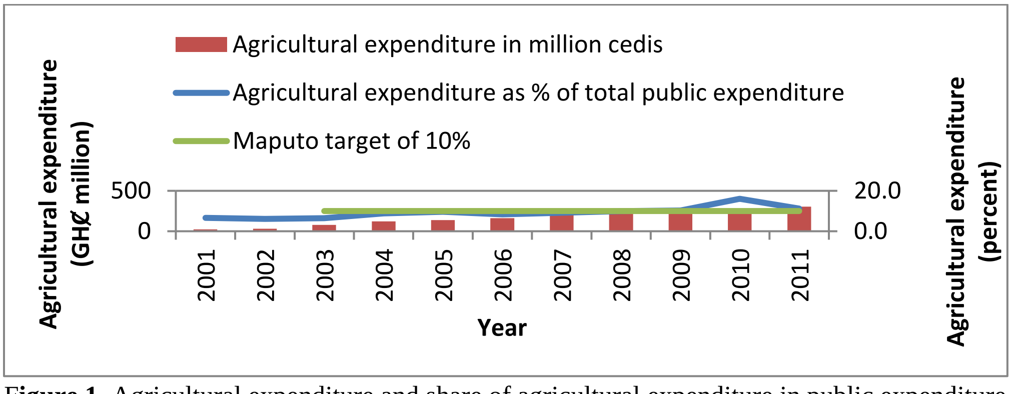

Figure 1. Agricultural expenditure and share of agricultural expenditure in public expenditure
Source: SRID/MoFA, 2013

Table 2 shows the agricultural subsector expenditure in millions of Ghana cedis. The expenditure pattern shows the dominance and importance of the crops (without cocoa) and cocoa subsectors in the agricultural sector. There has been a consistent increase in the expenditure on crops (without cocoa) over the years, rising from GHS 10.8 million in 2001 to GHDS 200.8 million in 2011. However, for cocoa it increased from 2001, attaining its highest value of GHS 98.9 million in 2008 and then declined in 2009. During 2001 – 2011, real expenditure averaged GHS 97.5 million for crops (without cocoa), GHS 55.1 million for cocoa, GHS 4.1 million for livestock, GHS 2.7 million for fisheries and GHS 10.2 million for forestry.

Table 2. Agricultural subsector expenditure (in 2001 constant prices), GHS million

Year	*Crops (without cocoa*	*Cocoa*	*Livestock*	*Fisheries*	*Forestry*
2001	10.8	13.3	0.3		1.0
2002	14.7	16.0	0.3		0.9
2003	35.9	37.7	0.8		2.2
2004	67.9	43.6	0.9		12.0
2005	78.2	50.6	3.1	0.1	6.3
2006	84.2	62.7	3.8	0.1	11.1
2007	115.2	69.5	3.2	2.4	17.5
2008	144.5	98.9	4.1	1.6	15.9
2009	158.2	66.0	9.5	9.7	10.6
2010	162.5	68.9	11.6	2.4	22.6
2011	200.8	79.4	7.9	2.8	11.8
Average	97.5	55.1	4.1	2.7	10.2

Source: Adopted from World Bank (2013)

Public expenditure on extension, training and technical assistance

Agricultural extension services play a crucial role in the dissemination of innovations in the development process of agriculture. Agricultural extension agents (AEAs) serve as a bridge linking the technologist and the farmers in the chain facilitating the adoption of new and improved innovations and better farm management practices. Figure 2 shows the public expenditure on extension/technology transfer, training and technical assistance in the agricultural sector. In 2008 and 2010, expenditure on extension/technology transfer was at its lowest. By 2012, the spending was almost double (GHS 13.9 million) the amount in 2006 (GHS 7.1 million). The annual expenditure averaged GHS 7.2 million for extension/ technological transfer, GHS 30.5 million for training and GHS 7.1 million for technical assistance.

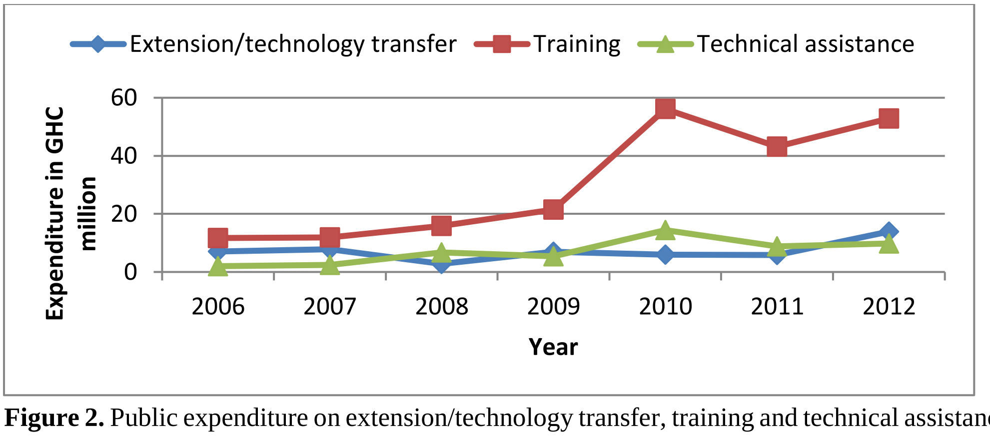

Figure 2. Public expenditure on extension/technology transfer, training and technical assistance (in GHS million), 2006 – 2012

Source: FAO, 2014

Components of agricultural sector expenditure

The main items of expenditure in the budget are personnel emoluments, administrative expenses, and service expenditure and investment. Based on World Bank's definitions, personnel emoluments, administrative expenses and service expenditure are classified as recurrent expenditure. Personnel emoluments are sometimes referred to as wages since they relate to salaries, while the other recurrent expenditure is referred to as non-wage recurrent. Figure 3 shows vividly that while the share of expenditure on investment is increasing, that of personnel emoluments and non–wage recurrent are declining. The share of investment increased from 11% in 2001 to 58% in 2011, while the share of personnel emoluments declined from 43% in 2001 to 27% in 2011, and the share of non-wage recurrent expenditure declined from 47% to 15% during the same period (World Bank, 2013). The declining share of wage and non-wage recurrent expenditures raises two issues: first, lack of sustainability of the operation and maintenance of investment items and facilities; and second, the adequacy of the provision of technical services delivery in the sector (World Bank, 2013).

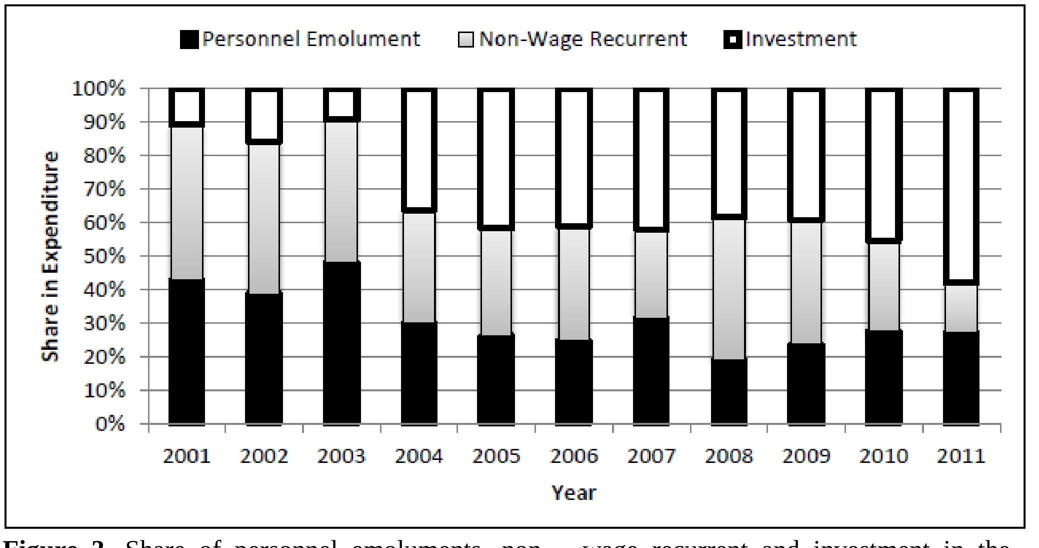

Figure 3. Share of personnel emoluments, non – wage recurrent and investment in the agricultural sector expenditure (percent), 2001 – 2011
Source: World Bank, 2013

Trends in Agricultural Research Spending

To generate the desired growth in the agricultural sector, agricultural research has to deliver new and improved technologies capable of yielding continuous gain for the society. Through sustained growth in agricultural productivity, sustainable benefits are achievable through growth in household incomes, especially in the rural areas, reduction in poverty among the farming population and ensuring food and nutritional security. In effect, agricultural research must introduce innovations that overcome the "business as usual" phenomenon and increase agricultural efficiencies. This therefore requires conscious government investment efforts in public goods that produce innovations in agriculture.

Generally, in absolute terms, there has been a consistent increase in total agricultural R & D spending since 1992 (table 3 and figure 4). However, total agricultural R & D has been less than one million Ghana cedis from 1981 to 1993. In contrast, there has been a significant improvement in spending on agricultural R & D, especially during 2003 – 2014 period. This reveals the increased commitment by government to invest in R & D to accelerate agricultural production. In 2014, spending on agricultural R & D was more than ten times the spending in 2003. Table 4 and figure 5 present the trends in agricultural research spending as a share of agricultural GDP in Ghana. The evidence indicates that agricultural research intensity measured as public spending on agricultural R&D as a share of agricultural GDP in Ghana has consistently been less than 1%, reaching the highest of 0.71% in 2009.

Table 3. Total agricultural R & D spending (current local currency, GHS million)

Year	*Total Agriculture R&D Spending (current local currency GHS million)*	*Year*	*Total Agriculture R&D Spending (current local currency GHS million)*
1981	0.01	1998	3.98
1982	0.01	1999	4.38
1983	0.02	2000	5.65
1984	0.03	2001	7.34
1985	0.06	2002	9.04
1986	0.14	2003	15.43
1987	0.23	2004	18.66
1988	0.29	2005	21.27
1989	0.39	2006	28.31
1990	0.53	2007	36.75
1991	0.50	2008	53.72
1992	0.64	2009	80.36
1993	0.88	2010	86.58
1994	1.11	2011	97.22
1995	1.69	2012*	101.76
1996	2.30	2013*	153.93
1997	3.00	2014*	179.16

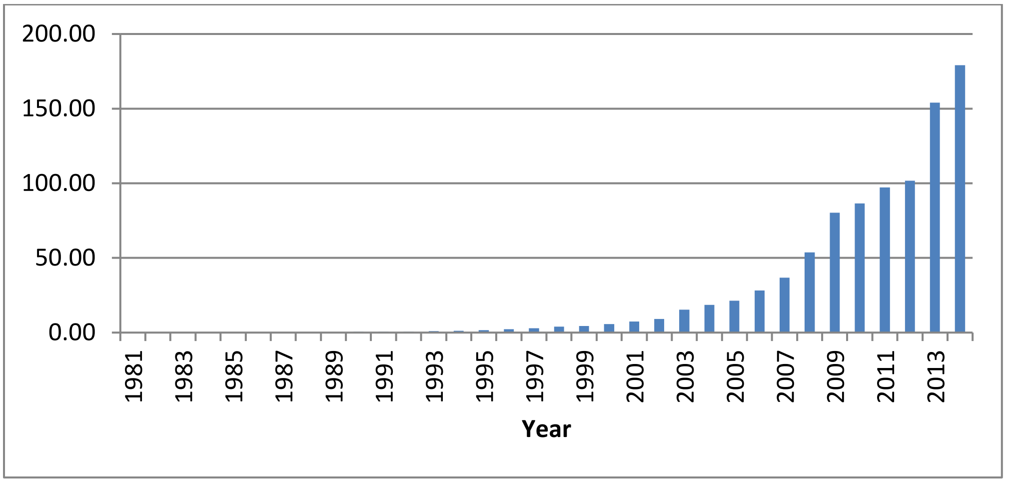

Figure 4. Total agricultural R&D spending (current local currency, GHS million)

According to figure 4, agricultural R&D started increasing only after the late 1990's. This is an indication of when the realization of the importance of research in agriculture at the state level began to increase. It coincides with the period when world leaders rigorously began to look for research to solve national challenges.

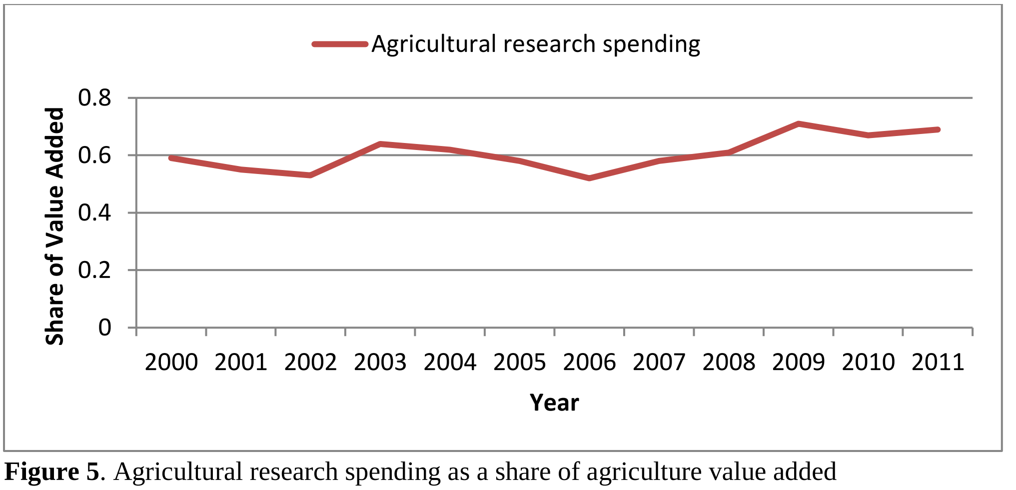

Figure 5. Agricultural research spending as a share of agriculture value added
Source: FAO (2015)

Total number of agricultural researchers and research intensity

Table 5 and figure 6 show the total number of agricultural researchers (full-time equivalents – FTE) and agricultural research intensity in Ghana. The total number of agricultural researchers declined from 469.6 in 2000 to 409.8 in 2002, and then increased consistently from 2003, growing at 4.5% annually. The increase in the total number of agricultural researchers is found to be strongest at Ghana's public universities (Beintema et al., 2014). Another indicator of agricultural research intensity is the number of agricultural researchers (FTE) per 100,000 farmers. This ratio was at its lowest in 2002, declined in 2006, following an increase that occurred in 2003 – 2004. However, since 2007, a rising trend was observed, which peaked at 9.7 in 2011.

Performance of agricultural sector in Ghana

Agriculture made significant contributions to Ghana's socio-economic development. As a result, its growth and development is of paramount concern to policy makers. It is common knowledge that agriculture's growth over the decades of Ghana's economic development has been heavily influenced by weather variables and world market price for its principal export crop – cocoa. In this section, indicators such as the contribution of agriculture and its subsectors to national GDP, growth rates of GDP of agriculture and its subsectors, growth rates of some selected crops and yield levels of these crops are examined.

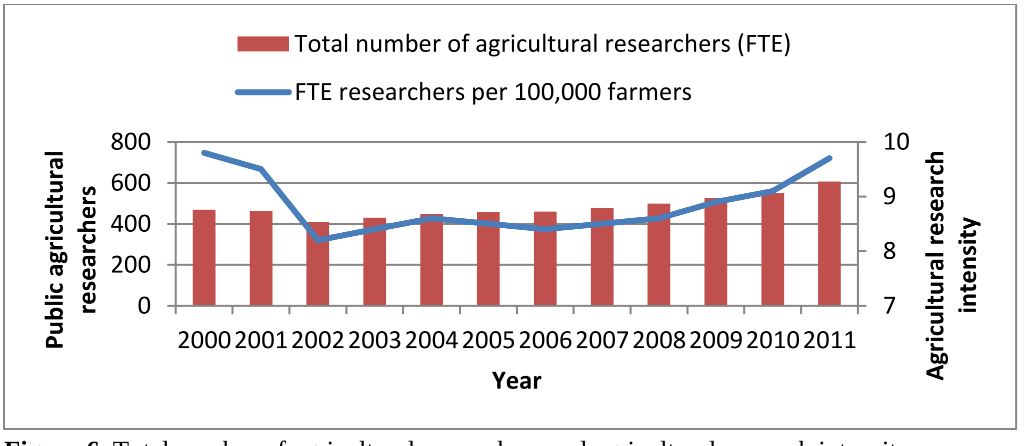

Figure 6. Total number of agricultural researchers and agricultural research intensity
Note: FTE: Full–time equivalent
Source: FAO (2015)

Contribution of agriculture and agricultural subsectors to national GDP

The agricultural sector consists of crops (without cocoa), cocoa, livestock, forestry and logging and fishing subsectors. Table 6 presents the share of agricultural subsectors in agricultural GDP. Crops make up the largest subsector, with a share of more than 60%. The share of cocoa in agricultural GDP ranges between 8 and 12%. Figure 7 shows that the share of agricultural subsectors in agricultural GDP for 2006 – 2014 averaged 62.9% for crops (without cocoa), 11.4% for forestry and logging, 10% for cocoa, 8.5% for livestock and 7.3% for fishing.

Table 6: Share of agricultural subsectors in agriculture GDP at constant 2006 prices

Subsectors	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*Average*
Crops (without cocoa)	60.1	61.1	62.2	64.4	62.4	63.1	63.7	64.2	64.5	62.9
Cocoa	9.9	9.3	8.9	8.7	10.5	11.8	10.6	10.2	10.2	10.0
Livestock	8.1	8.6	8.8	8.2	8.2	8.5	8.8	8.7	8.7	8.5
Forestry & Logging	13.6	13.3	11.9	11.2	11.7	10.0	10.5	9.9	10.2	11.4
Fishing	8.3	7.8	8.5	7.5	7.2	6.6	6.5	7.0	6.3	7.3

Source: SRID/MoFA, 2013; GSS, 2014 and 2015

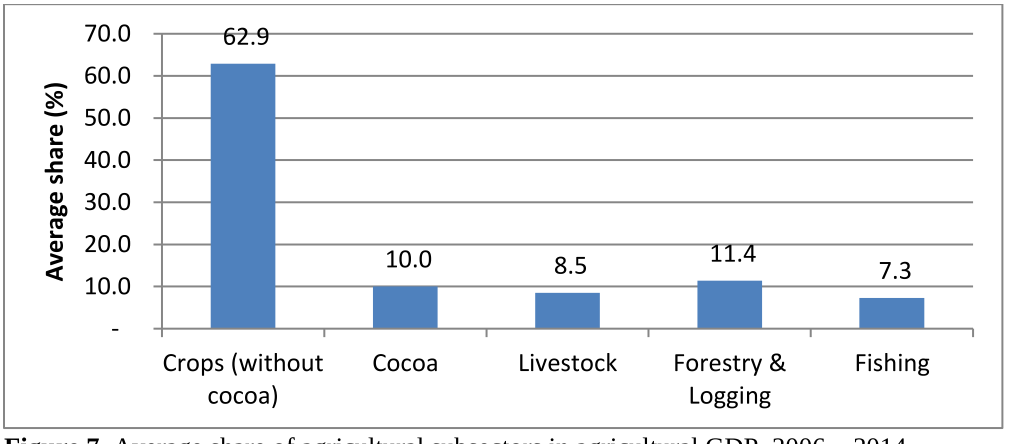

Figure 7. Average share of agricultural subsectors in agricultural GDP, 2006 – 2014
Source: SRID/MoFA (2013); GSS (2014; 2015)

Table 7. Contribution of agriculture and its subsectors to national GPD (at basic prices)

Item	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*Average*
Agriculture	30.4	29.1	31.0	31.8	29.8	25.3	22.9	22.4	21.5	27.1
Crops	21.3	20.3	22.4	23.6	21.7	19.1	17.2	17.4	16.8	20.0
Cocoa	3.0	2.7	2.5	2.5	3.2	3.6	2.6	2.2	2.2	2.7
Livestock	2.5	2.3	2.1	2.0	2.0	1.8	1.6	1.4	1.2	1.9
Forestry & Logging	4.1	4.2	3.7	3.7	3.7	2.8	2.6	2.2	2.3	3.3
Fishing	2.5	2.3	2.7	2.5	2.3	1.7	1.5	1.4	1.2	2.0

Source: Adapted from GSS (2015)

Traditionally, one of the roles of agriculture is its contribution to total GDP. Table 7 and figure 8 show the contribution of agriculture and its subsectors to total GDP. Among the subsectors, the crops subsector dominates in terms of agricultural contribution to total GDP during 2006 – 2014, and this has been the case for several decades. This evidence is clearly shown in figure 8, where crop GDP lies below agricultural GDP, and the two trends seem to be moving in a parallel fashion. Figure 9 also corroborates this dominant role of crops as the contribution of agricultural subsectors to total GDP averages 20% for crops, 3.3% for forestry and logging, 2.7% for cocoa, 2.0% for fishing and 1.9% for livestock. A factual observation about the contribution of agriculture to total GDP is that it declines as the economy transforms successfully, as clearly shown by a declining trend of agricultural GDP in figure 8. This implies that during economic transformation, irrespective of the country, the economy diversifies away from agriculture into services and manufacturing.

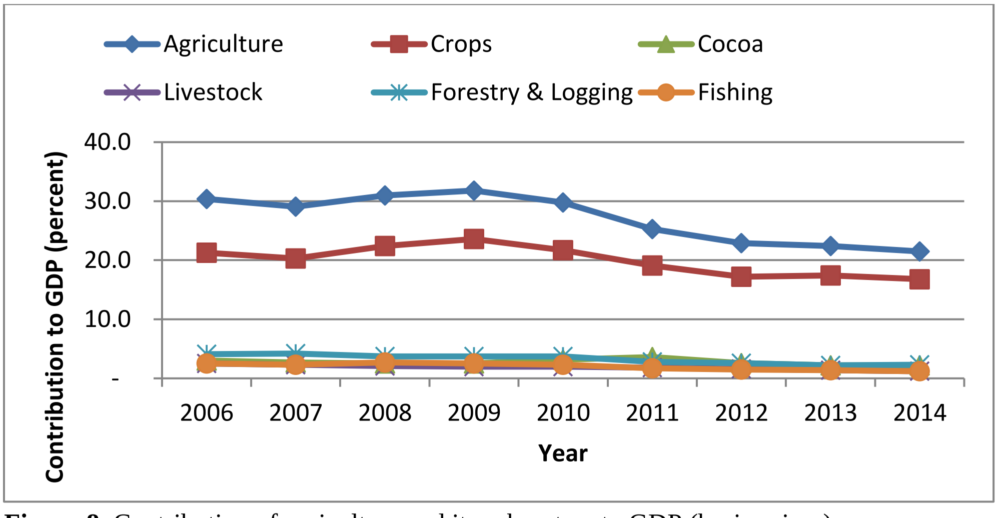

Figure 8. Contribution of agriculture and its subsectors to GDP (basic prices)
Source: GSS, June 2015 Bulletin

Table 8 and figure 9 show the annual growth rates of agriculture, agricultural subsectors and total GDP for the period. The agricultural sector experienced positive growth, but declining since 2004 and, by 2007, the growth became negative (-1.7%). This downward trend was reversed afterwards and, in 2008, it attained a peak of 7.4%, and thereafter experienced a declining trend reaching 0.8% in 2011. A positive steady growth is observed afterwards reaching 5.7% in 2013 and declining again in 2014.

In 2007, crops (without cocoa) and cocoa subsectors experienced negative growths and, from 2008-2011, both experienced a positive growth. Crops (without cocoa) and cocoa subsectors attained impressive growth rates of 10.2% in 2009 and 26.6% in 2010, respectively. However, growth in both subsectors began to decline and by 2012, crops (without cocoa) and cocoa attained 0.8% and -9.5%, respectively. Growth in both subsectors recovered again in 2013 and stayed positive since then. During the entire period under consideration, growth in the livestock subsector has always been positive. An observation that can be made is that there is greater variability and sometimes negative growth associated with crops (without cocoa), cocoa, forestry and fisheries subsectors compared to the livestock subsector. This is because weather and external (movements in world market variables) conditions influence output from crops, cocoa, forestry and fisheries as compared to livestock.

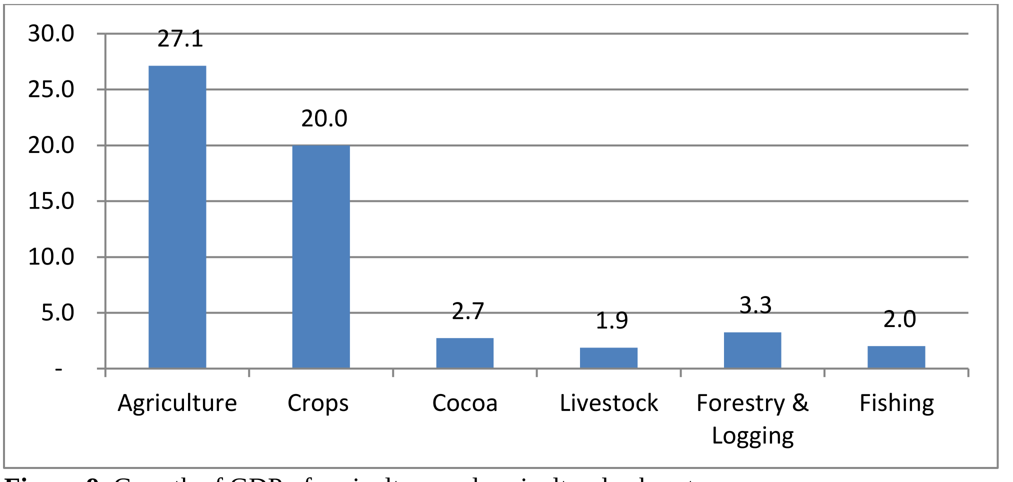

Figure 9. Growth of GDP of agriculture and agricultural subsectors
Source: Adapted from GSS (2015)

Table 8: Annual growth rate of agricultural subsector and national GDP at 2006 constant prices (percent)

Year	*Crops*	*Cocoa*	*Livestock*	*Forestry& Logging*	*Fishing*	*Agricultural GDP*	*National GDP*
2003						6.1	
2004						7.5	
2005						4.5	
2006						4.5	
2007	-1.3	-8.2	4.7	-4.1	-7.2	-1.7	4.3
2008	8.6	3.2	5.1	-3.3	17.4	7.4	9.1
2009	10.2	5.0	4.4	0.7	-5.7	7.2	4.8
2010	5.0	26.6	4.6	10.1	1.5	5.3	7.9
2011	3.7	14.0	5.1	-14.0	-8.7	0.8	14.0
2012	0.8	-9.5	5.2	6.8	9.1	2.3	9.3
2013	5.9	2.6	5.3	4.6	5.7	5.7	7.3
2014	5.7	4.3	5.3	3.8	-5.6	4.6	4.0
Average	4.8	4.8	5.0	0.6	0.8	4.5	7.6

Source: GSS (2015)

Overall, the annual growth rates averaged at 4.5% for agriculture, 4.8% for crops, 4.8% for cocoa, 5.0% for livestock, 0.6% for forestry and logging and 0.8% for fishing (figure 10). It is important to note that growth in the crops (without cocoa) subsector contributes more than 50% to the agricultural GDP growth (Coulombe and Wodon, 2007).

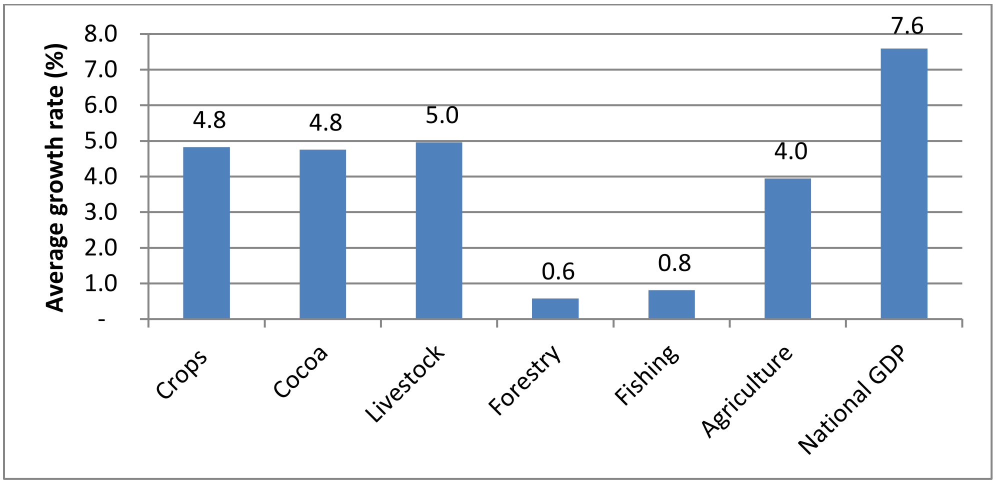

Figure 10. Average growth rates of national, agriculture and agricultural subsectors GDP
Source: GSS (2015)

Figure 11 shows the trends in agricultural sector growth in reference to the targeted annual 6% growth rate. Doing performance analysis in reference to the 6% benchmark set by CAADP, it can be concluded that the impressive growth rates of 6.1%, 7.5%, 7.4%, 7.2% recorded in 2003, 2004, 2008 and 2009, respectively, could not be sustained to achieve the annual target of 6%. In 2007 and 2011, the agricultural sector grew rather abysmally.

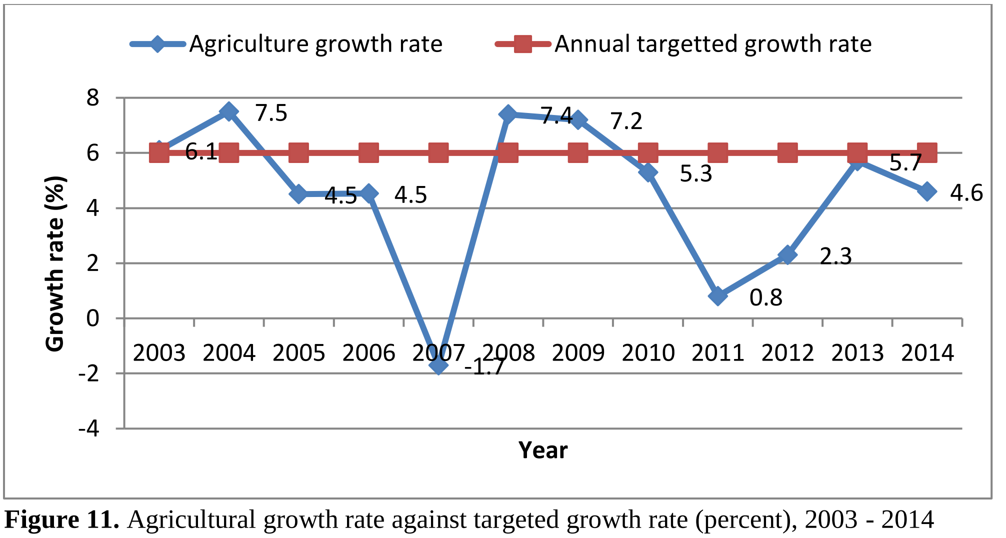

Figure 11. Agricultural growth rate against targeted growth rate (percent), 2003 - 2014
Source: GSS, MoFA/SRID (2013)

Performance of Staple Crops

Table 9 and figure 12 show the annual growth rates of selected crops from 1980 to 2013. Figure 13 shows that the annual growth rates for all the crops have varied, with more pronounced spikes during the 1980s and early 1990s. From the late 1990s onwards, growth trends have been somewhat stable, with minor ups and downs for all crops, except rice that still exhibited major spikes. Cocoa has a relatively small share of the agricultural GDP, of between 8 and 12%, and yet it contributes more than double its size to the agricultural GDP growth. Coulombe and Wodon (2007) estimated that between 1991 and 2006, cocoa contributed 14-28% to agricultural GDP growth. Figure 14 shows that the annual growth rate of the selected crops averages at 9.1% (rice), 11.4% (maize), 4.4% (millet), 5.5% (sorghum), 8% (cassava), 2.4% (cocoyam), 11.5% (yam), 5.7% (plantain) and 4.9% (cocoa).

Trends in the yields of selected crops

The average annual yields of crops are presented in table 10. Figures 14, 15 and 16 show the trends in average annual yields of cereals (rice, maize, millet, and sorghum), starchy staples (cassava, cocoyam, yam, and plantain) and cocoa. Annual yields of all crops have been lowest in the early part the 1980s as a result of the drought and wild fires that caused havoc to crops and forest in 1982 – 1983. Since 1992, rice yield has been rising, but with more variability relative to maize, millet and sorghum, which are somewhat stable. The yields of cassava, yam and plantain have experienced a steady increase since 1990, while that of cocoyam recorded no growth during the same period. In the case of the latter, very little attention is given to its development as cocoyam grows on its own after field preparation. Cocoa yield remained almost flat in the early 1980s, which increased dramatically from 1987 to 1988. It experienced an upward and downward trend and, by 2002, cocoa yield had fallen below the 1990s levels. A rebound can be seen afterwards due to the introduction of technological packages, improved access to credit, cocoa mass spraying exercise, among others, which have translated into productivity increase. Figure 18 shows the average yields of crops under rain-fed conditions and achievable yield under appropriate or farm trial conditions. The figure confirms the known fact that wide gaps exist between observed yields and achievable yields of crops in Ghana.

Table 9. Annual growth rates of selected crops from 1981 to 2013

Year	*Rice*	*Maize*	*Millet*	*Sorghum*	*cassava*	*Cocoyam*	*Yam*	*Plantains*	*Cocoa*
1980	-16.1	0.5	-45.0	-16.5	5.6	-14.2	8.0	-6.4	-1.3
1981	24.4	-1.0	45.1	-0.8	11.2	-1.9	-9.1	12.9	-11.1
1982	-62.9	-8.5	0.8	-3.8	-3.8	-0.5	-0.5	-8.0	-17.8
1983	11.1	-50.3	-5.0	-15.9	-13.0	14.6	47.3	-1.0	-17.0
1984	62.5	304.7	21.9	62.3	27.3	11.1	36.0	63.4	-0.8
1985	23.1	-16.1	-19.4	-15.7	4.5	12.5	-16.2	9.4	16.6
1986	-13.0	-4.3	-1.8	-11.7	25.1	11.7	6.2	-19.4	16.5
1987	15.9	6.9	57.4	60.9	-5.2	0.7	13.1	-0.8	-16.9
1988	17.7	25.6	-19.7	-21.8	21.1	10.2	-23.9	11.3	31.1
1989	-22.4	-4.8	29.5	33.5	0.6	7.6	39.5	-13.3	19.6
1990	9.8	-22.7	-58.6	-36.8	-18.2	-32.1	-30.3	-23.2	-0.6
1991	86.5	68.6	50.9	77.8	109.8	59.1	200.1	47.5	-17.6
1992	-12.9	-21.6	18.6	7.2	-0.7	-7.3	-11.4	-8.2	29.1
1993	19.7	31.5	48.6	26.9	5.5	2.8	16.7	22.1	-18.4
1994	3.1	-2.2	-15.3	-1.3	0.9	-7.1	-37.5	11.6	13.1
1995	24.3	10.0	19.6	11.2	9.7	20.5	25.0	11.0	40.2
1996	6.9	-2.6	-3.7	-1.9	7.6	12.2	7.0	11.4	-0.2
1997	-8.6	-1.2	-25.8	-5.9	-1.6	-1.4	5.9	-0.3	-20.0
1998	-1.8	3.9	19.9	16.5	2.5	3.1	12.3	5.2	26.9
1999	8.3	-1.9	-7.1	-22.0	9.4	8.3	20.2	7.0	6.1
2000	18.6	-0.2	6.0	-7.4	3.3	-4.8	3.5	-5.6	0.6
2001	10.4	-7.4	-20.7	0.0	10.6	3.8	5.5	7.3	-10.8
2002	2.0	49.3	18.4	13.0	8.5	10.2	10.0	9.9	-12.6
2003	-14.7	-8.0	10.4	6.8	5.2	-3.0	-2.2	2.2	45.9
2004	1.3	-10.2	-18.2	-15.0	-4.9	-4.9	2.1	2.2	48.3
2005	18.7	1.2	28.7	6.3	-1.8	-1.7	0.8	17.3	0.4
2006	-12.9	1.5	-10.8	3.3	0.7	-1.5	9.3	3.9	-0.8
2007	-25.9	2.6	-31.5	-50.8	6.0	1.8	2.1	11.5	-16.3
2008	62.9	20.5	71.5	113.8	11.1	-0.1	11.9	3.2	10.8
2009	29.7	10.2	26.7	5.9	7.7	-10.9	18.0	6.7	4.4
2010	25.6	15.6	-10.8	-7.5	10.4	-9.9	3.2	-0.7	-11.1
2011	-5.6	-10.0	-16.0	-11.5	5.5	-4.1	5.6	2.3	10.8
2012	3.7	15.8	-2.3	-2.5	2.2	-2.3	5.5	-1.7	25.6
2013	18.4	-9.5	-13.7	-8.3	9.9	-0.7	6.6	3.3	-5.0
Average	9.1	11.4	4.4	5.5	8.0	2.4	11.5	5.7	4.9

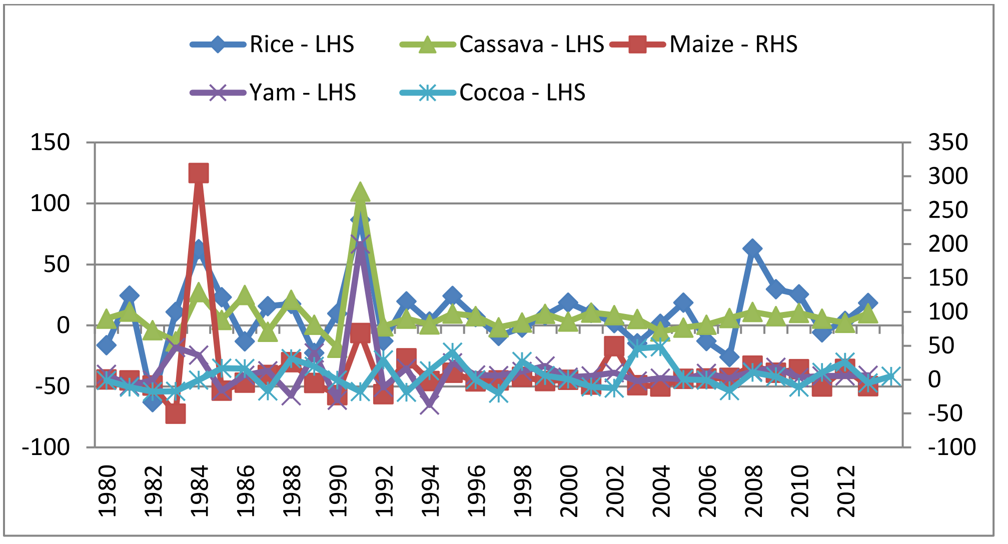

Figure 12. Annual growth rate of selected crops from 1980 to 2013
Source: FAO (2015)

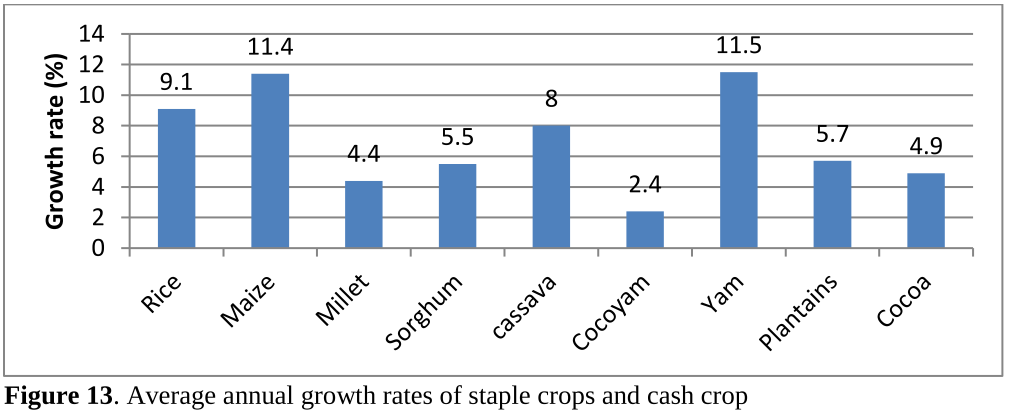

Figure 13. Average annual growth rates of staple crops and cash crop
Source: FAO (2015)

Table 10. Average yields of selected crops from 1980 to 2013

Year	*Rice*	*Maize*	*Millet*	*Sorghum*	*Cassava*	*Cocoyam*	*Yam*	*Plantains*	*Cocoa*
1980	0.8	0.9	0.6	0.5	8.1	4.7	5.8	6.0	0.2
1981	0.8	1.0	0.8	0.7	9.8	4.7	5.1	6.5	0.2
1982	0.6	0.9	0.7	0.6	8.6	4.3	5.3	5.4	0.2
1983	1.0	0.4	0.7	0.5	8.2	6.4	6.1	5.3	0.2
1984	0.9	1.0	0.6	0.7	8.8	2.0	5.3	5.3	0.2
1985	1.2	1.0	0.6	0.7	7.9	2.8	5.5	5.1	0.2
1986	0.9	1.2	0.7	0.7	7.4	4.9	5.9	5.7	0.2
1987	1.1	1.1	0.7	0.8	7.0	5.2	5.8	5.7	0.3
1988	1.8	1.4	0.6	0.7	7.4	7.9	5.4	5.7	0.3
1989	1.0	1.3	0.7	0.8	7.4	5.8	5.8	5.7	0.4
1990	1.7	1.2	0.6	0.6	8.4	5.8	7.3	6.2	0.4
1991	1.6	1.5	0.5	0.9	10.7	6.4	11.6	6.8	0.3
1992	1.6	1.2	0.6	0.8	10.3	6.1	10.4	6.9	0.4
1993	2.0	1.5	1.0	1.1	11.2	7.1	13.2	8.0	0.4
1994	2.0	1.5	0.9	1.1	11.6	6.4	11.0	8.0	0.4
1995	2.0	1.5	1.0	1.1	12.0	6.8	12.1	7.7	0.4
1996	2.0	1.5	1.0	1.1	12.0	7.3	12.8	8.0	0.4
1997	1.7	1.5	0.8	1.0	11.9	7.4	12.8	8.1	0.3
1998	1.5	1.5	1.0	1.2	11.4	7.2	12.8	7.8	0.3
1999	2.0	1.5	0.9	1.0	12.3	6.9	13.4	8.1	0.3
2000	2.2	1.5	0.8	1.0	12.3	6.6	12.9	7.9	0.3
2001	2.0	1.3	0.7	0.8	12.3	6.4	12.3	7.8	0.3
2002	2.3	1.5	0.8	0.9	12.2	6.6	13.0	8.2	0.3
2003	2.0	1.6	0.9	1.0	12.7	6.5	11.9	8.1	0.3
2004	2.0	1.6	0.8	1.0	12.4	6.4	12.5	8.5	0.4
2005	2.4	1.6	1.0	1.0	12.8	6.6	10.8	9.6	0.4
2006	2.0	1.5	0.8	1.0	12.2	6.4	13.2	9.7	0.4
2007	1.7	1.5	0.7	0.7	12.8	7.1	13.5	10.6	0.4
2008	2.3	1.7	1.1	1.2	13.5	6.7	14.1	10.7	0.4
2009	2.4	1.7	1.3	1.3	13.8	6.7	15.3	11.0	0.4
2010	2.7	1.9	1.2	1.3	15.4	6.6	15.5	10.8	0.4
2011	2.3	1.6	1.0	1.2	16.0	6.4	15.6	10.8	0.4
2012	2.5	1.9	1.0	1.2	16.7	6.5	15.6	10.5	0.5
2013	2.6	1.7	1.0	1.1	18.3	6.5	16.8	10.8	0.5
Average	1.8	1.4	0.8	0.9	11.4	6.1	10.8	7.9	0.3

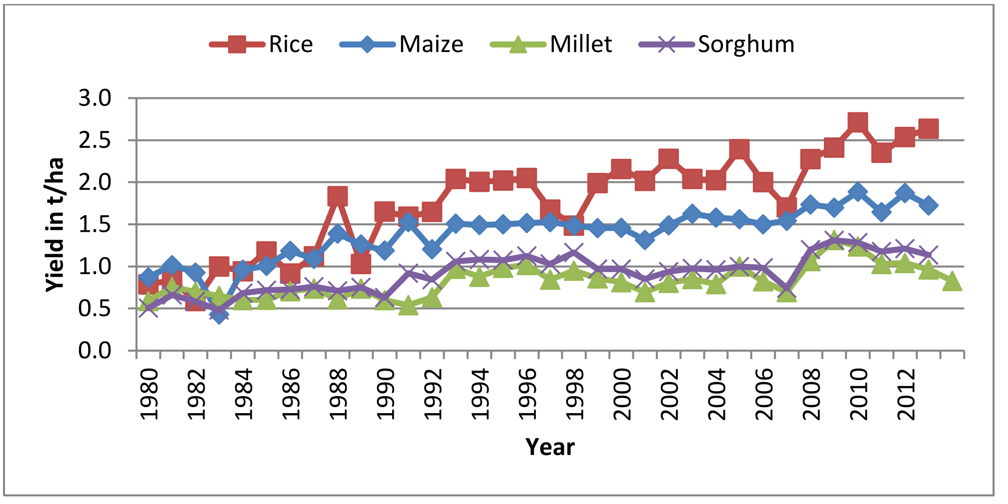

Figure 14. Average yield of selected cereals in Ghana from 1980 to 2013
Source: FAO (2015)

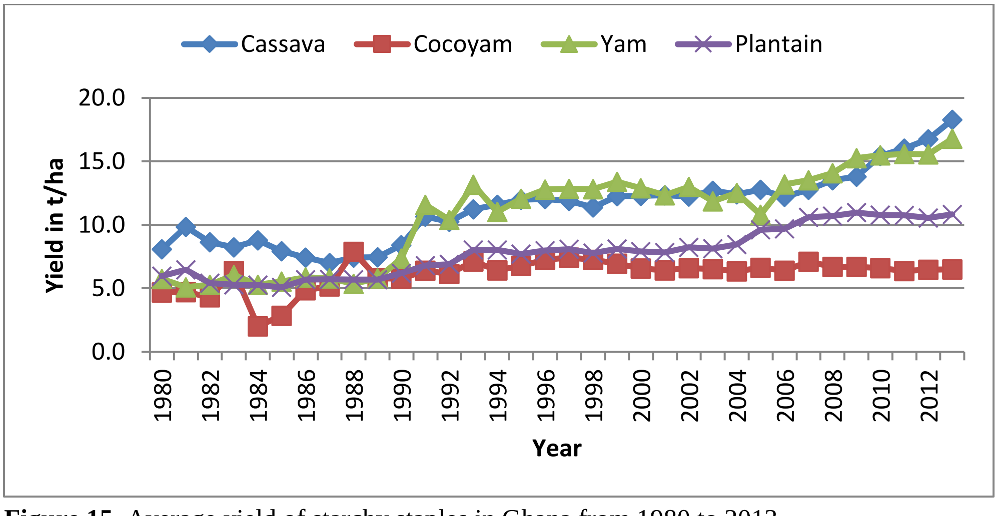

Figure 15. Average yield of starchy staples in Ghana from 1980 to 2013
Source: FAOSTAT, 2013

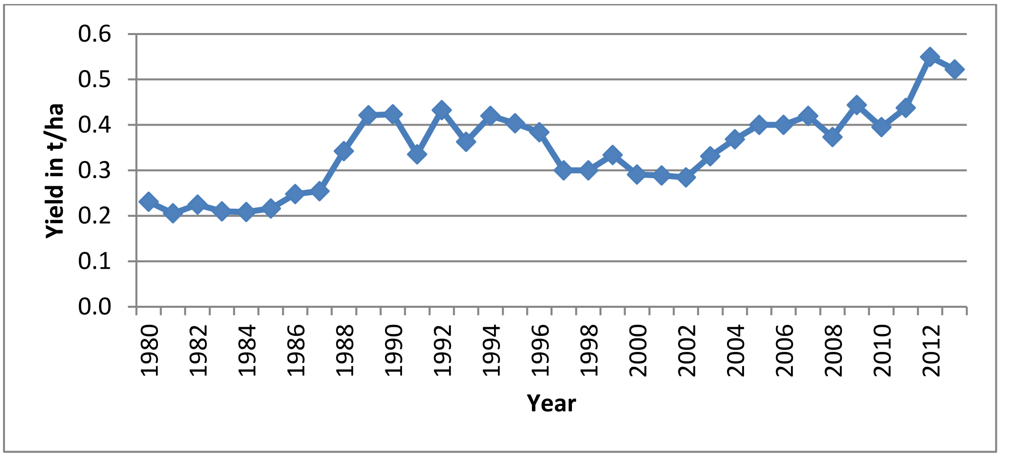

Figure 16. Yield of the major foreign exchange crop (cocoa) in Ghana from 1980 to 2013
Source: FAOSTAT, 2013

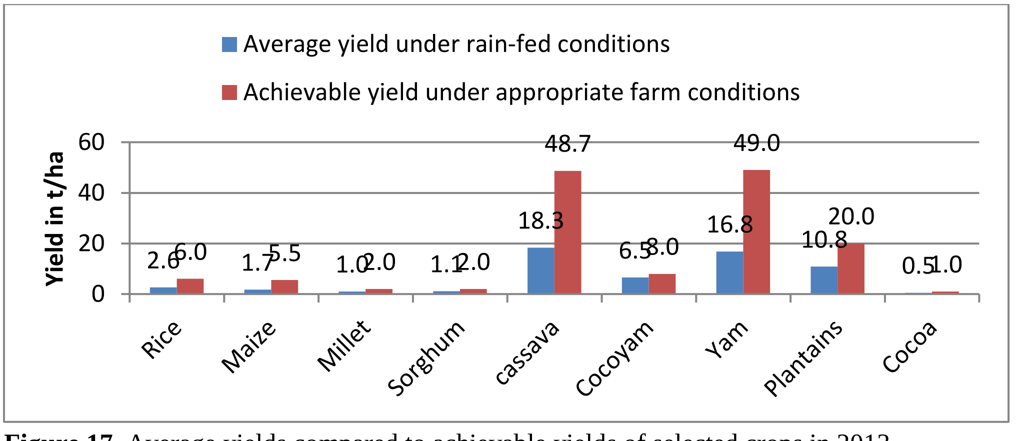

Figure 17. Average yields compared to achievable yields of selected crops in 2013
Source: SRID/MoFA, 2013

Trends in production of selected crops

Table 11 and figure 18 show the production of selected crops (three year averages) and trends in production of rice, maize, cocoa, cassava and yam. Figure 18 shows the rapid growth in the production of rice, maize, cocoa, cassava and yam, following the sluggish growth between 1981 and 1984.

Table 11. Production of selected crops (000Mt), three year averages for 1981 to 2013

Years	Rice	Maize	Millet	Sorghum	Cassava	Cocoyam	Yam	Plantains	Cocoa
1981-1983	57.7	298.7	117.7	121.0	1926.3	659.7	681.7	782.3	205.7
1984-1986	71.5	613.0	120.3	148.3	2458.7	901.7	1071.0	1223.8	195.8
1987-1989	83.1	687.9	164.0	194.0	3115.3	1108.9	1115.1	1106.2	243.3
1990-1992	121.1	738.2	106.7	212.0	4693.5	1104.7	1946.8	1019.8	282.4
1993-1995	173.8	978.4	188.9	337.4	6203.0	1255.5	2182.0	1477.9	315.5
1996-1998	202.1	1012.7	169.6	357.8	7094.1	1552.8	2461.9	1851.5	378.3
1999-2001	244.3	988.4	154.5	287.2	8306.0	1673.3	3386.2	2017.5	420.1
2002-2004	253.5	1282.1	159.6	313.6	9903.1	1793.6	3868.4	2329.4	524.9
2005-2007	240.8	1193.2	154.3	258.3	9807.6	1678.7	4195.7	2975.3	696.2
2008-2010	395.0	1653.8	219.4	335.3	12361.9	1515.7	5544.4	3479.3	674.5
2011-2013	504.9	1799.5	172.9	274.6	14926.0	1277.1	6669.6	3617.2	804.9

Source: FAO (2015)

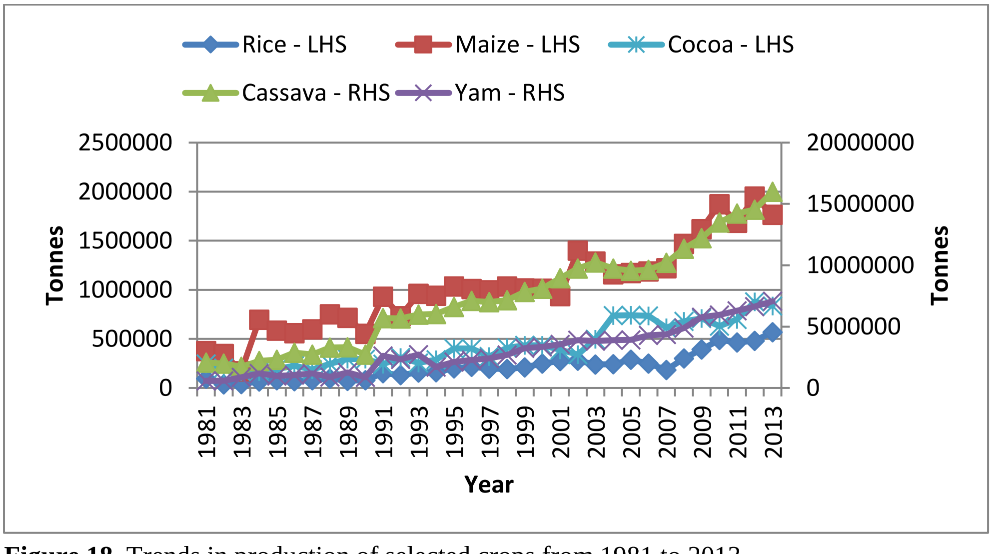

Figure 18. Trends in production of selected crops from 1981 to 2013
Source: FAO (2014)

Sources of growth in the agricultural sector

The agricultural sector is dominated by the crops and cocoa subsectors, which also drive more than 50 percent of the growth of the agricultural GDP. During 2007 – 2014, the crops and cocoa subsectors both grew at 4.8% each per annum, while agriculture grew at 4% per annum. Moreover, available data, as shown in figure 14, indicate that wide gaps exist between observed and achievable yields for all the crops we have examined. Growth in agricultural commodities (crop output), which translates into growth of agriculture and subsectors, emanates from two sources: area expansion and productivity increase. Which of them accounts for the output, sub-sectors and agricultural growths recorded over the years? An attempt is made to identify the sources of growth in agricultural commodities which translate into growth of the sub-sectors and agricultural sector. We applied the method used in a *Nigerian report* to compute the percentage contribution to observed production of each crop by area and yield, defined as:

$$Area(\%) = \frac{[\log(Area2011/2013) - \log(Area2004/2006)]}{[\log(Prod2011/2013) - \log(Prod2004/2006)]} \times 100$$

This implies that $Yield(\%) = 100 - Area(\%)$. Therefore, the expression for yield becomes:

$$Yield(\%) = 100 - \left\{ \frac{[\log(Area2011/2013) - \log(Area2004/2006)]}{[\log(Prod2011/2013) - \log(Prod2004/2006)]} \times 100 \right\}$$

Table 12 shows the results of the contribution of area and yield to observed output between 2004/2006 and 2011/2013 at the national level. The results show that area expansion contributes more to the growth trends reported, while productivity increase contributes less for rice, maize, sorghum, cocoyam and plantain. However, growth in production due to productivity increase was observed for cassava, yam and cocoa. Area expansion accounts for 100% of the growth in cocoyam output because in Ghana little or no attention is given to the development of this crop as it sprouts following the rains after field preparation. These results provide evidence to support calls and recommendations by scientists to close the yield gap through R&D tailored at developing innovations and effective extension service that connects innovators or innovations to the farmers. This way the untapped potential in agriculture will yield maximum benefits to stakeholders in the agricultural sector.

Table 12. Contribution of area and yield to observed production between 2004/2006 and 2011/2013

	Rice	Maize	Millet	Sorghum	Cassava	Yam	Cocoyam	Plantain	Cocoa
Area (%)	68.8	72.3	-215.1	288.2	28.61	24.3	100.0	51.5	-57.3
Yield (%)	31.2	27.7	315.1	-188.2	71.39	75.7	0.0	48.5	157.3

Source: Computed using figures from SRID/MoFA, 2009 and 2013.
Note: Area in ha; yield in t/ha and production in Mt.

IMPACTS OF AGRICULTURAL RESEARCH IN GHANA

Impact analysis at the micro-level

Technology adopters are influenced by socio-economic, intuitional and technical factors of whether or not to accept the new technology. Adoption of improved agricultural innovations is expected to enhance performance of an enterprise by increasing productivity and income (Wiredu et al., 2010). Quite a number of improved agricultural technologies are available, yet yield levels of crops are far below their potentials.

Evidence of technology adoption

Under this section, we provide evidence of some selected technologies and their respective adoption rates using previous studies on technology adoption. Table 13 shows the rate of adoption for selected innovations. It is important to note that the authors of the papers reviewed used different methods for calculating the rates of adoption. The rates of adoption were calculated based on either the area allocated with the improved variety or the proportion of adopters adopting the technology. Again, the sample size and location of the study differ among the studies reviewed. Rice (Jasmine) has an adoption rate of 53%. Others have adoption rates at or above 40%, including rice (NARS) with an adoption rate of 41.3%, maize (Obatanpa) with an adoption rate of 41%, improved sorghum variety with an adoption of 40%, yam (Yam Minisett Technology) with an adoption rate of 43.9% and cocoa (CRIG's production technology) with an adoption rate of 44%. Cassava (Abasafitaa) innovation has the lowest rate of adoption of about 5.1%. The low estimates for adoption rate for this crop indicate that either farmers were not aware, have no access to these technologies or they simply prefer to use the traditional varieties. The role of agricultural extension agents will play critical role in this regard. Since these estimates are case study-based, sweeping generalizations cannot be made for the whole country. However, according to Ragasa et al. (2013), in terms of maize hybrid adoption, Ghana lags far behind some of its African counterparts (for example, Zambia, Kenya and Zimbabwe with 90% adoption rates as against 3% in Ghana).

Table 13. Evidence of technology adoption in Ghana

Name of commodity	*Name of innovation*	*Adoption rate (%)*
Rice	NERICA	36.7
Rice	NARS	41.3
Rice irrigated	Jasmine 85	53.0
Rice irrigated	Togo Marshall	20.0
Rice irrigated	GRUG7	25.0
Rice irrigated	Sikamo	20.0
Rice upland	Jasmine	37.0
Rice upland	Digang	13.0
Rice lowland	Togo Marshall	25.0
Rice lowland	Mandii	25.0
Rice lowland	GR 18	15.0
Maize	Obatanpa	41.0
Sorghum	Improved variety	40.0
Cassava	Bankyehemaa	10.9
Cassava	Bankyeafisiafi	12.2
Cassava	Abasafitaaa	5.6
Yam	Yam Minisett Technology	43.9
Cocoa	Hybrid variety	44.0

Estimating the impact of technology adoption on income

Because of data unavailability, we resorted to the literature to provide estimates of the impact of innovation adoption on the income of households. The methods for generating the estimates however differ across the papers reviewed. In the case of cassava, a non-parametric propensity score matching (PSM) technique was employed to examine the impact of adopting improved cassava varieties on farmers' incomes (Acheampong and Owusu, 2015). In the case of maize, benefit–cost–ratio computation was done to assess the profitability of hybrid maize and Obatanpa (Ragasa et al., 2013). In the case of rice, the local average treatment effect (LATE) estimation method was used to estimate the impact of adopting NERICA rice on household incomes in northern Ghana (Wiredu et al., 2014). Table 14 shows some estimated results of the impact of technology adoption on household income. Adopting Obatanpa maize results in an additional income of GHS 545 per hectare or 56% of profits. In the case of cassava growers, and focusing on the average treatment effect (ATT), the outcome of adopting improved cassava varieties results in increased total crop income of farmers by GHS 1502 per hectare. Women adopters benefitted more from the adoption of improved maize variety, with an increase in total crop income by GHS 3173, while total crop income of men increased by GHS 149. Thus, the finding supports the fact that women tend to rely especially on food crop production for their livelihoods (Acheampong and Owusu, 2015). In the case of rice, adopting NERICA increased rice income by GHS 383.2 and agricultural income by GH₵ 870.4.These findings strongly confirm the fact that adoption of these technologies has improved the welfare of adopters.

Table 14. Impact of technology adoption on household income

Technology domain	Name of commodity	Name of technology	Benefits of technology adoption (in ₵)
Crop	Maize	Obatanpa	Adoption increases famers income by GHS 545 per ha or 56 percent of profit
Crop	Cassava	Improved, no distinction made	ATT: adoption increases total crop income by GHS 1502; ATE: adoption increases total crop income by GHS 1558.2. Disaggregation of farmers into men and women: ATT: adoption increases total crop income of women by GHS 3173 and men by GHS 149; ATE: adoption increases total crop income of women by GHS 3327.5 and men by GHS 98.9
Crop	Rice	NERICA	Adoption increased rice income by GHS 383.2 and agricultural income by GHS 870.4

Source: Acheampong and Owusu (2015), Ragasa et al. (2013), Wiredu et al. (2014)

Note: The values for NERICA rice were given in US$ by the authors, we used the exchange rate of GHS 1.95 per US$ 1 as at 2013. ATE: average treatment effect and it refers to estimates for the full sample (that is adopters and non – adopters); ATT (also LATE) is the average treatment effect on the treated and it refers to estimates for the adopters only.

Effects of agricultural innovation on household assets

Table 15 presents the effects of agricultural innovation on household assets. The adopters of the cocoa high technology programme reported an increase in their physical capital such as sprayers, pruners and harvesters. They were also able to increase their financial as well as human capital base.

Table 15. The effects of agricultural technology on household assets/livelihoods

Name of commodity	*Name of innovation*	*Effects of innovation on assets/livelihoods*
Cocoa	CHTP – Cocoa high technology programme	Adoption improved farmers' natural capital (productivity, high quality beans); Adoption increased farmers' physical capital (sprayers, pruners, harvesters); Adoption increased farmers' financial capital and improved their social capital (access to skilled and unskilled labour, extension), and human capital (pay school fees, support family and friends).

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APPENDICES

Agricultural technologies developed in Ghana from 1995-2015

	Name Technology/Innovation	*Brief Description of technology*	*Current dissemination method*	*Year technology was developed*	*Institutions that developed the tech*
	IMPROVED AGRONOMIC PRACTICES				
	Development of improved agronomic practices for maize and legumes	The practices have helped farmers manage crop residue and improve the environment through better fertilizer management	Disseminated through training	1997	CSIR-CRI
	Bud manipulation technology in plantain and banana	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.		2001-2006	CSIR-CRI
	Grafting of nutmeg	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.		2001-2006	PGRRI
	Minisett technology for yam production	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.		2001-2006	CSIR-CRI
	Optimum date of planting, plant population and fertilization of soybean	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 P2O5 per ha		2001-2006	SARI
	Timing and frequency of weeding	The technology involves weeding in the 3 weeks after sowing (21 days after planting) to coincide with fertilizer application. If land preparation		2001-2006	CRI

		is done well, weeding would be done once followed by hand removal of only a few weeds.			
	Under-cropping oil palm with cocoa	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)		2001-2006	OPRI
	Agronomic recommendation for seed maize production	The technology involves three sets of farm management recommendations: the use of modern varieties, planting in rows, and appropriate application of fertilizer.			CRI
	Coconut/food crop intercrop	It is a cultural practice that integrates food crop (e.g. cassava, maize) into coconut farms. It leads to effective weed control, enhances efficient nutrient uptake and provides income for sustaining farmers livelihood before coconut matures.		2001-2006	CSIR-OPRI
	Cotton-cowpea relay intercrop	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.		2001-2006	CSIR-SARI
	Mucuna and canavalia (leguminous cover crops) for sustainable maize production	This is a cultural practice for maize production involving planting either Canavalia four weeks after sowing maize or mucuna eight weeks after sowing maize as cover crop and growing maize in the dead canavalia or mucuna mulch the following major season for increased maize yields		2001-2006	CSIR-FORIG
	Oil palm intercropped with rice	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.	Field trails were conducted in the Volta Region, Extension officers have been trained. Farmers showed high level of enthusiasm	2002	CSIR-OPRI
	Procedures for production of healthy citrus seedlings	Procedural steps developed and published in a book to serve as a reference for farmers.		2001-2006	CRI

	Gliricidia sepium for sustainable plantain production.	The technology is a cultural practice for plantain production involving planting the plantain in alleys formed by Gliricidia with pruning from Gliricidia serving as mulch. Gliricidia trees serve as wind breaks; its mulch suppresses weeds while the decomposed leaves improves soil nitrogen status.		2001-2006	CSIR-FORIG
	WATER AND IRRIGATION-RELATED TECHNOLOGIES				
	Simple water control strategies for rice cultivation	The innovation is aimed at effectively harvesting water rich in plant nutrients through its passage from the hilly side to irrigate rice fields. It is designed to help reduce the cost of applying chemical fertilizer to rice fields. The major requirement is for the rice field to be cited in a valley or bottom of a sloping hill.	Transferred to to a considerable number of rice farmers throughout the country	1990; 2001-2006-improvements	CSIR-WRI
	Simple water control structures (earth bunds) dyke to harvest stream water for irrigation	A temporary dyke is constructed with bags of sand supported by wood stakes close to a stream, which allows water to be impounded for irrigation. It is less expensive, can be used to harvest runoff from roadsides, settlements, perennial streams and can be used by farmers who rend land		2001-2006	CSIR-SRI
	Standardized Roof Rainwater Harvesting (RWH) Technology	Roof rainwater harvesting (RWH) is the capturing of rainfall from roof surfaces and storing the collected water for use in households, schools and other private and public institutions. RWH systems can be constructed in a multitude of ways. However, the standardized systems have been developed to provide water of good quality after days, weeks and months of storage required between rains and to be environmentally, economically and socially sustainable over time. The technology has been designed based on standardized criteria that offer affordable, appropriate, and cost-effective RWH solutions, including water filtration and disinfection, for safe urban, peri-urban and rural water supply. Standardization included selection and specification of the sizes and quality of the materials for rain collectors (roof and rain gutters), down pipes and other piping components, storage tanks, cleaning and	Through seminars, workshops and field demonstrations with a wide variety of stakeholders	2013	CSIR-WRI

		disinfection methods and materials and water abstraction or distribution components.			
	Improved Small Scale Irrigation Technology At Anon River Valley in Ashanti Region	The technology entails the construction of improved small-scale irrigation systems after studying the unique properties of the soil material for gulley erosion control. It has a special characteristic to impound and control the flow of water.	Transfer has been done and MOFA, CSIR-SRI, ADRA and Ricerca et-cooperation were involved	1994 but with subsequent improvements	CSIR-SRI
	Improved rainwater productivity	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.			SARI
	PEST & DISEASE MANAGEMENT TECHNOLOGIES				
	Selective use of insecticide for oil palm leaf miner control	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.	Transfer done by CSIR-OPRI. Adoption rate is high among commercial farmers but low among small-scale oil palm farmers	1996	CSIR-OPRI
	Bio-control of Striga hermonthica with soybean	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.	Dissemination has been done but adoption rate is low.	2003	Crop Science Department, Faculty of Agriculture, University of Development Studies, Tamale
	Early warning system for the control of oil palm leaf miner	The technology involves the early detection of warning signs or symptoms and employing non-chemical and environmental friendly means of curtailing the spread.	Promotion and publicity on the innovation has	2001-2006	CSIR-OPRI

			been low. Some has been done through durbars, seminars and MOFA training modules		
	Field management of the banana weevil	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: • 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	Transfer has been done through on-farm demonstrations with the help of MOFA extension staff. Dissemination is 50% done	2001-2006	CSIR-CRI
	Integrated pest management in Groundnut	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.	Dissemination done through participatory farmer field schools.	1997	CSIR-CRI
	Improved production of groundnut through deployment of IPM practices	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.			CSIR-SARI
	Integrated pests and disease management in onions	It involves the development of appropriate disease and pest control techniques for onions			CSIR-PGRRI
	Integrated Practices to control Pests and Disease of Citrus in Ghana.	Improves citrus productivity and solves the problem of indiscriminate use of insecticide in citrus production.	Manuals have been produce to facilitate dissemination and adoption. MOFA and		CSIR-CRI

			Citrus Growers Association are involved		
	IPM for control of sorghum head bugs	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.	Dissemination done by MOFA through field trials and demonstrations	2002	CSIR-SARI
	IPM package for controlling pests and diseases of cowpea	The technology is an integrated crop production and pest management strategy for cowpea, It 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.		2001-2006	Department of Crop Science, Faculty of Agriculture, KNUST, Kumasi.
	Management of Oryctes (beetle) in young coconut palms	The technology involves the use of old fishing nets to control Oryctes in young coconut palms. The technology is low cost, hazard-free, environmentally safe and easy to use.		2001-2006	CSIR-OPRI
	Management of the Cape St. Paul Wilt Disease (CSPWD) in disease endemic areas	It is a cultural practice that slows down the spread of Cape St. Paul Wilt Disease in endemic areas thereby prolonging the productive life of coconut farms. It is environmentally friendly and easy to use.		2001-2006	CSIR-OPRI
	Scouting system for managing bollworms on cotton	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.		2001-2006	SARI
	Field management of plantain nematodes using *Pueraria phaseoloides* cover crop	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.			CRI

	Neem-incorporated management strategy as an insecticide for cowpea pest	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.			SARI
	Plant-derived insecticide	Neem and jatropha are mixed together to form an insecticide for use on cereal, grain, and vegetable crops.			FORIG
WEED CONTROL TECHNOLOGIES					
	Round-up mixed with three types of salts (Common salt, ammonium sulphate and Urea) for weed control in oil palm farms.	A mixture of (i) sodium chloride, (ii) ammonium sulphate, and (iii) urea is used for weed control in oil palm farms. It reduces costs of chemical weed control, provides longer weed-free period (at least 3 months) and is environmentally friendly		2001-2006	CSIR-OPRI
	Knapsack spray shield for herbicide weed control in field crops	It is a knapsack spray in the form of a right angled triangle. It uses drift reduction off-centre nozzle during operation. It is easier and convenient to use. The shield is used to apply broad-spectrum herbicides to control inter-row weeds in row crops. Very low rate of herbicide is applied, about 1.5 litres product/ha	Following on farm demonstrations and training some farmers have adopted the technology		CSRI-CRI
	Herbicide use and efficacy in oil palm	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.			OPRI
SOIL FERTILITY MANAGEMENT TECHNOLOGIES					
	Organic and inorganic fertilizer recommendation for pawpaw	It is an agronomic practice that combines organic and inorganic fertilizers for pawpaw production. The technology the per-unit cost of production as well as environmental hazards and is compatible farming systems.		2001-2006	Department of Crop Science, Faculty of Agriculture, University of Ghana, Legon

	Organic and inorganic fertilizer recommendation for Yardlong bean	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.		2001-2006	Department of Crop Science, University of Ghana, LEGON
	Organic fertilizer rates for citrus farms	Organic fertilizer recommendation for matured citrus trees based upon deep litter from poultry (layer) farms	Extension support services, Farmer Field Schools, Production guides		CSIR-CRI
	Organic Fertilizer recommendations for pawpaw	The technology is an organic approach to fruit production. It has been existence for a long time but has been repackaged and re-introduced for use in fruit and vegetable production	Done through workshops, publications and fact sheets. CSIR and MOFA are involved.	2001-2006	Crop Science Department. University of Ghana
	Appropriate fertilizer recommendations for oil palm intercropped with food crops	The technology is an improvement of an existing farming practice of intercropping oil palm with food crops. It provides optimum rates of applications of different fertilizers for food crops intercropped with oil palm. It is a fertilizer management strategy for increased food crop and oil pam production.	Demonstration done only at farmer field school. But dissemination rate has been very low	2002	CSIR-OPRI
	Blended fertilizer for maize	It is an updated fertilizer recommendation which has been formulated for maize production specifically to supply nitrogen, phosphorus, potassium, sodium, magnesium and boron. The advantage of the technology is that farmers no longer have to weigh and mix straight fertilizer materials.	CSIR-SSRI, CSIR-CRI and MOFA are doing the dissemination but it is at a slow pace due to lack of funds	2001-2006	CSIR-SRI

	Inorganic fertilizer rates for citrus	This is a specially formulated inorganic fertilizer rate for optimum yields of young bearing citrus (7-9 years old) in the semi-deciduous forest region of Ghana	Extension support services, Farmer Field Schools, Production guides	2001-2006	CSIR-CRI
	Integrated soil fertility management technology for maize production.	It is a cultural practice for maize production in the savanna ecological zone involving planting Calapogonium cover crop one week after planting maize. This helps maintain excellent levels of soil organic matter, reduces weed growth, soil degradation and inorganic fertilizer requirements.		2001-2006	CSIR-SARI
	Oil palm food crop fertilizer management strategy	The technology is a fertilizer application and management strategy developed to maximize yield of oil palm intercropped with food crops.			OPRI
	Identification of soil suitable for economical oil palm production	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.			OPRI
	Improved fallow systems for soil fertility maintenance	The technology addresses low soil fertility due to N deficiency, high cost of purchasing inorganic fertilizer, environmental pollution, and issues of releasing carboninto 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.			SRI
	Management of acid soil	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.			SRI

		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.			
	Rate and timing of N fertilizer application for improved production	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.			CRI
	Rock phosphate recapitalization: A phosphorous fertilizer for matured oil palm in the semi-deciduous forest zone of Ghana	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.			SRI
	Sawah technology: for lowland rice production (effective land, water and nutrient management)	Seeks to improve lowland rice production in Ghana through effective management of land, water and nutrients.			SRI
	Soil database and information bank ion	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			SRI

		development of appropriate soil management interventions for agriculture, forestry, and general land use planning.			
	Geo-spatial modeling for agro-ecological assessment	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.			SRI
	Soil, plant, water, and fertilizer testing calibration/correlate	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.			SRI
	Use of crotalaria/ calopegenium with rock phosphate for improved soil fertility	Developed to improve soil nutrient by using a leguminous plant for a short period of fallow coupled with the use of rock phosphate.			SARI
	Sediment filter technology	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.			SRI
	Sesbania and mimosa for sustainable rice production	The technology involves the use of green manure for irrigated rice cultivation. It improves both the physical quality and fertility of the soil and thus enhances the cultivation of various crops. Sesbania and mimosa are grown in the area intended for rice cultivation and at the time of flowering, they are ploughed and mixed with the soil. Planting of rice is done after two weeks and the plants decompose and serve as		2001-2006	Agricultural Research Centre, University of Ghana, Kpong

		manure for rice. The technology is cheap and can be used for the cultivation of other crops.			
	Utilization of Azolla as manure in lowland rice cultivation on the Vertisols of the Accra Plains	It involves the development of techniques in which Azolla could be used as green manure in rice fields. Azolla is a fern that grows on the surface of water in ponds and other water bodies. It fixes nitrogen through symbiotic association with *anabaena azollae* (alga) and in this way Azolla provides nitrogen to the rice crop. Azolla serves as the host plant while the alga fixes nitrogen using atmospheric nitrogen. The Azolla grows profusely and adds organic matter to the soil. It also has the property of rejuvenating both the physical and chemical properties of the soil.	Demonstrations done at farmers' forum. Involvement of MOFA has been minimal	2001-2006	Agricultural Research Centre, Kpong, University of Ghana
	LIVESTOCK-RELATED TECHNOLOGIES				
	Controlling round worms in sheep and cattle	The technology was first developed in 1995 but has been improved continuously to take care of wide spectrum of round worms and identify worm types that are of pathogenic importance. Calves are given suitable drugs to de-worm them 4-6 weeks after birth. This reduces costs of mortality by 60-80%, improves growth performance and prevents stunted growth.	Dissemination done through the Research-Extension Linkages Committees of MOFA	1995; 2001-2006	CSIR-ARI
	Ensiled Brewer's Spent Malt for Pig feeding	Fresh Brewers Spent Grain (BSG) ensiled and used as protein component of pig diets for improved productivity. Higher levels of ensiled BSG are included as compared to dried BSG thus reducing cost of feeding. Ensiling makes most nutrients of the BSG available to pigs. The technology offers a better method of preservation and is effective all year round, including rainy seasons. The shelf-life of BSGis enhanced and mould infestation is prevented.	Not yet started due to lack of funds		CSIR-ARI
	Ensiled whole cassava for pig feeding	Freshly grounded whole cassava ensiled and used as energy component of pig diet for improved productivity. Has advantage over existing method of sun-dried cassava. The technology reduces level of hydrocyanic acid in cassava to safe levels for pig feeding.	Not yet started due to lack of funds		CSIR-ARI
	Feed pellets for grasscutter	Carefully selected locally available feed ingredients are processed into meal, and formulated into balanced diets; mixed and pelletized. The feed pellets are relatively cheaper, highly digestible and acceptable to	The technology is disseminated through	2001-2006	CSIR-ARI

		grasscutters. The technology ensures wholesome delivery and increased utilization of feed; reduces wastage and ensures sustainable supply of feed. Provides balanced diets; prevents ingredient selection and ensures improved animal performance while reducing production cost. Pellets are easy to handle and have comparatively longer shelf life.	training of grasscutter farmers' Associations, MoFA Extension support services and On-station demonstrations.		
	Feeding package for growing finisher cattle	The innovation involves a feeding programme for producing beef cattle over a short period (11-18 months) using weaner calves. It saves time, results in juicy tender beef cattle and slaughter weights are attained faster (30 months)		2001-2006	CSIR-ARI
	Formulated concentrate for dairy cattle	It involves the formulation of dry mash feed used to supplement grazing cattle. The feed is compounded using agro-industrial by-products. It results in increase in milk yield by 40%, enhanced growth rates and increased profitability.		2001-2006	CSIR-ARI
	Formulated feed for grasscutter	The feed is formulated based on usual feedstuff that replace fodder for feeding grasscutter. Locally available agro-industrial by-products are used in the formulation. This innovation results in reduction in the transportation and drudgery of ‘cut and carry’, reduction in slaughter age by 50%, and it enables grasscutter rearing in urban areas.		2001-2006	CSIR-ARI
	Husbandry package for small ruminant production	It involves the use of leguminous fodder crops – Gliricidia sepium and Cajanus cultivated near human settlements as fodder banks, harvested and fed as supplement to sheep and goats towards the end of dry season and 2-3 times during the rainy season. It provides livestock with good quality fodder throughout the year, serves as a protein supplement to complement the carbohydrate in cassava peels, reduces mortality by 70% and increases growth rate by 30%.	Done through MOFA	2001-2006	CSIR-ARI
	Practical suckling pig feed	It is a balanced formulated feed in which agro-industrial by-products completely replace maize. These by-products include copra cake, palm kernel cake, coconut chaff, cassava peels, cocoa pod husks, maize bran,		2001-2006	CSIR-ARI

		wheat bran, rice bran, spent malt and *pito* mash. It is cheaper and results in pigs growing faster.			
	Practical weaning pig feed	It is a balanced formulated feed in which agro-industrial by-products completely replace maize. It is cheaper and results in pigs growing faster.		2001-2006	CSIR-ARI
	Parasite control package for small ruminants	It involves administration of coccidiostat and dewormers to the lamb and kids. This results in reduced kids/lamb mortality by at least 60%, less drug use and increased profitability.		2001-2006	CSIR-ARI
	Evaluated pasture for animals: drought-tolerant plant species and nutrient value	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.			ARI
	Use of sugarcane as a vehicle for administrating anthelmintics in grasscutters	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			ARI
	Improved feed packages and housing for small ruminant production	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.			ARI
	DNA technology for plant identification	The development of this technology was in response to the lack of technology for diagnosing biological poisoning in livestock.			ARI
	Pelletized feed for domestic grasscutter	Developed to relieve grasscutter farmers from the drudgery of feeding their animals and also enabled faster growth of grasscutters.			ARI

	Local mineral saltlick block	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.			ARI
	Grower-finisher diets using agro-industrial by-products (especially palm kernel cake).	It is a well-balanced grower-finisher diet prepared using agro-industrial by-products for weaner pigs until market weight. This can completely replace cereal based diets. The innovation is cheaper than commercial diets and results in faster achievement of slaughter weight.		2001-2006	Department of Animal Science, Faculty of Agriculture, KNUST, Kumasi Non-ruminants.
	ARIPEED	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, pito mash, 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.			ARI
	Simple on farm fodder conservation	The technology involves the conservation of fodder as silage in shallow pits for off-season feeding of ruminants (cattle, sheep, goats). It is simple, economical, does not require heavy machinery and provides feed all year round.		2001-2006	CSIR-ARI
	Technology for Snail Farming	The technology is a set of management practices that include identifying suitable species, choosing a site, constructing a snailery	Disseminated through		CSIR-FORIG

		(hutch boxes, etc.), feeding and breeding practices, and more. It further stipulates the feeding and breeding habits, site selection and housing of the species and effective methods for snail rearing. The technology encourages profitable snail rearing.	training of extension officers, Agriculture Science teachers, farmers, church groups, rural forest communities and individuals. The technology has been integrated into many rural development programmes as an alternative livelihood		
	POULTRY-RELATED TECHNOLOGIES				
	A single stage broiler diet.	It is a 21% crude protein balanced diet fed as sole diet to broilers. This decreases cost per kg feed, reduces cost/kg live weight gain and gives good final body weight.		2001-2006	Department of Animal Science, Faculty of Agriculture, KNUST, Kumasi.
	A three-stage feeding regime for broiler production	It is an effective feeding strategy for broilers, which utilizes three different diets. 23% crude protein starter diet is given first followed by 21% crude protein developer diet and then 19% crude protein finisher diet. It gives faster growth rate and good feed conversion ratio and is associated with good economic gains.	Done through MOFA extension	2003	CSIR-ARI

	Artificial brooding management of guinea keets.	It involves the construction of wooden cages using hard wood, wire mesh and aluminum roofing sheets for brooding guinea keets. The cage is opened from the top and fitted with a padlock. The technology reduces keet mortality, improves keet performance and increases grow rate thus reducing slaughter age by at least 60%	GTZ has used hands-on demonstration of the innovation to farmers in Northern and Upper East Regions	2006	Animal Science Department, University for Development Studies, Tamale
	Intensive production of keets at brooder stage	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 38oC until the eggs begin to pop, then the temperature is reduced to 36oC 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/m2. Room temperature is maintained at 35oC in the first week, 33oC in the second week, 31oC in the third week, and 29oC 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.		2001-2006	ARI
	ARIBRO Broiler	ARIBRO Nucleus population of broiler parents was developed as a renewable and sustainable source of day old chicks. Birds developed with better growth rate, low mortality rate and low fat deposition. Commercial farmers have relatively cheaper priced day old chicks	Technology has been patronized by commercial farmers and	2001-2006	CSIR-ARI

		compared to imported ones. Chicks attain a comparatively high final body weight which attracts higher prices. ARIBRO has good feed conversion efficiency and growth rate of chicks is impressive.	consumers. Disseminated at National farmers' fora / exhibitions, workshops and seminars.		
	Combine starter and finisher Diet for Broilers of chicken	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.	Partially transferred. Dissemination done at workshops and to some poultry farmers	2001-2006	Animal Science Dept, KNUST
	Regime for Newcastle disease vaccine	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.			ARI
	Improved brooding management of local guinea fowl	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.			Animal Science Dept, UDS
	Improved vaccination schedule for control of Gumboro disease in Ghana	The vaccination schedule was prescribed to poultry farmers to counter the high mortality rate of poultry from the infectious bursal disease (gumboro).		2001-2006	CSIR-ARI
	FISHERIES-RELATED TECHNOLOGIES				
	Improved Akosombo strain of Nile Tilapia (Oreochromis niloticus)	The improved Akosombo strain of Nile tilapia was developed from different strains of O. niloticus, the most popular fish in culture, from the different ecological zones of the Volta Lake. The different strains were evaluated for their culture attributes with respect to growth, disease resistance, fecundity and quality of flesh. Breeding and selection of these different strains has resulted in the current improved strain that grows 30% faster than those in the wild. Normally, tilapia takes eight months to reach maturity from the fingerling stage when they are purchased from hatcheries. However, under cage culture	Through Fish Farmers Associations, Fisheries Commission, Extension Officers and Training Workshops. In	1997; 2001-2006 improvements	CSIR-WRI

		condition or system, it takes five months for the strain to reach a mean weight of 420 grams from an initial stocking weight of 15 grams. Most of the hatcheries have adopted the new strain as their brood stock and are producing fingerlings for the whole industry. At the current pace, tilapia production in Ghana is projected to increase tenfold by 2015.	the Volta Basin diffusion has been done through the collaborating countries, Burkina Faso, Cote d'Ivoire, Togo and Mali		
	A protocol for production of mudfish fingerlings by fish farmers.	It involves period transfer of fries from the hatchery to nursery then to production ponds		2001-2006	CSIR-WRI
	Formulated feed for growing tilapia in ponds and cages	It is a balanced feed formulated from locally available agro-industrial by-products developed for fattening tilapia. It produces 5-fold faster growth compared with traditional fertilization and feeding of rice bran only and reduces rearing period for fish and increases fish size	Has been transferred to local feed manufacturing companies	2001-2006	CSIR-ARI
	Integration of fish with broilers and/ or layers of chicken	This is an integrated aquaculture-agriculture system in which chicken are reared in coops built over fish ponds. The tilapia fingerling-broiler combination gives higher production and income and results in better growth of chicken. This technique prevents jumpers from feeding on small ones, which causes high mortality.	Not fully disseminated but some NGOs have been trained with help of MOFA and Fish Farmers Association	2001-2006	CSIR-WRI
	Polyculture of mudfish and tilapia (Clarias gariepenus/hetero brandus longifilis and Oreochromis niloticus).	It entails the keeping of two different species of fish in the same pond. The technology gives higher yield (2-8 times) in polyculture than monoculture system and results in better feed conversion rate s different species feed at different niches of the pond.		2002	CSIR-WRI
	Polyculture of Tilapia and Catfish	The technology involves management practices for producing tilapia and catfish that increase pond productivity and income. The resources	Disseminatioin has been done		CSIR-WRI

		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.	by CSIR-WRI through workshops		
	AGRO/FOOD PROCESSING TECHNOLOGIES				
	Technology for producing fufu flours from cassava, plantain, cocoyam and yam	Fufu flour is dehydrated pre-cooked cassava and cocoyam milled and mixed with a small portion of cassava starch. Appropriate technologies have been developed and transferred for the production of several new convenience foods which are either adequate alternatives to imported materials or have export potential.	The products are marketed directly to the public at the Food Research Institute and a few firms are now currently producing them commercially. These technologies have been transferred to various local entrepreneurs. CSIR-FRI has started some form of Agro Processing Technology Incubation where entrepreneurs are nurtured.		CSIR-FRI
	Technology for producing bambara flour,	Appropriate technologies have been developed and transferred for the production of several new convenience foods which are either adequate alternatives to imported materials or have export potential.			CSIR-FRI

	Technology for producing Banku Mix	As above	As above		CSIR-FRI
	Technology for producing Breakfast Cereals	As above	As above		CSIR-FRI
	Technology for producing composite flours, and	As above	As above		CSIR-FRI
	Technology for producing cowpea flour with recipe manual,	As above	As above		CSIR-FRI
	Technology for producing dehydrated fermented maize meal,	As above	As above		CSIR-FRI
	Technology for producing Fermented Maize Meal	As above	As above		CSIR-FRI
	Technology for producing Fruit and spices drying Marmalades	As above	As above		CSIR-FRI
	Technology for producing Fruit Juices	As above	As above		CSIR-FRI
	Technology for producing Good Quality Kokonte	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	As above		CSIR-FRI
	High Quality Cassava Flour Technology	The high quality cassava flour or HQCF is intermediate cassava flour which could be used for adhesives in the plywood industry, for the formulation of composite flours in the bakery industry, and for the production of cassava glucose syrup for use in the confectionery industry. The technology involves the use of mechanical chipping/grating techniques, fermentation, solar and mechanical drying to produce High Quality Cassava Flour. It costs at least the Cedi equivalent of $360 to produce 1 tonne of HQCF as compared to US$490 for Wheat Flour.	As above		CSIR-FRI

	Improved techniques for the preparation and preservation of Wagashie (soft cheese)	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.	Through training provided to women in the catchment area. World vision and MOFA extensions staff were also trained. Trainer of trainee workshop was organized at KNUST		Animal Science Dept, KNUST
	Pepper preservation: Blanching of hot peppers employing the solar blanching technology	The technology involves spreading the sorted pepper over a black polythene sheet in the open sun and covering it with a transparent one for between 2 and 3 hours depending on the weather conditions. The heat generated between the plastic sheets blanches the pepper, destroying all enzymes and most microbes on and in the pepper. To test that the produce is totally blanched a drop of 0.1% hydrogen peroxide is dropped to the freshly cut surface. Lack of gas bubbles is an indication that the pepper is adequately blanched			CSIR-SARI
	Processing of spices (nutmeg, black pepper, xylopia, grains of paradise)	Appropriate cultivation and harvesting of processes of different spices have been developed.			CSIR-PGRRI
	Snail Meat Preservation	This technology describes a more hygienic, appropriate and low-cost method for the preparation, spicing and solar dehydration of snail meat. A second technology developed involved spice extraction and snail meat preparation for the canning of snail meat in brine.	Disseminated through training. Tericom Company Ltd., Accra, Mr. Ntorinkansah, Tema businessman		CSIR-FRI

			and some Local Entrepreneurs have been trained.		
	Glucose Syrup from Cassava Technology	Glucose syrup is a concentrated aqueous solution of glucose maltose and other nutritive saccharides from edible starch, which is used in large quantities in drinks/liquors, crystallised fruits, bakery products, pharmaceuticals, and brewery products. The Institute has adapted and fine-tuned a technology for the production of glucose syrup (high maltose syrup) from the High Quality Cassava Flour. Hitherto, no industry in Ghana was producing glucose syrup. Meanwhile over 100,000 metric tons of glucose syrup is imported annually into the country for use in various industries. Through the efforts of the Institute four companies are now producing glucose syrup. This is saving the country a huge amount of foreign exchange.	Through the efforts of the Institute four companies are now producing glucose syrup.	2002	CSIR-FRI
	Cassava Flour as Plywood Adhesive Mix Extender Technology Profile	Wheat flour is commonly used as an extender in the adhesive mix for plywood production, but wheat flour is expensive. Utilization of wheat flour as an extender increases greatly the cost of plywood production due to increasing cost of importation. A cheaper but effective alternative will largely reduce the cost of production and increase production volumes.	Training has been beneficial in transferring knowledge to industry. For example, two staff each from twelve plywood companies have been trained to effectively use cassava flour.		CSIR-FORIG
	Starter Culture for Food Fermentation Technology	This technology aims at the introduction of some starter culture organisms to traditional foods to enhance their taste, flavour, texture etc. and also to prolong their shelf life			CSIR-FRI

	Technology for the Production of "Prekese" Syrup	In the current wave of concern about functional foods, considerable effort is being put into sources of "green" food, which includes syrup obtained from the fruit of Tetrapleura tetraptera (Prekese). Prekese fruit syrup quali.es as a green food source with no additives. It has inherent preservative and anti-hypertensive properties. Other therapeutic uses include management of convulsions and rheumatic pain. Prekese also has anti-ulcerogenic, molluscicidal, and antimicrobial activity. Fruits and seeds of Prekese have low sodium content and are rich in potassium, iron, magnesium, phosphorus, and vitamin C. Traditionally, Prekese fruit has been used as preservative and flavour for soup and stew. Thus, Prekese is a household name in Ghana and its value is appreciated. CSIR-FORIG developed techniques for extracting and processing of syrup from Prekese fruits after years of scientific research.			CSIR-FORIG
	Improved iced kenkey	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.			Dept of Nutrition & Food Science, UG
	Peanut-cowpea milk	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).			Dept of Nutrition & Food Science, UG
	Virgin Coconut Oil (VCO)	VCO is high quality oil in terms of taste, colour, nutrients and aroma. The technology for producing the oil conserves about 95% of nutrients found in the copra, hence the name virgin oil. The product has some unique qualities that make it acceptable above competing products. These qualities include: • Very good taste, colour and aroma; • High micro nutrients content; • Time saving and convenient to process; and • An attractive price of 3 to 4 times above the traditional copra oil.	Methods employed to disseminate the technology as follows: • Formation of FBO to learn the technology • Exhibitions		CSIR-OPRI

			•MOFA Extension support service • FACT SHEET •Research publications • Seminars • TV and radio talk shows • Production Guide		
	Sugar-free chocolate 'ASPIRE'	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.			Dept of Nutrition &Food Science, UG
	FOOD ENGINEERING/EQUIPMENT TECHNOLOGIES				
	Technology for fabricating dawadawa dehuller	Appropriate food processing machinery has been developed and transferred to various enterprises for small-scale food processing. CSIR-FRI has designed and constructed several food processing equipment that have helped various local food processing industries to establish their businesses whilst saving on imported alternatives to these equipment.			CSIR-FRI
	Flour sifters technology	As above			CSIR-FRI
	Hot air cabinet dryers technology	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.			CSIR-FRI
	Natural convention solar dryer	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.			FRI
	Grain cleaners technology	As above			CSIR-FRI
	Hammer mills technology	As above			CSIR-FRI

	Cassava graters technology	As above			CSIR-FRI
	Cassava pressers technology	As above			CSIR-FRI
	Honey centrifuge extractor technology	As above			CSIR-FRI
	Gari grading / sifting machine technology	As above			CSIR-FRI
	Industrial pressure cookers technology	As above			CSIR-FRI
	Rice parboiling vessel technology	Rice parboiling is a hydro-thermal process (that means it uses water and heat) applied to paddy rice to improve the quality of milled rice. The traditional method of parboiling is very time-consuming and laborious allowing for only parboiling of about 30 kg of paddy per batch. There are differences in the unit operations among women parboilers contributing to the varying quality of parboiled rice in Ghana. Some of the problems associated with the traditional parboiling include poor quality of products and the process being inefficient. The improved parboiling vessel allows for batches of up to 100kg to be parboiled at a time and produce more control over the process. Additionally the use of the vessel presents many advantages.	Transferred to women processors in Northern Ghana (Upper East, Upper West and Northern Regions) some parts of the Brong Ahafo Region). A training manual on the use of parboiling vessel.		CSIR-FRI
	Bin dryer	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.			FRI
	FRISMO (Chorkor Smoker) technology	The chorkor smoker was developed to eliminate labor inputs needed for interchanging tray positions during smoking. The ovens also reduce heat loss while reducing tar deposits. 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	Disseminated in at least 150 fishing villages. FRI has	2005	CSIR-FRI

		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. Socio economic and technological evaluation of the Chorkor Smoker has shown that it is much more efficient in terms of capacity and processing time per batch, fuel requirement, labour requirement and quality of finished product. Comparatively, low production cost and the higher prices attracted by the product have contributed about 30 percent higher incomes for fish processors in various parts of Ghana. In addition, the adoption of the Chorkor Smoker technology has contributed significantly to increased availability of processed fish, which serves as a major source (70%) of animal protein in Ghana.	collaborated with WIAD-MOFA Fisheries Department, University of Ghana, and National Council on Women and Development for the past 10 - 15 years to train 200 Fisheries Extension officers from Ghana, The Gambia, Kenya, Uganda, Ethiopia, Eritrea, Tanzania, Zambia, Lesotho, Nigeria and Sierra Leone in the design, construction and application of the technology.		

	Afrismo 150 smoker	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.			CSIR-FRI
	Locally constructed solar dryer for vegetables	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.			College of Agriculture Education, UEW
	Integrated cassava processing plant	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. The Integrated Cassava Processing Pilot Plant is designed to process 10-25 metric tonnes of fresh cassava tubers into traditional fermented derivatives including gari, kokonte, agbelima vis-à-vis relatively new product of unfermented high quality cassava flour. Another unique feature of the plant is the incorporation of an animal feed processing unit that converts the cassava peels into animal feeds supplements to promote rearing of goats, sheep, cows etc. Three main machine incorporated into traditional process techniques to ensure production of unfermented high quality cassava flour are dryer for drying the sieved fine dough into flakes, hammer mill for milling and sieving the dried flour flakes and sifter to capture and finally sieve and grade the finely milled unfermented high quality cassava flour.	Through training of farmers in Northern region of Ghana on how to operate the plant to produce various cassava products.		CSIR-IIR

	Diesel/kerosene fired dryer	The technology involves a dryer that employs indirect heating for drying grains and for processing food. The atomizer is locally manufactures and it does not use exhaust fumes for drying.			CSIR-FRI
	Mechanized palm kernel and shell separator technology	The palm kernel – shell separator is designed to separate cracked palm nuts into various components. Its design combines two distinct separation techniques into a compact single unit. These units are a rotary screen cylinder and an inclined belt conveyor. The rotary screen is made up of two concentric galvanized iron wire mesh screens (an inner and outer screen), rolled with a taper. This assembly is mounted on a shaft through which power is transmitted. The rotary screen is more or less a cleaning device designed to remove all the debris and fine particles and at the same time sort the cleaned mixture of kernels and shells into two size ranges. The output from the screen is deposited on to the conveyor belt assembly. As the material moves up the incline, separation takes place.	Three demonstration units were cited at three selected areas in the oil palm growing regions for the purposes of introducing the technology to end-users and also local artisanal fabricators.	2003	CSIR-IIR
	Soybean oil refining plant technology	The technology involves degumming, neutralization, bleaching, and deodorization of crude soy oil to obtain edible refined oil. The production of soy cake meal also yields dark-coloured soybean oil as a by-product. In order to increase income levels of small scale producers, a process technology for refining the oil has been developed. The designed pilot plant can refine crude soybean oil to edible soybean oil.	Through training workers of soybean cake companies		CSIR-IIR
	Groundnut processing equipment	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			IIR
	Design and construction of large capacity free convection greenhouse dryers to dry hot peppers	The pepper variety Capsicum chinense cultivated in the district is not amenable to open sun drying hence there is always a glut on the market and farmers get very little from their toil. Three greenhouse dryers were constructed in three communities within the district. The dryers dried a batch of 8 maxi bags of pepper between 9 and 14 days depending on			CSIR-SARI

		the weather conditions. Ratio of shrinkage of the dried pepper to the fresh one was 1:3			
	Twin or single hybrid energy saving stoves technology	The twin or single hybrid energy saving stove is an improvement over existing traditional stoves with emphasis on the mode of air .ow to facilitate combustion and enhance efficiency. It consists of the following units:	Through Gari processing associations, institutions such as prison services and schools.		CSIR-IIR
	Post-harvest maize and seed production	A drying process developed to improve the storage capacity of maize and cereals and to reduce post-harvest losses.			CRI
IMPROVED CROP VARIETIES					
	Improved cassava variety-Abasafitaa:	Higher yielding than local varieties and tolerant to local pests and diseases with acceptable food qualities. It also has a maturity period of 12-15 months with total dry matter of 35%. Its main uses are for starch, four and gari making. The variety is also tolerant to the cassava mosaic disease.		1993; 1997	CSIR-CRI
	Improved cassava variety-Afisiafi	Afisiafi is a disease- and pest-resistant variety that yields about 2.5 times the traditional varieties. It has a maturity period of 12-15months with total dry matter content of 32%. The mean root yield is between 28-35 tonnes per hectare and it is mainly used for starch, flour and gari preparations. The variety is tolerant to the cassava mosaic disease.		1993; 1997	CSIR-CRI
	Improved cassava variety-Agbelifia	It has a maturity period 12 months and a mean root yield of 40-45 tonnes per hectare. The total dry matter content is 33%. Agbelifia is mainly used for flour, starch and gari preparation.		2005	CSIR-CRI
	Improved cassava variety-Ampong	It resists African cassava mosaic disease, is drought-tolerant, and yield as much as 35 t/ha. It also demonstrates the highest starch yield ever recorded in Ghana.		2010	CSIR-CRI
	Improved cassava variety-Bankyehemaa	It has a maturity period 12 months and a mean root yield of 40-45 tonnes per hectare. The total dry matter content is 32%. Bankyehemaa is poundable into fufu and can also be used in four and gari preparation.		2005	CSIR-CRI
	Improved cassava variety-Broni bankye	It resists African cassava mosaic disease, is drought-tolerant, and yield as much as 35 t/ha. It also demonstrates the highest starch yield ever recorded in Ghana.		2010	CSIR-CRI

	Improved cassava variety-Dokuduade.	This variety is resistant to African cassava mosaic disease, has low cyanide content, and produces yields of about 2.5 times traditional varieties. It is mainly used for starch and gari making.		2005	CSIR-CRI
	Improved cassava variety-Essam bankye,	It has a maturity period 12 months and a mean root yield of 40-45 tonnes per hectare. The total dry matter content is 35%. It is mainly used for flour, starch and gari preparation.		2005	
	Improved cassava variety-Otuhia	It resists African cassava mosaic disease, is drought-tolerant, and yield as much as 35 t/ha. It also demonstrates the highest starch yield ever recorded in Ghana		2010	CSIR-CRI
	Improved cassava variety-Sika bankye	It resists African cassava mosaic disease, is drought-tolerant, and yield as much as 35 t/ha. It also demonstrates the highest starch yield ever recorded in Ghana		2010	CSIR-CRI
	Improved cassava variety-Eskamaye	Fresh roots yields 15.8-22.7t/ha; has high yields at both 8 and 12 MAP. Has high gari swelling power. Boiled roots are soft at 8 MAP (December) but hard in March. Has bland taste in Tuo zaafi. Gari colour is yellowish brown and slightly sour in taste			
	Improved cassava variety-Fil-Ndiakong	It performs well under many cassava-growing ecologies			
	Improved cassava variety-Nyeri-Kobga	Fresh roots yields 16.7-28.6t/ha; have high yields both at 8 and 12 MAP; Boiled root is hard at 8 MAP (December) but soft in March.			
	Improved cocoyam variety-Gye Me Di	This variety is purple in colour and has a maturity period of 12-18 months with a yield potential of 8 metric tonnes per hectare. It has a high dry matter, Ash & Carbohydrate (58.22%, 2.73%, 48.19%)content. Its food uses include Fufu, Eto, Ampesi, Mpotompoto, Confectioneries and Yoghurt.		2012	
	Improved cocoyam variety-Akyede	Akyede is also purple in colour and equally has a maturity period of 12-18 months with a yield potential of 7 metric tonnes per hectare. Its food uses include Fufu, Eto, Ampesi, Mpotompoto, Confectioneries and Yoghurt		2012	
	Improved cocoyam variety-Ma Aye Yie	This variety is white in colour and has a maturity period of 11-12 months with a yield potential of 6 metric tonnes per hectare. Its food uses include Ampesi, Mpotompoto, Confectioneries and Yoghurt.		2012	

	Improved cotton variety SARCOT 1.	Potential yield is 2,100kg/ha; Lint percentage is 46.15 and fibre length is 29.05mm. Fibre strength is 27.65 gf/tex; micronaire is 3.28			
	Improved cotton variety SARCOT 5	Potential yield is 2,100kg/ha; Lint percentage is 44.4 and fibre length is 30.7 mm. Fibre strength is 28.45 gf/tex; micronaire is 4.12			
	Improved cowpea variety - Apagbala	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.	Promotion through MOFA, NGOs, farmer groups;	2004	SARI
	Improved cowpea variety - Marfo Tuya	Seeds are fairly round and cream in colour with dull luster. It matures in 65-70 days	Promotion through MOFA, NGOs, farmer groups;	2001-2006	
	Improved cowpea variety- 'Videza'	'Videza' is a high yielding cowpea variety with ovoid seed shape, black seed eye and white seed coat with a smooth testa texture. It matures within 68-77 days.	Demonstrations, field days, open days, exhibitions, TV and radio		
	Improved cowpea variety- Baawutawuta	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.	Local seed companies, agro dealers, demonstrations and community seed producers		CSIR-SARI
	Improved cowpea variety- Bengbla	Bengbla 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).			CSIR-CRI
	Improved cowpea variety- Ayiyi	Developed to provide alternatives to low-yielding local varieties susceptible to pests and diseases.			CSIR-SARI
	Improved cowpea variety- Anidaso	Developed to provide alternatives to low-yielding local varieties susceptible to pests and diseases.			CSIR-SARI

	Improved cowpea variety-Asontem	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.			CSIR-SARI
	Improved cowpea variety-Bengbie	Developed to provide alternatives to low-yielding local varieties susceptible to pests and diseases.			CSIR-SARI
	Improved cowpea variety Marfo Tuya (medium maturing)	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 Bengbla 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 Bengbla			CSIR-SARI
	Improved cowpea variety-Pedi-tuya	The variety was developed to improve yield and resistance to aphids. It has large attractive white seeds, is early-maturing (65 days), and requires a shorter cooking time.	Local seed companies, agro-dealers, demonstrations and community seed producers		CSIR-SARI
	Improved cowpea variety-Songotra	Introduction from IITA. The variety is high-yielding, early-maturing and is resistant to Striga gesnerioides.	Local seed companies, agro dealers, demonstrations and community seed producers		CSIR-SARI
	Improved cowpea variety-Zaayura	The new variety is high-yielding, early-maturing, and resistant to aphid pest infections.	Local seed companies, agro dealers, demonstrations and community seed producers		CSIR-SARI
	Improved cowpea variety-Asomdwee	Asomdwee' is a high yielding cowpea with semi erect growth habit. It has a globose seed shape, black seed eye and a white seed coat.	Demonstrations, field days, open days,		

			exhibitions, TV and radio		
	Improved cowpea variety-Hewalɛ	'Hewalɛ' is a high yielding early maturing cowpea variety with white seed coat colour and brown hilum with rhomboid shape	Demonstrations, field days, open days, exhibitions, TV and radio		
	Improved cowpea variety-Nhyira	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.	Demonstrations, field days, open days, exhibitions, TV and radio		CRI
	Improved cowpea variety-Tona	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).	Demonstrations, field days, open days, exhibitions, TV and radio		CRI
	Improved cowpea variety-Vallenga	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.			CSIR-SARI
	Improved groundnut variety – Gusie-Balin	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.	Promotion through MOFA, NGOs, farmer groups;	2001-2006	CSIR-SARI
	Improved groundnut variety - Mani Pinta	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.	Promotion through MOFA, NGOs, farmer groups;		SARI
	Improved groundnut variety-CRI-Adepa	High yields, resistant to rosette and Cercospora leaf spot.	Demonstrations, field days,	2001-2006	CSIR-CRI

			open days, exhibitions, TV and radio		
	Improved groundnut variety CRI-Azivivi	Early maturing, high yielding, tolerant to drought and fresh seed dormancy	Demonstrations, field days, open days, exhibitions, TV and radio	2001-2006	CSIR-CRI
	Improved groundnut variety-CRI-Nkosour	High yields, resistant to rosette and Cercospora leaf spot. It has bold and tasty seeds and it is suitable for confectionaries and home consumption.	Demonstrations, field days, open days, exhibitions, TV and radio	2001-2006	CSIR-CRI
	Improved groundnut variety-Edorpor-Munikpa (SARGV 88001)	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. It yields 100% more than Chinese in drought prone areas, has higher oil content of 48.8%.	Promotion through MOFA, NGOs, farmer groups;	2005	CSIR-SARI
	Improved groundnut variety-F-Mix	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.			CSIR-SARI
	Improved groundnut variety-Kpanielli (ICGV 90084).	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). The most common variety used by farmers.	Promotion through MOFA, NGOs, farmer groups;	2001-2006	CSIR-SARI
	Improved groundnut variety-Oboshie	The kernel lacks dormancy. It matures within 105 and 110 days.	Demonstrations, field days, open days, exhibitions, TV and radio		
	Improved groundnut variety-CRI- Jenkarr	It has high yields and high oil content; resistant to rosette and Cercospora leaf spot.		2001-2006	CSIR-CRI

	Improved groundnut variety-Obolo	The kernel lack dormancy and matures after 105-110 days after planting.	Demonstrations, field days, open days, exhibitions, TV and radio		
	Improved groundnut variety-Chinese (Shi Tao Chi)	Among the varieties currently cultivated in Ghana, it has the lowest oil content. It is currently the most popular variety cultivated in northern Ghana	Promotion through MOFA, NGOs, farmer groups;		CSIR-SARI
	Improved groundnut variety-Nkatiesari (SARGV 88002)	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.	Promotion through MOFA, NGOs, farmer groups;	2001-2006	CSIR-SARI
	Improved groundnut variety-Otuhia	Dark green leaves with fresh dormancy kernel. The seed colour is brown and it matures within 115-120 days	Demonstrations, field days, open days, exhibitions, TV and radio		
	Improved groundnut variety-Sinkarzei	Seeds of Sinkarzei were initially supplied by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), India to Ghana in 1985. After extensive on-station and on-farm tests, the variety was found to be performing well. It yields an average of 2,200kg/ha compared with local varieties that yield 1,900kg/ha. It has an oil content of 45% and 120 days maturity. It is deep red in colour. 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.	Promotion through MOFA, NGOs, farmer groups; Phasing out of cultivation		CSIR-SARI
	Improved groundnut variety-Yenyawoso	The kernel lacks dormancy and is resistant to rust. . It matures within 85-90 days.			
	Improved maize variety-Abontem	Drought and striga tolerant yellow QPM OPV. The maturity period is between 80-85 days and it has a potential yield of 4.7tonnes/hectare.			CSIR-CRI, CSIR-SARI, IITA

	Improved maize variety-Aburohemaa	Drought and striga tolerant white flint/dent QPM OPV. Excellent for enhanced nutrition and human health			CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Akposoe	White dent QPM OPV with a potential yield of 3.5tonnes/hectare. Useful to bridge hunger gap	Not actively disseminated currently		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Aseda	3-way Cross tolerant to moderate drought	CSIR-CRI and NGOs		CSIR-CRI
	Improved maize variety-Aziga	Yellow flint/dent QPM. Good for poultry and livestock and excellent for enhanced nutrition and human health	Not actively disseminated		CSIR-CRI
	Improved maize variety-CSIR-Bihilifa	QPM White, OPV, drought and striga-tolerant, 75-80 days maturity with yield of 4.5 tons/ha, most suitable for Striga infested fields of the Guinea and Sudan Savanna, Stay green	MOFA Extension support services, NGOs, farmer groups.		CSIR-SARI
	Improved maize variety-CSIR-Ewul-boyo	Drought tolerant, 110 days maturity, yield 5.6 ton'ha, most suitable for the Guinea Savanna stay green	MOFA Extension support services, NGOs, farmer groups		CSIR-SARI
	Improved maize variety-CSIR-Sanzal-sima (Maize)	Open pollinated variety (OPV), drought and striga-tolerant, 110 days maturity, Yield 5.4 tons/ha, Most suitable for Guinea Savanna	MOFA Extension support services, NGOs, farmer groups. Some NGOs assisted with funds for field demonstrations		CSIR-SARI

			and farmer adoption		
	Improved maize variety-CSIR-Wang Dataa	Open pollinated variety (OPV), drought and striga-tolerant, 90 days maturity with potential yield of 4.7 tons/ha, most suitable for Striga infested fields of the Guinea and Sudan Savanna	MOFA Extension support services, NGOs, farmer groups.		CSIR-SARI
	Improved maize variety-Enibi	Drought tolerant white flint Quality Protein Maize (QPM) 3-way hybrid. They are early-maturing (75-90 days) and Striga-resistant.	Not actively disseminated currently		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Golden Jubilee	It involves the development of a yellow dent/flint version of the Obatanpa, which is quality protein maize (QPM) variety called golden jubilee maize for industrial use. The variety is high yielding, disease and pest resistant, drought tolerant and has high nutritional value with higher protein content and pro-vitamin A. It contains lysine, carotene, and tryptophan – all essential amino acids necessary for normal growth and development in both humans and animals. It is good for poultry and livestock feed and leads to increased egg production and meat quality.	CSIR-CRI, NGOs, and farmer groups	2007	CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Honampa	Yellow open-pollinated variety. Good for poultry and livestock and excellent for enhanced nutrition and human health	CSIR-CRI and Farmer Groups		CSIR-CRI
	Improved maize variety-Mamaba	White flint QPM 3-way hybrid. Excellent for enhanced nutrition and health of humans.	CSIR-CRI, NGOs, and farmer groups		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Nwanwa	Single cross yellow QPM hybrid. Suitable for human, poultry and livestock consumption Excellent for industrial preparations such as grits and kenkey	Not actively disseminated now		CSIR-CRI
	Improved maize variety-Obatanpa	Obatanpa is an open-pollinated white dent/flint streak resistant QPM with maturity period between 105-110 days. It has a potential yield of 5.5tonnes/hectare. It has high levels of lysine and tryptophan.	CSIR-CRI, NGOs, and farmer groups		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Odomfo	Single cross yellow QPM hybrid. Suitable for human, poultry and livestock consumption Excellent for industrial preparations such as grits and kenkey.	Not actively disseminated now		

	Improved maize variety-Okomasa	Okomasa is a high yielding 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.	Not actively disseminated currently		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety- Ope aburoo	Top cross hybrid with tolerance to moderate drought. Excellent for enhanced nutrition and human health	CSIR-CRI and NGOs		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Tintim	Top cross hybrid with tolerance to moderate drought. Suitable for preparation of local dishes	CSIR-CRI and NGOs		CSIR-CRI
	Improved maize variety-Abeleehi	Abeleehi is an improved maize white dent/flint variety that is streak-resistant, has a white dented grain/seed, matures in 105 days, and can yield	Not actively disseminated currently		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Dorke SR	White dent streak resistant QPM. Suitable for preparation of local dishes.	Not actively disseminated currently		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Etubi	White flint/dent QPM 3-way hybrid with a potential yield of 6.5tonnes/hectare. Excellent for enhanced nutrition and health of humans	CSIR-CRI, NGOs, and farmer groups		CSIR-CRI, CSIR-SARI, IITA
	Improved maize variety-Omankwa	Drought and striga tolerant QPM. It is early maturing within 90-95 days. It has a potential yield of 5.2tonnes/hectare			CSIR-CRI, CSIR-SARI, IITA
	Improved pepper variety- CRI Shito-Adope	Hot long Cayenne Pepper with the following characteristics: Plant height= 48cm, plant spread = 52cm and Days to flowering = 60 days. Early maturing, straight, uniform, longer shelf life, dark green, and hot fruit of export standards.	Through MoFA Extension support services, Farmer Field Schools, Posters & Exhibition		CSIR-CRI
	Improved pepper variety-Maako-Ntoose	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 used to feed children. It grows with little moisture, has a long shelf life, and can	Through MOFA Extension support	2005	CSIR-CRI

		be cultivated throughout the country. It is often used in place of tomatoes during lean tomato seasons.	services, Farmer Field Schools, Posters & Exhibition, print media and internet (AVRDC's website). Limited dissemination has been done to farmers for cultivation.		
	Improved plantain variety	Decorticated technique is used whereby already harvested corms are used to produce large quantities of healthy planting material	New technology yet to be disseminated on a large scale		CSIR-CRI
	Improved rice variety- Bodia	It grows on a lowland ecology. It also attains 50% flowering between 90 and 95 days. Bodia reaches maturity within 120 to 125 days with a potential yield of 8.0t/ha. It also has a tolerant resistance to leaf blast and a good resistance to lodging. It is white in colour, bold in shape and has a percentage milling yield of 66. It has good cooking quality but also lacks an aroma.		2010	
	Improved rice variety- CRI-Amankwatia	It grows on a lowland ecology and attains 50% flowering between 80 and 85 days. It matures within 115 to 120 days with a potential yield of 8.0 t/ha. It also has a tolerant resistance to blast and a good resistance to lodging. It is white in colour, long and slender in shape with a percentage milling yield of 70.4. It also has good cooking quality with an aroma.		2010	CSIR-CRI
	Improved rice variety- Digang	Imbred line, 110-115 days maturity, non-aromatic, long grain, loose panicle, erect flag leaf, average height (130cm), good tillering ability, yield up to 6t/ha	Promotion through demonstration,		CSIR-SARI

			MOFA, NGOs, seed companies and rice projects		
	Improved rice variety- EmoTeaa	It grows on an upland ecology. It attains 50% flowering between 75 and 80 days. It matures within 110 to 115 days with a potential yield of 4.8 t/ha. It is resistant to blast and has a good resistance to lodging. It is white in colour, long and slender in shape with a percentage milling yield of 65.6. It has good cooking quality but lacks high aromatic properties.		2009	
	Improved rice variety- Gbewaa	Imbred line, 110-115 days maturity, aromatic, long grain, loose panicle, erect flag leaf, average height (115cm), good tillering ability, yield up to 8 t/ha	Promotion through demonstrations, MOFA, NGOs, seed companies and rice projects		CSIR-SARI
	Improved rice variety- GR 18	Imbred line, 130-135 days maturity, non-aromatic, bold grain, loose panicle, erect flag leaf, average height (120cm), good tillering ability, yield up to 6t/h	Promotion through demonstration, MOFA, NGOs, seed companies and rice projects		CSIR-SARI
	Improved rice variety- GR 21	Imbred line, 125-130 days maturity, non-aromatic, bold grain, loose panicle, erect flag leaf, average height (130cm), good tillering ability, yield up to 5t/ha	Promotion through demonstration, MOFA, NGOs, seed companies and rice projects		CSIR-SARI

	Improved rice variety- Katanga	Imbred line, 135-140 days maturity, non-aromatic, long grain, loose panicle, erect flag leaf, average height (130cm), good tillering ability, yield up to 6 t/ha	Promotion through demonstration, MOFA, NGOs, seed companies and rice projects		CSIR-SARI
	Improved rice variety- Nabogu	Imbred line, leaf sheath anthocyan colouration, 125-130 day maturity, non-aromatic, long grain,loose panicle, erect flag leaf, average height (140cm), good tillering ability, yield is up to 6t/ha	Promotion through demonstration, MOFA, NGOs, seed companies and rice projects		CSIR-SARI
	Improved rice variety- NERICA 1	Imbred line, 90-100 days maturity, aromatic, long grain, loose panicle, erect flag leaf, average height (110cm), poor tillering ability, drought tolerant, yield up to 3.5 t/ha	Promotion through demonstration, MOFA, NGOs, seed companies and rice projects		CSIR-SARI
	Improved rice variety- NERICA 2	Imbred line, 90-100 days maturity, non-aromatic, long grain, loose panicle, erect flag leaf, average height (120cm), poor tillering ability, drought tolerant, yield up to 3.5 t/ha	Promotion through demonstration, MOFA, NGOs, seed companies and rice projects		CSIR-SARI
	Improved rice variety- Otoo Mmo	It also grows on an upland ecology and reaches 50% flowering between 80 and 85 days. It matures within 115 to 120 days with a potential yield of 5.6 t/ha. It is resistant to blast and has a good resistance to lodging. It is also white in colour, long and slender in shape with a percentage milling yield of 66.It has good cooking quality with no aroma.		2009	

	Improved rice variety- Sakai	It grows on a lowland ecology. It achieves 50% flowering between 95 and 100 days. It reaches maturity between 135 and 140 days with a potential yield of 8.0 t/ha. Sakai has a tolerant resistance to leaf blast with a good resistance to lodging. It is white in colour, long and slender in shape with a percentage milling yield of 66. Although Sakai has good cooking quality it also lacks an aroma.		2010	
	Improved rice variety- Sikamo	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. It also has good cooking quality, non-sticky and has a high expansion ratio.		1997	CSIR-CRI
	Improved rice variety- Wakatsuki	It grows on a lowland ecology and reaches 50% flowering between 93 and 98 days. It matures within 125 to 130 days with a potential yield of 8.0 t/ha. It has a tolerant resistance to leaf blast and a good resistance to lodging. It is also white in colour, long and slender in shape with a percentage milling yield of 66. It has good cooking quality but lacks an aroma.		2010	
	Improved sorghum variety- Kapaala	High yielding and realy maturing variety. Currenlty being used by Guinness Ghana Breweries LTD for adjunct brewing of lager and stout beer.	Through MOFA extension, NGOs and farmer groups		CSIR-SARI
	Improved soybean variety- Ahoto	Ahoto is a medium maturing (95-107 days after planting) soybean variety with high grain yield. The seed coat colour is cream with dark brown hilum. The name Ahoto' is an Akan word meaning comfort.	Done through Grains and Legume Development Board. Demonstrations, field days, open days, exhibitions, TV and radio	2001-2006	CSIR-CRI

	Improved soybean variety-Afayak	Maturity period is 110-115 days. Yield potential is 2.0-2.2 t/ha; Pod shattering score is less than 8%. Special attributes are excellent for striga control; very acceptable by consumers; benefit/cost ratio is 2.04; Broadly adapted to various ecologies	Through MOFA extension, NGOs and farmer groups		
	Improved soybean variety-Jenguma	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.	Through MOFA extension, NGOs and farmer groups		CSIR-SARI
	Improved soybean variety-Quarshie	Quarshie is drought-tolerant and suitable for cultivation in the Upper East Region because of its erratic rainfall pattern and poor climatic conditions.			SARI
	Improved soybean variety-'Nangbaar'	'Nangbaar' is an early maturing (89-93 days after planting) soybean variety with high grain yield. The seed coat colour is cream with light brown hilum. The name Nangbaar' is a Dagaare word meaning no more poverty	Done through Grains and Legume Development Board. Demonstrations, field days, open days, exhibitions, TV and radio	2001-2006	CSIR-SARI, CSIR-PGRRI, IITA
	Improved soybean variety-Songda	Maturity period is 110-115 days. Yield potential is 1.8-2.2 t/ha; Pod shattering score is less than 20%. Special attributes are excellent for striga control; very acceptable by consumers; benefit/cost ratio is 1.12. Broadly adapted to various ecologies Broadly adapted to various ecologies	Through MOFA extension, NGOs and farmer groups		CSIR-SARI,
	Improved soybean variety-Suong-Pungun	Maturity period is 85-92 days. Yield potential is 1.5-1.8t/ha; Pod shattering score is less than 10%. Special attributes are early maturing, very acceptable by consumers; benefit/cost ratio is 1.63. Broadly adapted to various ecologies	Through MOFA extension, NGOs and farmer groups		

	Improved sweet potato variety- CRI- Apomuden	Mean yield of 30 tonnes per hectare and can be used for flour products, baby foods, export, yoghurt (potaghurt)		2005	CSIR-CRI
	Improved sweet potato variety- CRI-Bohye	Mean yield of 22 tonnes per hectare and can be used Ampesi, chips, starch and flour)		2012	CSIR-CRI
	Improved sweet potato variety- CRI-Dadanyuie	Mean yield of 18 tonnes per hectare and can be used Ampesi, fufu, starch, flour and livestock feed)		2012	CSIR-CRI
	Improved sweet potato variety- CRI-Hi	Mean yield of 18 tonnes per hectare and can be used for Ampesi, fufu, flour and starch production. The starch content is 21% of its total weight, making it suitable for industrial use.		2005	CSIR-CRI
	Improved sweet potato variety- CRI-Ligri	Mean yield of 20 tonnes per hectare and can be used for Ampesi, chips, starch and flour.		2012	CSIR-CRI
	Improved sweet potato variety- CRI-Ogyefo	Mean yield of 20 tonnes per hectare and can be used for Ampesi, chips, weed control, livestock feed. It has only12.4% of starch content.		2005	CSIR-CRI
	Improved sweet potato variety- CRI-Otoo	Mean yield of 23 tonnes per hectare and can be used for Ampesi, chips,weed control and livestock feed.		2005	CSIR-CRI
	Improved sweet potato variety- CRI-Patron	Mean yield of 22 tonnes per hectare and can be used for Ampesi, chips, starch and flour.		2012	CSIR-CRI
	Improved sweet potato variety- Faara	Mean yield of 22 tonnes per hectare and used for Ampesi, chips and flour.		1998	
	Improved sweet potato variety- Okumkom	Mean yield of 20 tonnes per hectare and can be used for Ampesi, fufu, chips and flour.		1998	
	Improved sweet potato variety- Santom pona	Mean yield of 17 tonnes per hectare and mainly used for Ampesi, fufu and chips.		1998	
	Improved sweet potato variety- Sauti	Mean yield is 19 tonnes per hectare and mainly used for flour, chips and Ampesi.		1998	
	Improved yam variety- Mankrong pona,	The variety has yield potentials ranging from 45-70t/ha. The average maturity period for the varieties is between 7 and 8 months.		2005	
	Improved yam variety-CRI-Kukrupa	As above		2005	CSIR-CRI
	Improved yam variety-CRI-pona and	As above		2005	CSIR-CRI

	Improved oil palm planting material	It is a high yielding oil palm planting material developed which is suitable for all seasons and conditions. It is drought and wilt resistant, early bearing and has high oil extraction ratio of 0.28-0.35		2001-2006	CSIR-OPRI
	Improved coconut variety-A moderately tolerant variety MYD (Malaysian Yellow Dwarf) x VTT (Vanuatu tall).	The variety is characterized by early bearing, high nut yielding and tolerant to Cape St. Paul Wilt Disease.		2001-2006	CSIR-OPRI
	Improved coconut variety-A tolerant variety SGD (Sri-Lankan Green Dwarf) x VTT (Vanuatu Tall).	The variety is characterized by early bearing, high nut yielding and tolerant to Cape St. Paul Wilt Disease.		2001-2006	CSIR-OPRI
	OTHER TECHNOLOGIES				
	Biogas Technology Profile Brief Description of Technology	Biogas is a combustible gas produced by anaerobic fermentation of organic materials by the action of methanogenic bacteria. The most important constituent of Biogas as fuel is methane (CH4). Methane is odorless and invisible in bright daylight. It burns with a clear blue flame without smoke and is nontoxic. It produces more heat than kerosene, wood, charcoal, and cow-dung chips. Institute of Industrial Research has developed two types of biogas plants; the floating metal dome digester and a fixed brick dome digester. The organic matter for biogas production in Ghana include cowdung, straw, human feces, poultry manure, pig manure and water hyacinth. KVIP's can have biogas technology incorporated to treat the waste and also generate biogas. The organic matter is mixed with water to form a slurry of an appropriate concentration. Waste from food and beverage industries can also be used for biogas generation.	Through building of the biogas plant for communities, district assemblies, prison services, slaughter houses and individual households.		CSIR-IIR
	Long-term storage of yam tubers under farmers' conditions	Prolong the shelf-life of white yam by suppressing sprouting through gibberellic acid application			CSIR-PGRRI
	Soilless rooting medium-AgSSIP Mix	It is a formulation of composted sawdust and coconut coir as a medium for germinating and rooting cuttings. It is easy to use, devoid of soil pathogens, enhances early germination and reduces frequency of watering by at least 50%		2001-2006	Department of Horticulture, Faculty of Agriculture,

					KNUST, Kumasi.
	Technology for Methods for Rehabilitating Degraded Forests and Mined Sites	CSIR-Forestry Research Institute of Ghana has established a suitable time tested methodology for rehabilitating degraded forests and mined sites that cater for the diverse goals of forest management. The methodology provides guidance on land preparation and site-species matching and selection based on measured indicators; stand management as well as fire and tree health monitoring. The method has been designed to promote the use of both indigenous and exotic species for the rehabilitation and restoration of degraded forests and mined sites, respectively.	Diffusion of the technology has been through workshops, seminars and meetings with the officials of the Forestry Commission, mining companies and other relevant stakeholders.		CSIR-FORIG
	Development of mushroom seedlings	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. The launch of the National Mushroom Development Project in 1990 to produce exotic mushrooms such as Pleurotus species brought about small scale mushroom farms mostly for the urban unemployed and as supplementary income sources. CSIR-FRI is involved in cultivation of different kinds of mushroom, spawn multiplication as well as maintenance of the National Mycelium bank.	So far about 4,500 farmers, extension officers, church groups, NGOs and the general public have been trained. FRI trains mushroom growers in compost bag production for sale	1990	CSIR-FRI
	Technology for Mushroom Cultivation	Protein deficiency is one of the major challenges of rural communities in most third world countries. To overcome the challenge, mushroom consumption is being promoted to provide the needed nutrients for good health. However, due to pronounced environmental degradation in most	Large number of people have been trained in mushroom		CSIR-FORIG

		communities, the availability of wild mushrooms is diminishing at an alarming rate. There is therefore the need to domesticate mushroom for sustainable supply.	farming technology at CSIRFORIG.		
	Technology for the Production of Liquid Soap from Agriculture and Industrial Waste	The technology diversifies traditional soap (alata) and has a desirable pungent scent and enhanced colour. Cocoa husk is an abundant agricultural waste in the country. Ash obtained from the husk is used to produce the traditional soap known as alata soap. The IIR liquid soap has been produced under two brands: Golden Pod Liquid Soap and Palbun Liquid Soap. It comes in various colours including its natural yellowish brown. Varying shades of green and blue colouration can also be used. Citronella, lemon and lemon-lime essences are also used to perfume it. Total fatty matter in the IIR liquid soap varied between 20% and 30% matter insoluble in alcohol from 1.8 to 2.4% free caustic alkali from 0.03 to 0.05 and an average specific gravity of 1.08. The main raw materials used for the production of the soap are ash, waste lime and vegetable oil.	Through training for local/traditional soap makers and NGOs working with traditional soap makers and the Central Regional Development Commission		CSIR-IIR