TAILORING BIOTECHNOLOGIES
Vol. 3, Issue 1, Winter 2007, pp: 107-130

Biotechnology Innovations in Ghana: Re-conceptualizing the Role of Stakeholders

George O. Essegbey and Korbla P. Puplampu[1]

Abstract

This paper focuses on the need for re-conceptualizing the role of stakeholders in biotechnology innovations. Governments in several African countries are beginning to engage the role of biotechnology in the national development effort. One major avenue for the engagement is re-conceptualizing the role of the stakeholders in the National Innovation System and the National Agricultural Research System with particular reference to biotechnological innovations. However, the extent to which biotechnological innovations would support the national development effort would depend on the nature of the links among the identifiable actors in the research and innovation system. This paper examines the nature of such links and the role of actors in biotechnology innovations in Ghana. The paper also offers some policy options for biotechnology innovations in Ghana.

Introduction

Biotechnology has become an indispensable tool for enhancing the transformation, dissemination and utilization of biological resources for national development. In predominantly agrarian based societies, as is the case in several African countries, biotechnological innovations could, if properly engaged, provide an important context for socio-economic development (See UNDP, 2001). The conditional role of biotechnology in national development revolves around the extent to which the policy framework can spur innovations within the national agricultural research system. An appropriate policy and institutional framework is required because of the complexities (ranging from pessimism to optimism) that surround biotechnology (See Kelemu et. al., 2003; Wambugu, 2001).

1 The authors acknowledge the kind support of the International Development Research Centre (IDRC), Canada and the Social Science and Humanities Research Council of Canada in the preparation of this paper

A critical ingredient in such a policy framework is how it enhances the role of various actors or stakeholders by forging and creating a platform for dialogue. Specifically, the platform should address the question of what the various stakeholders should be doing to engender biotechnology innovation and its acceptance. Taking the case of Ghana, this paper seeks to examine the institutional framework for biotechnology with the view to re-conceptualizing the role of stakeholders as a means to optimizing biotechnological innovations for development. The paper examines the institutional framework for biotechnology innovation, by focusing on the relationship between the National Innovation System (NIS) and the National Agricultural Research System (NARS). The paper argues that an important means of addressing the relationship between the NIS and NARS is to re-conceptualize the role of stakeholders, particularly among policy makers, researchers and farmers in biotechnology innovations, development and applications.

In what follows, we first provide, in broad strokes, an overview of the state of biotechnology in Ghana, and outline some conceptual and theoretical points underpinning our paper. The next section identifies important components of the NIS. A subsequent section discusses how the relationship between the NARS and the NIS can be enhanced by re-conceptualizing the activities of identifiable actors. The discussion highlights how policy makers, the research community and farmers - indeed, the society at large, can be connected to both the NARS and NIS in order to enhance the role of the latter. We examine the policy implications for forging a stronger NIS and by extension the NARS, before proceeding to summary and conclusion.

The State of Biotechnology in Ghana: An Overview

Biotechnology, broadly defined, involves the transformation of living organisms to make or modify products or processes (See UNEP, 1992). Underpinning the technology are the dramatic breakthroughs in bioresearch, giving rise to a spectrum of technologies comprising traditional and modern techniques such as fermentation and genetic engineering respectively. The emphasis on biotechnology in Ghana is consistent with the general effort by several African countries to establish an institutional framework that would utilize biotechnology for national development (Tzotzos and Skryabin, 2000; Juma and Mugabe, 1997). Consequently, several African countries have made some efforts in building the national capacity for biotechnology.

In a survey of biotechnology development in some African countries, Alhassan (2001, 1999) contends that agriculture biotechnology in Ghana lags

behind South Africa, Zimbabwe, and Kenya. The basis for the lag was in the institutional framework, the technological capacity for key activities of genetic transformations, and the application of the technology in various sectors of the economy. One other problem in Ghana's biotechnology development and application program is how to create the link between the supply and demand ends of innovations (See Essegbey, 2004; Puplampu and Essegbey, 2004).

The crucial issue in Ghana and other African countries is the extent to which the research and innovation capacity can contribute to national development by reducing poverty and enhancing wealth creation. The need to focus on national capacity and biotechnology stems from, as stated earlier, the ongoing debate in the literature about the pros and cons (the optimism-pessimism continuum) of biotechnology. Thus the possibilities for achieving any of the benefits of biotechnology require an appropriate policy and institutional framework, especially with respect to innovation. Table 1 offers an overview of the activities of selected biotechnology institutions in Ghana. These activities of the specific institutions are not mutually exclusive with respect to each sector. The distribution of institutions across the sectors is thus simply for analytical purposes.

Table 1: Biotechnology Activities in Selected Institutions in Ghana

Sector	*Some Institutions /Organisations*	*Examples of Main Activities and Technologies*
Agriculture	Biotechnology and Nuclear Agric. Research Institute (BNARI), Crops Research Institute, Cocoa Research Institute of Ghana (CRIG), Animal Research Institute, Water Research Institute, Soil Research Institute, Savanna Agriculture Research Institute, Plant Genetic Resources Research Institute.	Research into plant diseases and pests (e.g. cocoa swollen shoot virus disease, blackpod and grain stemborers); characterization of genetic resources, conservation of biodiversity, multiplication of planting materials and improvement of varieties. These involve e.g. tissue culture, conventional breeding techniques and mutagenesis.
Health	Noguchi Memorial Institute of Medical Research, Ghana Medical School, Kwame Nkrumah University of Science and Technology (KNUST), Centre for Scientific Research Into Plant Medicine.	Research into human diseases (e.g. malaria, sickle cell anaemia, diabetes, HIV-AIDS); diagnostics and therapeutics. These involve use of MABs, PCR, ELISA, cloning and other molecular biology techniques
Industry	Food Research Institute, University of Ghana, KNUST, CRIG, BioResource Ghana Ltd.	Tissue culture of tree crops, development of new processes and industrial products (e.g. production of miraculin from miracle berry). Involves use of tissue culture and molecular biology techniques
Others	Water Research Institute, Ghana Atomic Energy Commission	Control of invasive plants in water bodies; research into nuclear energy. Involves quality control analysis and irradiation.

In the agricultural sector, researchers have used conventional breeding techniques, based on varietal selection and cross pollination, to produce improved seeds of traditional staples such as maize, cassava and cowpea. Tissue culture has also become a standard technology for a number of agricultural related institutions - BNARI, Crop Research Institute, Cocoa Research Institute of Ghana (CRIG) and some of the science departments of the University of Ghana, Kwame Nkrumah University of Science and Technology (KNUST) and the University of Cape Coast. Farmers have grown tissue cultured planting materials for food crops such as banana, plantain, yam, sweet potato and cassava. Pineapple exporters are also using tissue culture to produce crops that meet the quality standards of the export market - freshness, ripeness and size.

Maize producers have, following successful extension of research findings from on-farm studies, adopted improved seeds of maize (for example *Aburotia, Dobidi, Dadaba* and *Obatampa*), cowpea (e.g. *Asontem, Soronko, Ayiyi* and *Bengpla*), soybean (*Bengbi* and *Anidaso*) and cassava (*Tek bankye*) (Tripp, 1993; Edmeades et al, 1991; CSIR, 2001). Many of the research outcomes in maize research involved a complex interaction among state and non-state actors (non-governmental organizations) and farmers. Given the importance of cocoa to the national economy, researchers at the Cocoa Research Institute of Ghana (CRIG) have also been researching into how to develop a resistant variety of cocoa against the Cocoa Swollen Shoot Virus Disease through mutagenesis using gamma irradiation.

The health sector has also been the site of biotechnology research, with the Noguchi Memorial Institute of Medical Research (NMIMR) as the prominent institution. The Institute, a Level-3 facility, is equipped with fairly advanced laboratory instruments for research activities in virology, bacteriology, parasitology and nutrition. One research goal of the Institute is to develop genetically modified bacterial symbionts as control agents for the ubiquitous mosquito vector of the malaria disease, a major source of morbidity and fatality in Ghana (Brown and Wilson, 2002). The symbionts will be genetically modified to increase their potency against the vectors, specifically Anopheles gambiae. The level of biotechnology application at the NMIMR illustrates the gradual build up of capacity for biotechnology innovation to address national health problems.

In the industrial sector, one biotechnology innovation in Ghana is the production of the miraculin enzyme from the sweet berry. BioResource International (BRI) Ghana Limited in collaboration with Ghanaian scientists and Pharmacia Biotech, a Swedish biotechnology company, successfully produced miraculin enzyme from the miracle berry *Richadelia* (*Synsepallum dulcificum*) (*Biotech.Ghana*, 2000, p.10). The miracle berry is a shrub that grows in the wild. Local communities have the knowledge that the berries, when eaten first, make even the most bitter things taste sweet. Armed with that knowledge, scientists were able to develop a process to extract, stabilize and purify the miraculin-taste-modifier enzyme from the berries. The question, which immediately comes to mind is, to what extent have the role of the farmers been recognized in the appropriation of the miraculin enzyme and what benefit goes to them? The issues of benefit sharing in the exploitation of genetic resources have been very sensitive since the institution of the Convention on Biological Diversity (CBD) (United Nations Environment Programme, 1992). But it is precisely the reason why there is need to reconceptualise the role of the stakeholders.

However the patented enzyme has potential use for flavouring sour foods, beverages and medicaments. BRI holds United States of America Patent No. 5,886,155 for the purification process (*Biotech.Ghana*, 2002, p.10). The patent was taken in the United States to attract American investment. Ghana also has instituted a patent regime with the Patent Law (Act 657) of 2003, which enables the registration of patents at the Registrar-General's Department. Besides, the African Regional Intellectual Property Organization (ARIPO) also offers options for intellectual property rights protection.

The above overview of the state of biotechnology in Ghana suggests the existence of competent institutions and a certain degree of human capital resources. The question, however, is how the activities of the respective institutions engender innovation and ultimately the acceptance of biological research outcomes for development.

The Concept of National Innovation System

Innovation suggests an attempt by various economic agents working in such a way to bring about improvements or advances in their work. In effect, innovation implies a specific behavior and performance, with obvious implications for outcomes (Lundvall, 1992; Nelson, 1993; Mytelka, 2000). Embodied within a system, the National Innovation System (NIS) succinctly underscores the vitality of mechanisms that enhance the participation of stakeholders in the utilization and development of technology. Within the NIS, the emphasis is on how these agents or actors influence each other to generate new forms of knowledge. More importantly, the NIS puts the spotlight on the insti-

tutions and the relationships among the respective actors, drawing on and harnessing their synergies for biotechnology innovation and development (Essegbey, 2004; Njobe-Mbuli, 2000).

The NIS contextually rationalizes the innovation process and its outcomes by focusing on the significant stakeholders and their salient roles. It therefore provides a basis for biotechnology policy innovations for national development. Specific actors and their roles are as follows:

- *formal knowledge bases* - scientists and researchers (mainly research institutions and universities);

- *end-users* of innovations (for example farmers and industrialists);

- *consumers* of produce and or products from end-users;

- *policy makers and government* (the executive overseeing public ministries, departments and agencies, parliament and judiciary);

- *investors* in both the private and public sectors;

- *public information and education institutions such* as the mass media;

- *civil society* organizations, for example, non-governmental organizations, social and political agents.

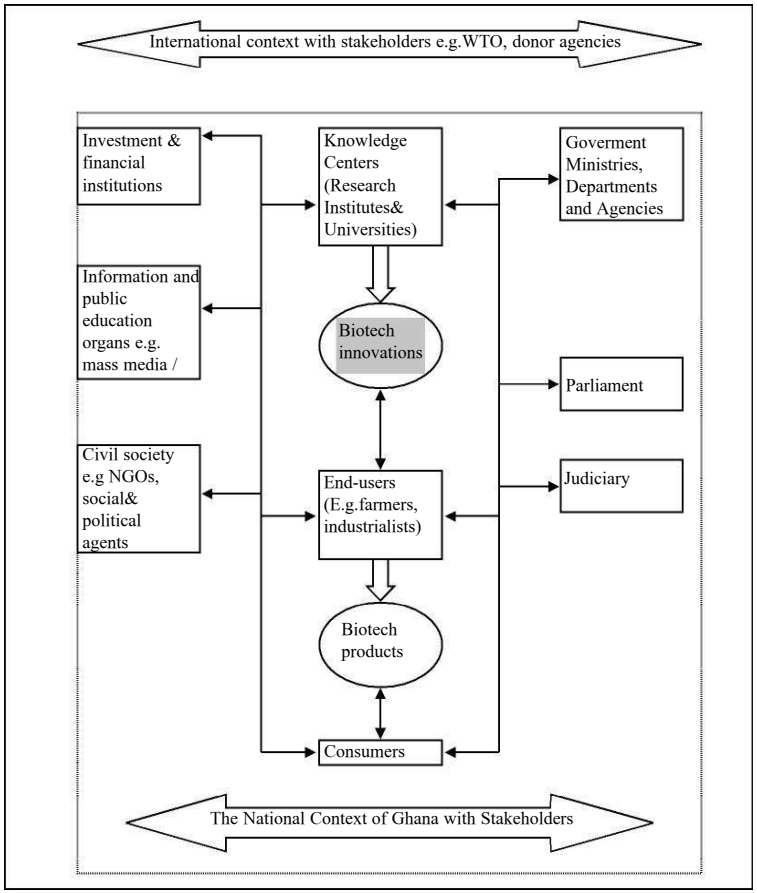
Figure 1 outlines the nature of the roles, linkages and interactions among the various stakeholders in the system. Needless to say, the inter-relationships among the units of the system are much more complex. For example, the knowledge centers acquire or generate knowledge to produce innovations for the respective users such as farmers and industrialists, who in turn produce for consumers. Other actors in both the public and private sections of the society also influence the chain of activities with feedback through various means. The government, for example, through its budgetary allocation directs the activities in the knowledge bases. Investment activities whether from the private sector or public sector stimulate innovations from the knowledge bases.

A national innovation system connotes a closed system given that every country has definitive borders of not only geographical construct, but also political, economic and national boundaries (Lundvall, 1992; Fransman, 1991). The national context therefore receives stimuli and influences from actors in the international milieu. Current trends in globalization and the structure of international trade and politics make the international context as relevant for innovation as the national one. The challenge therefore is how socio-cultural factors. However, the NIS is also an open system because of the inflow and outflow of

innovations, tangible and intangible processes, both within and outside nations are able to cope with their obligations from international institutions such as the World Trade Organization (WTO), the World Bank and the International Monetary Fund (IMF)(Abbott and Young, 2001; Anderson, 2000).

Figure 1:

The National Innovation System for Biotechnology Development in Ghana



Thus, knowledge generated through bilateral and multi-lateral institutions (for-profit or non-profit) would be enabling and constraining in forging biotechnology research and innovations not only in Ghana and other developing countries, but also worldwide (See Puplampu and Tettey, 2000; Puplampu and Essegbey, 2004).

Given their features and respective duties, it is important to draw the relationship between the National Innovation System (NIS) and the National Agricultural Research System (NARS). First, the two systems are related though they are organizationally different. NARS comprises the institutions or organizations and agents who apply knowledge and the products thereof for improving agricultural activities. For instance, the farmer, agricultural extension officer and the Minister for Agriculture are significant as the scientist in the NARS. Second, the NARS is a sub-set of the NIS and shows clear distinctions compared to the NIS. While NARS has an implicit hierarchical logic organizationally, NIS stresses multiple lines of linkage among the various actors in the hope of generating innovation.

Finally, there is an implicit systemic conceptualization of knowledge and the role of farmers in the NARS, but the conceptualization is explicit in the NIS. For biotechnology innovations to have the desired impact in agriculture, it is essential to demonstrate how technology and its transfer would contribute to national development. The demonstration should not only draw on lessons from the relationship between knowledge centers and farmers from the national perspective, but also the detailed knowledge, including risk, available in the international context (See Clark, 2001; 2002). As the following section further demonstrates, it is the nature of the relationship between farmers and the knowledge centers that would account for some of the breakthroughs in biotechnology innovation and application.

Biotechnology Innovations, the NIS and NARS in Ghana

Biotechnology innovations, as stated earlier, entail a complex relationship among various actors within the framework of the agricultural research system. The strides in maize research in Ghana underscore how the link between researchers and farmers could lay the groundwork for biotechnology innovation and application. The role of farmers in the improvement of the Quality Protein Maize (QPM), such as *Obatampa and Dadaba*, highlight their significant role in the innovation and the subsequent utilization process. They adopted the improved varieties of maize not because the researchers developed the

varieties and then 'forced' their acceptance through extension officers. Rather, the farmers were active partners in the research studies that gave rise to the new varieties (See Twumasi-Afriyie et. al., 1999; Tripp, 1993; Edmeades et. al., 1991). Through on-farm trails, farmers and the researchers worked together. The outcome illustrates the capacity of the scientific community in utilizing available techniques and knowledge to address national problems.

In addition to maize research, the innovation with respect to the sweet miracle berry is instructive. First, it aptly illustrates the role of investors in moving biotechnology innovation to the market place. Investors, by definition, are interested in the extent to which the market will reward their work. Investing in and moving the innovation to the marketplace is an indication of their confidence in a successful market product. Second, the miracle berry case shows how the knowledge base of the farmers can serve as a crucial point of departure for biotechnology innovations.

The local community and farmers have had the knowledge that the berry can sweeten almost any bitter taste. This knowledge constituted the foundation for the subsequent work of researchers at the Noguchi Memorial Institute for Medical Research (NMIMR) to extract, stabilize and purify the miraculin-taste-modifier enzyme from the berries. The local researchers have also through the miraculin innovation demonstrated a capacity to explore and build on existing indigenous knowledge. This is a tangible expression of forging relationships that are conducive for the adoption of new technologies that would promote agricultural development.

One aspect of the innovation and extension system in Ghana is the increasing reliance on non-governmental or private sector organizations. In both the maize and miracle berry cases, these organizations were pivotal in the process. Sasakawa-Global 2000, an international NGO, was a major participant in the case of maize while BioResource International, a business organization, was the dominant player in the case of the miraculin enzyme. Put differently, the role of non-state actors has greatly affected the innovation and diffusion system in Ghana (Twumasi-Afriyie et al, 1999). The effect has been positive in these cases cited. However there is need to be aware of potential negative effects or outcomes such as when international NGOs come in to pursue programs, which destabilizes their self-sufficiency.

Indeed, the increasing reliance on non-governmental organizations in agricultural research and development in many African countries has not been problem free (See Puplampu, 2003; Puplampu and Tettey, 2000; Tripp, 1993). Puplampu and Tettey (2000, pp. 257-259), for instance, draw attention to the

emergence of both non-profit and for-profit non-governmental organizations, and thus stress the need to pay attention to the role of each with respect to the agricultural sector. To be sure, many non-governmental organizations have assumed their current role because of the declining capacity of the African state to finance agricultural research and development.

The increasing reliance on non-governmental organizations has given rise to a situation in which policy makers "have come to believe that [they] can leave [agricultural research and innovation] to somebody else, in this case [powerful and sometimes for-profit non-governmental organizations] that can prod, but cannot replace, government service to agriculture" (Tripp, 1993, p. 2012; See also Puplampu, 2003). Thus, an uncritical acceptance of non-governmental organizations would produce "too simplistic an analysis that often results in premature abandonment of public sector" research and development (Clark, 2001, p. 27). As Tripp (1993) argues with reference to maize research in Ghana, a properly nurtured public sector agricultural research system is capable of producing positive results.

The foregoing implies that both government and non-governmental actors have a bearing on the outcome of biotechnology applications and their diffusion. Essegbey (2004) argues that governments in the developing context, such as that of Ghana, should play an imperative role in biotechnology innovation. Government needs to occupy a prominent role in establishing a regime for capacity building; policy and program formulation and implementation as well as priority setting (See also Berman, Puplampu and Tettey, 2003). This is simply because the private sector will not readily fill that gap because of the nature of their orientation.

Beyond the state and non-state actors in the innovation system, there are other broader conditions that need to be considered in order to attain successful outcomes. These include systemic factors, such as the cost and availability of inputs for farming, the prices of agricultural produce and the state of the physical infrastructure. In effect, the nature of agricultural markets and the impact on the allocation and rewards for agricultural inputs and outputs affect the achievement of sectoral objectives. One over- arching factor in the broader perspective is the nature of state agricultural policies. These policies, in turn, stem from or reflect a country's structural location in the global political economy (Puplampu, 2004, 1999; Michelman, 2001; Jebuni and Seini, 1999).

The impact of external policies sustain the argument that the state of agricultural productivity in Ghana has more to do with inadequate inputs, such as fertilizer and weak management systems than with the types of planting materials or genetic resources. That reality also brings to the fore the value of biotechnology in enhancing the positive traits of biological resources. For instance, biotechnology can alter the genetic traits of seeds and produce a seed that can withstand certain diseases or adverse conditions. Biotechnology would then help to ensure that intrinsic traits of local crops could be boosted through the incorporation of the identifiable traits. Furthermore, improvements in seed technology also suggest that farmers would be able to create better products that meet specific needs, and within a shorter period of time. As a result, through the NIS, the limits in yield and resistance to pests and diseases would be better addressed. Genetic engineering therefore offers the precision and accuracy in improving crops because scientists would use modern techniques to carry out their research innovations.

However, biotechnology, without the sensitivities to the local context can also pose problems, for example, to biodiversity. Biotechnology can contribute to the narrowing of the genetic base of the respective crops, a process common in large-scale commercial farming of particular varieties. Where the preferred varieties of the crops are exotic species, the existence of the landraces may be eventually threatened. This imposes greater responsibilities on scientific institutions to ensure the conservation of the country's genetic resources. Although the work of the Plant Genetic Resources Research Institute (PGRRI) (Table 1) illustrates strategic thinking on the part of the Ghana Government, that is not a sufficient condition for the preservation of the genetic stock. The Institute, like many other agricultural research institutions in Ghana, does not have the requisite resources to satisfactorily discharge its role (See Puplampu and Essegbey, 2004). Perhaps the greater challenge is ensuring that the traditional knowledge of farmers or local communities is preserved over time. As shown in the case of the miraculin berry, traditional knowledge constitutes important pointers to scientific inventions and innovations. Currently there seems to be a gap in the institutional arrangements to provide incentives for the preservation of traditional knowledge.

Technology is not without risks. Some of the risks are inherent to the technology or may emerge because of situational (socio-cultural and economic) factors. In the case of biotechnology, the inherent risks may have an impact on both the biotic and abiotic components of the environment. Examples are the possible deleterious effects on non-target organisms and the contamination of the genetic resources of a given area. In the situational realm, for-profit non-governmental organizations (agro-based multinational companies) can dominate national governments and farmers, specifically small-scale producers, to

the point in which the benefits of biotechnology innovations would be minimal to local entities. There are also the culturally-related ethical issues such as public sensitivity over scientists playing God and, as it were, meddling with nature. These are issues that can be properly catered for within the purview of public policy for biotechnology innovation that takes account of the specific socio-economic, political and cultural context of the country.

From the foregoing, the issue is not whether one is for or against biotechnology, but rather the need to focus on the policies and institutions that will provide the necessary platform, if biotechnology is to live up the expectation as the "breakthrough technology of developing countries" (UNDP, 2001b:E-2-1). Indeed, the emerging literature on agricultural biotechnology in Africa has also stressed the need to address policy and institutions issues since that would determine how agricultural biotechnology is harnessed and utilized, the choices that have to be made with respect to the private sector, civil society, biosafety, technology transfer and the patent regime (See Puplampu and Essegbey, 2004; Hickey and Mittal, 2003; Omiti, Chacha and Andama, 2002; Alhassan, 2001, 1999).

Biotechnology Innovation and Application: Re-conceptualizing the Role of Stakeholders

With the state and non-state actors as the dominant players in the NIS, any re-conceptualization of roles, naturally, will entail these actors. Within the policy framework, Ghana, cognizant of the risks associated with biotechnology, has finalized the guidelines for risk assessment of genetically modified organisms including trade on the local marketing and transporting of all types of genetically modified organisms (Quaye et. al., 2004; Owusu-Biney et. al.). The general principles include the need for assessments on the basis of scientifically sound and transparent processes. However, it is also necessary to appraise the politics and socio-economic impact of genetically modified organisms with respect to cultural practices, because the success of any technology innovation requires both objective and subjective conditions.

Each unit of the NIS influences the generation of an innovation. In order to facilitate stakeholder participation, there is the need to streamline communication among the stakeholders. Where there is such a communication, and it is effective, the "anti (non) debate" (Ruivenkamp, 2003, p.2) that highlights the negative potential of genetic engineering is lessened. Otherwise, opposition to biotechnology innovation may become what Ruivenkamp (2003) describes as fundamentally illiberal, overly critical and can be inherently destructive.

Africa has to focus on building the needed capacity for harnessing the benefits of genetic engineering while reducing the risks through an effective regulatory framework (Kelemu, et al, 2003; Mugabe, 2003; Essegbey and Stokes, 1998; UNIDO, 1996).

For the re-conceptualization process to include and go beyond the state and non-state institutions (public, private, national or international), there are four main dimensions to ponder: the new perception of the potential of biotechnology as a generic technology; a demystification of the science and technology; an understanding of the dynamics of the new markets; the centrality of policy and strategy. Firstly, there is the need to perceive the potential of biotechnology as a generic technology, which provides a two-edged dimension for technological progression. One edge aims at the progression of contextual traditional technologies such as grafting techniques, composting and fermentation technologies. The other edge focuses on discontinuous technologies such as enzyme-linked-immunosorbent assay (ELISA), polymerase chain reactions, gene transfers, DNA extractions in the context of modern biotechnology applications. The characteristic and indeed the quality of innovation come with a clearer grip of what modern biotechnology can do and therefore the need for stakeholders to reorient their functions and interactions to the new biotechnology.

For example, an understanding of gene theory is fundamental to biotechnology as a tool for multiple applications across various sectors of the economy. So long as gene is the basis of life, the capacity to manipulate it is the gateway to transforming various life forms. The growing international body of knowledge on genetics, the evolution of genomics, bioinformatics and other related sciences, advances in tools for gene manipulation, the potential of biotechnology as a generic technology has been greatly enhanced. Undoubtedly, new areas of technology gap are emerging with the continued growth in genetic knowledge in the North and only a slow progression in knowledge generation and application in the South.

The 2003 Human Genome Project mapped out the entire human genome. This enormous information has tremendous implications for the health care industry, in areas such as gene therapy. However, Ghana, because of infrastructural inadequacies, has yet to secure access to the totality of the information arising from this project. Addressing this challenge calls for the knowledge bases in the NIS, specifically the tertiary educational institutions and their research institutions, to redouble their efforts in biotechnological sciences, by way or training, research and application. In effect, policy makers in Ghana need to improve upon the conditions in the institutions of higher learning, so

that researchers could satisfactorily contribute to innovation and national development (See Tettey, 2006).

Secondly, science and technology will have to be demystified within the broad framework of science acculturation. There is an unstated perception in the global science community that countries such as Ghana, a Highly Indebted Poor Country (HIPC), should not be getting into the "science game". The unstated argument is that Highly Indebted Poor Countries should stay with poverty-alleviation challenges and not venture into areas apparently reserved for rich countries. The logic here is that modern biotechnology requires expensive capital intensive that poor countries cannot afford.

However, to the extent that biotechnology can address development problems for poor countries, they need to explore the technology to its fullest extent. It all boils down to the part of the spectrum of the constituent technologies that the country invests in and masters. Progress in biotechnology should not be postponed simply because of the HIPC status of a country. Indeed, it is conceivable that countries will explore different aspects of the technology in ways that are consistent with their national needs and technological capacities. However, progress in biotechnology in Ghana should not be postponed simply because of the HIPC status of the country especially as such progress can be made context-specifically. Advances in knowledge are occurring virtually on a daily basis and no country gains by lagging in knowledge.

Thirdly, understanding the dynamics of the new markets is important. The global market for the first generation of rDNA therapeutics is expected to grow over the next six years from about 35,000 million USD in 2004 to about 42,000 million in 2006 and 52, 000 million in 2010, overtaking conventional therapeutics as the leading source of clinical pharmaceuticals (Pavou and Reichert, 2004; 1518). With these blossoming markets, it is not surprising that both public and private sectors are investing heavily in these blossoming markets, even in newly industrializing countries. For example, Taiwan invested 579 million USD in biotechnology research and development between 1998 and 2005, Korea invested 3.8 billion USD in biotechnology by 2002 and India is investing 2 billion USD by 2010 (Ochem, 2006; 4). The key question then is whether Ghana, or any of the Sub-Saharan African countries, can afford this level of investment. The possibilities are there in drawing out the priority areas the country must invest in and thus priority-setting and credible domestic planning should guide the allocation of available national resources.

The fourth dimension of the re-conceptualization is the centrality of research, policy and strategy. The Ghana 2000 National Science and

Technology Policy among other things stressed: the need for a well-coordinated and integrated system of scientific, technological and social innovation within which public and private institutions can interact in an inclusive and consultative approach concerning decision making; resource allocation for scientific and technological activities. The policy also called for improved support for innovations that are fundamental to sustainable economic growth, employment and socio-cultural development (MEST, 2000). In the specific area of biotechnology, the policy aims to promote "the research and application of new technologies including biotechnology, genetic engineering, etc, which hold potential for increasing productivity" (MEST, 2000; 15).

While the pronouncements indicate, to some extent, the intention of policy makers, the implementation of Ghana's policy pronouncement falls far short in several areas. For example, the extent of public investment in research is minimal, existing agricultural research and policy institutions do not have the requisite human and capital resources to establish or sustain a credible research environment (See Puplampu and Essegbey, 2004). The ultimate effect is the reliance on donors to fund research and policy initiatives, a situation that worsens once donor support is exhausted. The crucial link between the knowledge centers and the other sites in the NIS with respect to innovation is thus unsustainable.

The value of the NIS at the conceptual level is its capacity for innovation. Each country has peculiar factors and a specific kind of socio-political cum economic climate that invariably determines the outcomes of the innovation process. Therefore, each country may accelerate or decelerate the process of innovation to the extent that it is able to strategically engage its stakeholders, allocate resources based on clearly defined and verifiable parameters. It also means that policy makers have to engage in consistent attempts to synthesis, if not coordinate, the activities of the diffuse stakeholders in the NIS with an explicit aim of infusing biotechnology innovations into the national development effort. In effect, it is critical to provide the required vital stimuli and incentives for innovation in terms of the enunciated vision and policy, beyond mere political rhetoric.

Conclusion

In this paper, we have argued for re-conceptualizing the role of various institutions within the NARS, against the background of the NIS, with regard to biotechnology innovation. With specific reference to agriculture, some of

the innovations have come about because of linkages between researchers and farmers. That reality suggests that the frontiers of biotechnology innovations in Ghana can be pushed further if the relationship between researchers and their respective groups, as part of the overall research strategy, is at the centre of the policy process. Thus, there is the need for a credible policy framework that can provide the necessary platform for the producers and consumers of knowledge in shoring-up biotechnology innovations for national development.

References

Abbott, P. and L. Young (2001), "State Trading Enterprises and the WTO: Importing Versus Exporting." In Michelman, H.J. et al (eds.) Globalization and Agricultural Policy. Boulder: Lynne Rienner Publishers, 133-150

Alhassan, W.S. (2001), The Status of Agricultural Biotechnology in Selected West African and Central African Countries. Ibadan: IITA Consultation Group on International Agricultural Research.

Alhassan, W.S. (1999), Agricultural Biotechnology - Survey of Ghana, Kenya, Uganda, Zimbabwe and South Africa. Accra: FAO.

Anderson, S. (2000), (Ed.) Views from the South: The Effects of Globalization and the WTO on Third World Countries. Oakland, CA.: Food First Books and International Forum on Globalization.

Biotech.Ghana (2000), "Miraculin Developed for Export", Vol.1 No.2, p.10

Brown, C.A. and Wilson, M.D. (2002) "The Search for Bacterial Symbionts in Mosquitoes for Malaria Control" Biotech.Ghana, Vol.2.No.1, pp. 6-7.

Clark, N. (2002), "Handling the Risks of Biotechnology in the Third World" Technology Policy Briefs, Volume 1, Issue 2, pp. 7-8.

Clark, N. (2001), Innovation Systems, Institutional Change and the New Knowledge Market: Implications for Third World Agricultural Development. Maastricht: United Nations University Institute for New Technologies (Discussion Paper No. 2001-10).

Council of Scientific and Industrial Research (CSIR) (2001), Annual Report 2000. Accra: CSIR

Edmeades, G. et al. (1991), "On-Farm Maize Research in the Transition Zone of Ghana" In Tripp, R. ed. Planned Change in Farming Systems: Progress in On-Farm Research. Chichester: John Wiley, 63-84.

Essegbey, G.O. (2004) "Biotechnology in Ghana: The Challenge of Capacity Building", AgBiotechNet, Vol.6, ABN 123, 1-5.

Essegbey, G.O. and K. Stokes (1998), "Developing a Biosafety Regime in Ghana: Issues and Options for Policy Makers", Science, Technology and Development, Vol. 16 no. 2, pp.32-54.

Fransman, M. (1991), Biotechnology: Generation, Diffusion and Policy - An Interpretative Survey, UNU/ INTECH Working Paper No. 1, Maastricht: UNU/ INTECH.

Hickey, E. and A. Mittal (eds.) (2003) Voices from the South - The Third World Debunks Corporate Myths on Genetically Engineered Crops. Oakland, California: Food First/Institute for Food and Development Policy and Pesticide Action Network North America.

Jebuni, C.D. and W. Seini. (1992), Agricultural Input Policies Under Structural Adjustment: Their Distributional Implications. Ithaca: Cornell Food and Nutrition Policy Program (Working Paper No 31).

Juma, C. and J. Mugabe (1997), "Public Policy and New Genetic Technologies: The Case of Biotechnology in Sub-Saharan Africa." In Bhagavan, M.R. (Ed.) New Generic Technologies in Developing Countries, London: Macmillan Press Ltd.

Kelemu, S. et al. (2003), "Harmonizing the Agricultural Biotechnology Debate for the Benefit of African Farmers". African Journal of Biotechnology, Vol. 2, 11, 394-416.

Lundvall, B-A (1992), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London: Pinter.

Michelman, H.J. et al (eds.) Globalization and Agricultural Policy. Boulder: Lynne Rienner Publishers

Ministry of Environment, Science and Technology (MEST) (2000), National Science and Technology Policy Document, Accra: MEST.

Mugabe, J. (2003), Keeping Hunger at Bay: Genetic Engineering and Food Security in Sub-Saharan Africa, Technology Policy Brief 5, Nairobi: African Technology Policy Studies Network (ATPS).

Nelson, R.R. (1993) National Systems of Innovation: A Comparative Study, Oxford University Press, Oxford and New York.

Njobe-Mbuli, B. (2000) "South Africa: Biotechnology for Innovation and Development." In G.J. Persley and M.M. Lantin (eds.) Agricultural Biotechnology and the Poor: Proceedings of an International Conference, Washington D.C. 21-22 Washington: Consultative Group on International Agricultural Research.

Mytelka, L.K. (2000) "Local Systems of Innovation in a Globalised World Economy", Industry and Innovation, Volume 7, Number 1, June, pp. 15-32

Ochem, A.E. (2006) "New Developments in Biotechnologies: Challenges for Africa", ARCT Ministerial Conference on Frontier Environmentally Sound Technologies (FEST) for Africa's Sustainable Development - the Role of the Diaspora, M-Plaza Hotel, 27th - 29th April, 2006, Accra.

Okafor, N., G. Okereke, E. Miambi and S. Odumfa (1999), Biotechnology for Development in Africa, Proceedings of an International Conference on Biotechnology for Development in Africa: Priorities for the Early Twenty-first Century, Enugu, Nigeria

Omiti, J. R. Chacha and M. Andama (2002) "Biotechnology Can Improve Food Security in Africa" African Journal of Food and Nutritional Sciences, Vol. 2, No. 2, 14-21.

Owusu-Biney, A. (Ed) National Biosafety Guidelines Part 3 - Movement of Regulated Materials and Commercial Releases, UNEP-GEF, NBC, BNARI: Accra

Pavlou, A. K. and Reichert J. M. (2004) Recombinant protein therapeutics - success rates, market trends and values to 2010. Nature Biotechnology, Vol. 22, No 4, Dec. 1513 - 1519

Puplampu, K.P. (2004), 'Research and Development in Africa: An Analysis of Policies and Programs in the Agricultural Sector', in S. Adjibolosoo (ed.), The International Development Program of Activities: What Are We Doing Wrong? Bloomington, IN: Ist Books, 111-138.

Puplampu, K.P. (2003), "State-NGO Relations and Agricultural Sector Development" In Tettey, W.J., K. Puplampu and B.J. Berman (eds) Critical Perspectives on Politics and Socio-Economic Development in Ghana. Leiden and Boston: Brill, 135-151.

Puplampu, K. P. (1999), "The State, Agricultural Policies and Food Security in Ghana (1983-1994)" Canadian Journal of Development Studies, Vol. 20, No. 2, 337-359.

Puplampu, K.P. and G.O. Essegbey (2004) "Agricultural Biotechnology and Research in Ghana: Institutional Capacities and Policy Options" Perspectives on Global Development and Technology 3,3 pp.271-290.

Puplampu. K.P. and W.J. Tettey (2000), "State-NGO Relations in an Era of Globalisation: The Implications for Agricultural Development in Africa." Review of African Political Economy, No. 84: 251-272.

Quaye, E. C. et al (2004), Guidelines for Risk Assessment of Genetically Modified Organisms in Ghana, UNEP/ GEF Project on "Development of National Biosafety Framework", Accra.

Ruivenkamp, G. (2003) "Monitoring Biotechnological Developments: Looking back for finding new perspectives", Biotechnology and Development Monitor, No. 50, March, pp. 2-5.

Tripp, R. (1993), "Invisible Hands, Indigenous Knowledge and Inevitable Fads: Challenges to Public Sector Agricultural Research in Ghana" World Development, Vol. 21, No. 21, 2003-2016.

Twumasi-Afriyie S., Haag, W. and Villegas, E. (1999), "Quality Protein Maize in Ghana: A Partnership in Research, Development, and Transfer of Technology", Breth, Steven A., ed. Partnerships for Rural Development in Sub-Saharan Africa, Centre for Applied Studies in International Negotiations, Geneva, pp. 17-26.

Tettey, W.J. (2006) Staff Retention in African Universities: Elements of a Sustainable Strategy. Washington D.C.: New York

Tzotzos, G.T. and Skryabin, K.G. (2000), (Eds.). Biotechnology in the Developing World and Countries in Economic Transition, Wallingford: CABI Publishing.

United Nations Development Program (UNDP) (2001) Human Development Report 2001, New York: UNDP.

United Nations Environment Program (UNEP) (1992), Convention on Biological Diversity, Nairobi: UNEP.

United Nations Industrial Development Organization (UNIDO) (1996), "Why a Biosafety Protocol?" Genetic Engineering and Biotechnology, Emerging Technology Series, 2, Vienna: UNIDO.

Wambugu, F. (2001) Modifying Africa: How Biotechnology Can Benefit the Poor and Hungry, A Case Study From Kenya, Nairobi.