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Fostering a bio-economy in eastern Africa: Insights from Bio-Innovate

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# Acronyms

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AATF</td>
<td>African Agricultural Technology Foundation</td>
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<tr>
<td>ABI</td>
<td>African Bioscience Initiative</td>
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<td>ASEAN</td>
<td>Association of Southeast Asian Nations</td>
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<td>AU</td>
<td>African Union</td>
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<td>BecA</td>
<td>Bioscience eastern and central Africa</td>
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<td>BGA</td>
<td>Blue-green algae</td>
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<td>BIC</td>
<td>Biotechnology innovation centre</td>
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<td>BIL</td>
<td>Banana Investments Ltd</td>
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<tr>
<td>BIO-EARN</td>
<td>The Eastern Africa Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development</td>
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<td>Bio-Innovate</td>
<td>Bio-resources Innovations Network for Eastern Africa Development</td>
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<tr>
<td>Biotechnology YES</td>
<td>Biotechnology Young Entrepreneurs Scheme</td>
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<td>BIPCEA</td>
<td>Bioscience Innovation Policy Consortium for Eastern Africa</td>
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<td>BIRAC</td>
<td>Biotechnology Industry Research Assistance Council</td>
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<td>CAADP</td>
<td>Comprehensive Africa Agriculture Development Program</td>
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<td>CEO</td>
<td>Chief executive officer</td>
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<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>CSIR</td>
<td>Council for Scientific and Industrial Research</td>
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<td>Danida</td>
<td>Danish International Development Agency</td>
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<tr>
<td>DST</td>
<td>Department of Science and Technology</td>
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<td>DTI</td>
<td>Departments of Trade and Industry</td>
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<td>ETP</td>
<td>Effluent treatment plant</td>
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<td>EU</td>
<td>European Union</td>
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<td>ILRI</td>
<td>International Livestock Research Institute</td>
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<tr>
<td>IP</td>
<td>Intellectual property</td>
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<td>ISAAA</td>
<td>International Service for the Acquisition of Agribiotech Applications</td>
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<tr>
<td>KALRO</td>
<td>Kenya Agricultural and Livestock Research Organization</td>
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<tr>
<td>KBBE</td>
<td>Knowledge-based bio-economy</td>
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<td>KEPHIS</td>
<td>Kenya Plant Health and Inspection Service</td>
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<td>NEPAD</td>
<td>New Partnership for Africa’s Development</td>
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<td>NGO</td>
<td>Non-governmental organization</td>
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<tr>
<td>NSI</td>
<td>National system of innovation</td>
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<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<td>R&amp;D</td>
<td>Research and development</td>
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<td>S&amp;T</td>
<td>Science and technology</td>
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<td>SDG</td>
<td>Sustainable Development Goal</td>
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<td>SEARCH</td>
<td>Southern and Eastern African Regulatory Committee on Harmonization</td>
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<td>Sida</td>
<td>Swedish International Development and Cooperation Agency</td>
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<td>SME</td>
<td>Small and medium enterprise</td>
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<td>Acronym</td>
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<td>SSA</td>
<td>Sub-Saharan Africa</td>
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<td>STI</td>
<td>Science, technology and innovation</td>
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<td>STISA</td>
<td>Science Technology and Innovation Strategy for Africa</td>
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<td>TCBN</td>
<td>Tissue Culture Business Network</td>
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<td>TIA</td>
<td>Technology Innovation Agency</td>
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<td>UK</td>
<td>United Kingdom</td>
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<td>US</td>
<td>United States (of America)</td>
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<tr>
<td>WEMA</td>
<td>Water Efficient Maize for Africa</td>
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Chapter 4
Bioscience innovation systems for an African bio-economy

E Jane Morris, School of Biology, University of Leeds, UK and Julius Ecuru, Uganda National Council for Science and Technology

Introduction

Inclusive socio-economic growth and sustainable development are imperative for Africa. No longer can it be a ‘lost continent’, marginalized by the rest of the world. Already levels of growth are starting to surge ahead of much of the developed world, but for this to be maintained and to translate into sustainable benefits and improved living standards for the population in general, innovative approaches will be essential. Bioscience innovation offers many opportunities for Africa, as described in this chapter.

What is bioscience innovation?

Innovation can occur on many fronts and in many contexts and, as pointed out by Krause (2013), it has become a popular catch-all term that is often used in a fuzzy manner. It is therefore important to define the meaning of innovation as used in this chapter.

We define innovation as the generation of new knowledge or the use of existing knowledge to generate a solution that has not existed before. It involves the incorporation of new knowledge into products, processes and services. Innovation does not necessarily mean ‘brand new’ but could be an approach applied for the first time in a particular country or countries, or could involve new applications or adaptations of an existing technique or initiative.
The concept of innovation has developed markedly in recent years and the field of innovation studies has become a discipline in its own right (Fagerberg and Verspagen 2009). Popadiuk and Choo (2006) describe a variety of types of innovation but for the purposes of this chapter, we refer primarily to technological innovation, which they describe as ‘the knowledge of components, methods, linkages between components, processes and techniques that go into a product or service’. In considering the future for bioscience innovation (which we shall term bio-innovation from here on) in African countries, we therefore need to take into account the integration of bioscience with a wide range of other factors such as intellectual property (IP) management, licensing and knowledge transfer, business development, venture financing and government policies. All of these play a role in bioscience translating to bio-innovation.

Three important and relatively new concepts in innovation are particularly relevant for African bio-innovation. The first is frugal innovation, the second is the innovation systems approach, and the third is open innovation.

**Frugal innovation**

The term frugal innovation was popularized in a special report in The Economist (Woolridge 2010) on innovation in emerging markets. Frugal innovation responds to limitations in resources, whether financial, material or institutional, and uses a range of methods to turn these constraints into advantages. Through minimizing the use of resources in development, production and delivery, or by leveraging them in new ways, frugal innovation results in dramatically lower-cost products and services. Successful frugal innovations are not only low-cost, but outperform alternatives and can be made available at large scale (Bound and Thornton 2012). Frugal innovation may redefine business models, reconfigure value chains and redesign products to use resources in different ways and create more inclusive markets by serving users with affordability constraints, often in a scalable and sustainable manner (Bhatti 2012). What is important for Africa is that researchers and entrepreneurs in developing countries, who are themselves resource constrained, are in the best position to think outside the box and to use creative improvisation to develop products that are fit for purpose and relevant to the needs of local consumers. Business models and organizational structures in the developed world are traditionally designed for the development of advanced products for the affluent few at the top of the economic pyramid (Zeschky et al. 2012), whereas developing countries are not constrained by pre-existing paradigms governing the concept of innovation and so have a real competitive advantage.

To date, examples of frugal innovation in the biosciences are limited in number but show promising signs of future growth. Examples include low-cost eye surgery and affordable water purifiers in India.
The innovation systems approach

The innovation systems approach dictates that there should be an integrated approach to the development of a bio-innovation value chain. An innovation system has been defined as ‘a network of organizations, enterprises, and individuals that focuses on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behaviour and performance’ (Rajalahti et al. 2008), or as ‘the network of institutions in the public and private sectors whose activities and interactions initiate, import and diffuse new technologies’ (Freeman 1987). Lundvall (2010) posits that it is better to look at innovation systems as open, evolving and complex systems of relationships within and between organizations, characterized by intense learning. Figure 1 shows one example of the elements of an innovation system.

Figure 1: Elements of an agricultural innovation system

This concept is especially important for African bio-innovation because it stresses the need to have all the pieces of the jigsaw puzzle function as an integrated system. The elements of a
functioning innovation system need to be communicated, tailored and embedded at national and regional levels. Increased cooperation between stakeholders represents a key component. A study in Kenya (Nyende et al. 2013) highlighted the fragmented nature of the innovation system there, which hinders bio-innovation. Constraints were grouped into those that were financial, human and physical, policy and processes, information and lack of incentives, and home-grown demand. Another study in Rwanda and Kenya (Tigabou et al. 2015a, b) highlighted how the lack of a functioning innovation system in those countries had hampered the introduction of bio-digesters for the production of biogas. Ecuru (2011) studied the emerging innovation system in Uganda and identified a number of gaps, including weak linkages between academia and industry and a need to prioritize research and innovation activities in line with national priorities.

A program such as Bio-Innovate that involves the eastern Africa region as a whole in innovation partnerships provides the linkages between actors so that they all know their specific roles within the innovation system.

For Bio-Innovate to achieve success it is important that functioning innovation systems develop at both national and regional levels.

The concept of a national system of innovation (NSI), embedded in the policies of many governments around the world, has been defined as ‘the system of interacting private and public firms (either large or small), universities and government agencies, aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, inasmuch as the goal of the interaction is the development, protection, financing, or regulation of new science and technology’ (Niosi et al. 1993). Historically, there have been major differences between countries in the ways in which they have organized and sustained an NSI within their national economies (Freeman 1995), and it is, therefore, essential that countries collaborating in the innovation space should try to harmonize their NSIs in a regional context.

Open innovation

The concept of open innovation was introduced by Chesbrough (2003), who identified that firms were increasingly utilizing external knowledge sources through partnerships and alliances in order to maintain their competitive advantage. Chesbrough’s initial model was focused on firms in developed countries, but more recently increasing attention is being paid to public institutions and the relevance of the concept to developing countries. Vrgovic et al. (2012) proposed that small and medium enterprises (SMEs) in developing countries should collaborate with independent inventors and marketing companies to improve their innovativeness using a communication network supported by government. Their model suggests that a product idea generated by an SME would be tested by a linked marketing agency, and if evaluated as
feasible it would be forwarded to a networked pool of inventors. A study in South Africa (Gastrow 2011) revealed that there is already a high level of collaboration between SMEs and other organizations involved in the biotechnology sector. These studies as well as others have recognized that the implications of open innovation need to be incorporated in national and regional innovation policies (Karo and Kattel 2011).

The concept of open innovation is now being extended to collaborative projects that are not (at least initially) driven by the private sector, or where the primary intention is to deliver social benefit. An example is the Golden Rice project, which has been a collaborative technological success, utilizing intellectual property from many different sources. However, the lack of some complementary elements of the open innovation system has hampered successful deployment (Kowalski 2015). The majority of projects supported by the Bio-Innovate program have also been driven from a collaborative technological perspective, and it has been recognized that for these projects to reach the marketplace, additional involvement of the private sector and others with marketing and business development know-how will be necessary.

Innovation systems for an African bio-economy

A bio-economy can be thought of as a world where biotechnology contributes to a significant share of economic output (OECD 2009). There is an increasing emphasis on bio-innovation and the development of a bio-economy in many countries around the world. Where then do African countries stand in regard to the development of a bio-economy?

The only country in Africa to have formally produced a bio-economy strategy is South Africa (DST 2013). Nevertheless, there is considerable discussion about the stimulation of a bio-economy, as evidenced by presentations at the meeting of the African Science Academies held in November 2013 with the theme ‘Biotechnology for Africa’s development’ and the theme of the International Consortium on Applied Bioeconomy Research conference ‘Bio-economy and development’ held in Kenya in June 2014. In Ethiopia, an NGO, Bio-Economy Africa, has been established to implement pro-poor agricultural and environmental solutions (Hamilton and Mohammed 2012). The recognition of the importance of a bio-economy is linked to the need for innovation systems that ensure sustainable use of resources to create opportunities for new bio-based companies in food, agriculture, health, energy and industrial applications.

It is, however, vital that such innovation systems for the development of an African bio-economy should lead to inclusive growth, which does not widen the gap between rich and poor. In this regard, small-scale users become important actors to be targeted for growth of an African bio-economy. Henry and Trigo (2010) reviewed a range of bio-economy opportunities with potential application in small-scale rural settings and found that varying levels of research and technology delivery and/or policy interventions were needed to
optimize their suitability and subsequent diffusion. Clearly any effective bio-economy strategy needs to address the development of capacity in these areas.

What needs to be put in place?

If bio-innovation and the bio-economy are to take off in Africa, all elements in the bio-innovation eco-system must be firmly embedded. Since most research and innovation in Africa is publicly funded, often by donor organizations, it is useful to refer to the OECD publication on commercializing public research (OECD 2013). This document outlines the structural factors and policy actions that characterize the generation, transfer and commercialization of knowledge. The OECD lists the following strategies and policies to enhance the transfer and commercialization of public research:

Legislative and administrative reforms to provide certainty and clarity in the legal framework and to encourage public research institutions and universities to protect and commercialize their IP.

• Capacities to link with the external environment through bridging and intermediary organizations.

• Incentives for collaboration to induce ‘open innovation’ including licensing and joint ventures.

• Collaborative IP tools and funds to coordinate and execute knowledge and innovation activities.

• Mechanisms to facilitate the flow of knowledge and research data.

• Recognition of researcher participation in the commercialization process.

• Supporting the emergence of entrepreneurial ideas from public research.

• Financing of public research-based spin-offs.

To these can be added other essential components for bio-innovation that are particularly relevant for developing countries, some of which are discussed in another OECD document (OECD 2012):

• Relevant, good quality research

• Access to relevant technology from the developed world

• Education and human capital

• Appropriate research incentives
• Entrepreneurship education
• Expertise to evaluate an invention
• Market knowledge
• Ability to develop a business plan
• Funding at all stages from proof-of-concept to pilot-scale development.

Meanwhile, in spite of the limitations, there is considerable innovation taking place in Africa, as shown by a study in Ghana (Fu as reported in SciDevNet 2014) though most of it is incremental and little knowledge is coming from outside the country. Policies that build all the components listed above are essential to stimulate more innovation in future.

Where can Africa be competitive?

Despite the many limitations, a number of countries on the African continent are turning a corner and putting in place reforms and initiatives that will stimulate bio-innovation. This is driven at a high level through the policies of the AU and the NEPAD (Mugabe and Ambali 2006), supported by a variety of knowledge partnerships within Africa and also with developed countries (Obambo 2013). Nevertheless, it is important that the continent is not just playing catch-up, but using its ingenuity and inherent competitive advantages to leapfrog into a leading position in niche areas.

There are many opportunities where African countries can be competitive, either through adapting, adopting and applying bioscience technologies originating elsewhere in the world, or through exploiting some unique factor such as its biodiversity and indigenous knowledge. For eastern Africa, the primary focus for competitive innovation must be improving food security and livelihoods. Socio-economic scenario forecasting shows that with growing populations, food security will remain a major challenge, even more than environmental well-being (Vervoort et al. 2013).

For food security, innovations that improve the food supply will be of enormous benefit. Apart from the many opportunities to increase agricultural production, one necessary intervention is the reduction of postharvest losses. A study in Tanzania identified cumulative postharvest losses of 40–45% of farm outputs for maize and sorghum, due to insect pests, fungal infections, termites, rodents, wild animals, theft and birds (Tefera and Abass 2012). There are significant opportunities for bioscience innovation to reduce losses, for example through the use of bio-pesticides, anti-microbials and natural biodegradable coatings and packaging. However, additional crop-specific research is needed (Kitinoja et al. 2011).
African indigenous crops such as vegetables with high nutritive value have been neglected as food crops even though over 1000 species of plants are used in traditional diets in sub-Saharan Africa (Muhanji et al. 2011). With the development of improved varieties and business support, many of these crops have the potential for high market value, both locally and for export.

Many African indigenous plants also hold potential value as herbal medicines. While herbal medicines are widely used among local communities and may in fact be commercialized, their use in mainstream medicine is difficult due to the costs and complexities of proving safety and efficacy in order to register a product (Ndhlala and van Staden 2012). Yet Africa’s vast biodiversity could well yield new breakthroughs in medicine, and traditional medicines are increasingly a focus of attention both in terms of research and in terms of defining the requirements for validation and registration (Addae-Mensah et al. 2011).

Agro-processing is another area with enormous potential for Africa by adding value to primary agricultural production, both through increased employment in agro-processing activities and increased demand for primary agricultural produce. Many eastern and central African countries, including Ethiopia and Burundi, export more than 75% of their agricultural produce without processing. Kenya and Tanzania have increased the degree of processing to more than 30% of exports, but this figure is still low in comparison with South Africa, which processes more than 75% of its agricultural exports (Roepstorff et al. 2011). However, on a positive move, the Kenyan government, as part of its Vision 2030, has indicated that it will establish a number of agro-processing parks for SMEs to stimulate the agro-processing industry.

Agro-processing can be carried out at community level but needs to be integrated into the overall value chain. Ouma and Jagwe (2010) use the example of the banana value chain in central Africa, where banana beer is produced as a cottage industry but there is a lack of integration with higher-value markets due to a lack of quality standards. A more positive example comes from South Africa, where traditional herbal honey bush and rooibos teas have made the leap from a local cottage industry to a global market (Joubert et al. 2011). Some Bio-Innovate projects are focusing on agro-processing opportunities, such as the development of new products from sorghum and millet.

However, agro-processing also has a negative aspect in that it can produce waste and the discharge of untreated or partially treated wastewater. Waste from agro-processing has the potential to be used for production of biogas or as animal feed. In some cases high-value products can be extracted from the waste, such as bromelain from pineapple or papain from papaya. Integration of agro-processing, energy recovery and water reuse for economic activities, especially in the agricultural sector, requires more attention (Njau et al. 2011).

In addition to the specific issues around agro-processing wastes, there are wider opportunities for Africa to become competitive in environmental remediation and waste beneficiation. One promising opportunity is in phytoremediation, where plants are used to remove pollutants...
such as toxic heavy metals or organic pollutants in the environment (Nwoko 2010). These plants often are used as filters in constructed wetlands, but a variety of techniques are available. This is one area that Bio-Innovate (and Bio-EARN before that) has supported. Phytoremediation is often a low-cost alternative to conventional remediation and a recent survey of the field revealed that developing countries are putting increasingly more resources into research in this field (Koelmel et al. 2015).

The examples given above are not intended to be comprehensive, but to give some idea of the opportunities available. Bio-Innovate projects address opportunities in a number of the areas discussed above, and the Bio-Innovate program is addressing the need to build functional innovation systems in these areas.

**Conclusion**

For African countries, and eastern Africa in particular, to embrace the opportunities offered by bioscience innovation and for a bio-economy to develop, an integrated approach will be necessary, involving scientists, government, the private sector and donor organizations working together towards a common goal. Bold initiatives and visionary thinking are needed to build the systems to link key competencies and skills necessary to develop a vibrant innovation system for a bio-economy. Nevertheless, Africa has such a wealth of opportunities that the future for a bio-economy looks bright.

**References**


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