Opportunities and Resources for Agbiotechnology Research and Innovation: What Lies Ahead for Aspiring and Young Scientists in Kenya?

Report of a Preliminary Study

Cassava plant, Machakos District, Kenya.

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Executive Summary

This report summarizes the results of an exploratory study that examined the experiences and observations of bioscientists and managers regarding several elements of the bioinnovation ecosystem in Kenya. It concentrated on demand development, applications and resources available to stimulate bioagricultural research and commercialization (non-veterinary).

The report identifies what scientists themselves say constrains commercialization of the bioscience research they carry out. It outlines specific resources they that they need to move forward. And indicates actions recommended to realize the many benefits that can be derived from bioinnovation including increased access to sufficient, safe and nutritious food for the population of Kenya.

The report cites thirteen issues that merit further investigation. One is the innovation management system and processes in place where scientists work. These systems and processes likely affect the motivation, performance, entrepreneurial aspirations of scientists and bioinnovation that occurs. The report, though limited in scope, provides an indication of what lies ahead for young and aspiring scientists who seek to create and commercialize intellectual property in agbioscience for the benefit of the nation.

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Purpose of Exploratory Project

The purpose of this preliminary study was to explore the feasibility of carrying out a large-scale, comprehensive examination of biotechnology research and commercialization by scientists and other entities in Kenya across multiple domains (e.g. agriculture, health, industrial, etc.). This beta test examined only bioagriculture (non-veterinary). It concentrated on opportunities and resources for innovation.

Agriculture was selected as the start point owing in part to widespread recognition of large-scale food insecurity in the country. Agriculture is the basis for economic growth, and employment creation. The sector accounts for 51% of GDP directly or indirectly. It provides over 60 percent of informal employment in the rural areas and more than 18 percent of formal employment. It is therefore "the mainstay of the country's economy and the custodian of food for the growing population…" (Republic of Kenya, 2012, p. 1). Biotechnology is not a panacea since agro processing machinery and equipment, irrigation as well as political, economic, ecological and other factors clearly affect agricultural productivity and therefore food security. However, multiple stakeholders in science and business have recognized that traditional and modern biotechnology can be a source of increased efficiency and significant innovation in ensuring that people have access to sufficient, safe and nutritious food.

Scientists in academic, research, and other organizations within Kenya have been called upon to think like bioentrepreneurs in order to enhance the social and economic well-being of individuals within the nation (JKUAT, 2012). Thinking this way requires that scientists identify and act on opportunities to create products of social and economic value from the bioscience research they conduct. The latter requires resources. Specific resources that aspiring and existing scientists need in order to pursue opportunities now and in the future are addressed in this report.

The report identifies what scientists themselves say constrains commercialization of the bioscience research they carry out. It outlines specific resources they that they need to move forward. And indicates actions recommended to help realize the social and economic benefits that can be derived from bioinnovation within Kenya.

Previous Research

This study was unique because the focus was on scientists' experience and observations. It did not focus on farmers, consumers or other entities that play an important role in translating present and future intellectual property created by scientists into products of social and economic value. Among other issues, existing research has examined:

a) scientific projects (Igbatayo 2012),

b) use of biotechnology techniques such as tissue culture, marker assisted selection, RNA/DNA sequencing/synthesis/amplification (Olembo et al., 2010)

c) the yield from and economic impact of these bio-techniques (Kabunga et al 2012; Muyanga, 2009)

d) biosafety (Mugo et al 2011)

e) the technical and marketing efficiency of farmers (Nzioka, 2009),

f) the history of government policy (Wambugu et al., 2011),

g) public private partnerships (Mabeya and Ezezika, 2012)

h) the attitudes of farmers, consumers or gatekeepers toward biotechnology (Kimenju et al., 2011)

i) scientific evidence regarding GM crops (Khush, 2012)

j) other issues such as action by international organizations, government ministries, academic and scientific institutions in or outside Kenya (AU-NEPAD 2010, UNCTAD 2010)

Institutions and Participants

Sampling was purposive. The aim was to obtain a wide variety of individuals engaged in biotechnology research able to observe and comment on the status of agbio research and commercialization of it in Kenya. The sample included scientists at Jomo Kenyatta University of Agriculture and Technology, the University of Nairobi, Kenyatta University, Strathmore University, Moi University and Egerton University as well as public research institutes such as Kenya Agricultural Research Institute (KARI) and Kenya Medical Research Institute (KEMRI) along with councils and/or ministries within the Government of Kenya (GOK). The total number of participants was of less concern than the representativeness across institutions. They numbered twenty-three.

Participants in this preliminary study collectively had 188 years of experience in conducting biotechnology research with 134 years of experience operating within the context of Kenya. Approximately one-third managed scientists and/or scientific institutes/ organizations. Thirty-three percent reported that they were the primary decision-maker/key expert in their organization. All were born in Kenya. Half earned their advanced degree outside the country in South Africa, Japan, the US, Canada, Germany or the UK. In total they managed 2080 scientists and supervised 108 post-doctoral or graduate students (PhD or MSc).

Results are reported using simple descriptive statistics. The small number of respondents prohibits use of sophisticated statistical analyses that depend upon having a large data set with hundreds of participants. It also calls for caution in drawing conclusions about opportunities and resources available to agbio scientists in the whole of Kenya. However, the background, experience and current responsibilities of the respondents suggest that they are intimately aware of conditions that face recent and potential entrants into science and technology careers in Kenya. Moreover, they are capable of assessing these both in the absolute and relative to other countries within and outside the continent of Africa.[1]

Method

All participants in the project agreed to complete the survey(s) voluntarily. They were promised confidentiality and provided informed consent. The terms of the project indicated that "no personal information about you will be shared with any person or organization". Thus, the respondents remain nameless and any information that would identify them has been omitted below in order to honor these terms. The project plan calls for follow-on interviews to clarify responses and further explore questions raised by participants in this preliminary study. These have not yet occurred.

Initial project activities focused on developing an interview protocol and written survey to gauge the following:

- Ongoing biotechnology research with agricultural applications
- Perceived demand for applications of biotechnology research and shifts thereof
- Valuable resources obtained by scientists at no cost, if any
- Intellectual property created and protected by patent
- Factors that enhance or limit biotechnology research, technology development and commercialization in Kenya
- Specific constraints that hinder commercialization of processes, tools, ideas derived from biotechnology research and the extent to which scientists have been able to overcome these obstacles
- Impact of resources available on the advancement of science, technology and innovation for the population of Kenya, scientific institutes/academic organizations and scientists
- Action recommended to enhance the nature, amount and potential commercialization of biotechnology research that will produce the largest social and economic benefit to people in Kenya

The interview protocol was unstructured. The survey was semi-structured. The open-ended questions permitted respondents to write lengthy responses and to raise questions/issues not initially included such as the link between ICT connectivity and bioinnovation. The project team pre-tested the draft survey so as to insure that the questions were relevant, covered issues important to scientists, managers and policy makers and clearly written. Twelve scientists engaged in biotechnology research and commercialization outside Kenya provided feedback on the draft survey. Feedback from these scientists was used to modify and design a suite of survey tools. Half of the respondents in Kenya who participated in the project received and returned the survey in-person. The remaining half received and returned the survey(s) electronically. Missing data on one or more items precluded using fourteen of the surveys returned.

Suite of Survey Tools

The suite of tools created as part of the project incorporate many more issues that those identified above. Additionally, it assesses:

a) the abilities and attitudes of scientists toward bioentrepreneurship

b) the management, systems and processes that affect innovation within the organizations at which scientists work, and

c) a wide range of government policies and implementation thereof to stimulate bioentrepreneurship and bioinnovation within Kenya.

The tools are modular in design. They can be used to zero in on particular factors such as policies that affect business opportunities from the vantage point of those who shape, implement and are affected by policies. Or, they can be used together to provide a multi-level, multidimensional picture of many factors simultaneously such as selected characteristics of scientists (abilities, attitudes, social capital), management processes to stimulate innovation in organizations, and policies that affect the likely success of new ventures.

The model upon which the suite of tools was created incorporates but extends well beyond *general* factors such as communication, culture, commercialization and capacity-building identified in recent case study research (Ezekiel et al 2012). The suite includes *specific* questions concerning more than ten factors and six potential channels of government intervention that affect the choice of and likely success of efforts by scientists and others to develop biobusiness opportunities. Moreover, each of the six potential channels of government intervention includes several actions that affect the factors.

Most variables are measured with multiple items so as to estimate the reliability of responses and calculate the validity of the indices developed. Ultimately, the aim is to use multivariate models and statistics to test hypotheses concerning the relationship among sets of factors that are likely to affect the choice of scientists to engage in

bioentrepreneurial activity in Kenya and in other developing countries. The intent is to better understand exactly what factors are important and how they operate in this and other contexts.

The suite of tools created differs markedly from surveys that have been used in other countries such as New Zealand or South Africa. The latter emphasize outcomes of biotechnology research and commercialization, not inputs or processes. They provide valuable information. However, it is difficult to diagnose strengths and weaknesses in the bioinnovation ecosystem in these countries based upon the survey data obtained. See, for example, Bascand 2011 and Mulder and Henschel 2003. Additionally, the questions included in the suite of tools can be used to examine and test assumptions concerning entrepreneurial activity and innovation across a wide variety of sciences and types of technology (e.g. biomedical engineering, renewable energy technology)

Results

Ongoing Research and Commercialization Activity by Scientists

The OECD defines biotechnology as t*he application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.* Biotechnologies include: nanobiotechnology, bioinformatics, gene and RNA vectors, process biotechnology techniques, cell and tissue culture and engineering, sequencing/ synthesizing/engineering proteins and other molecules as well as genomics and related tools/methods (OECD, 2011). Applications can be found in health (red), agriculture (green), marine (blue), environmental management and industrial operations (white). This is a broad definition that includes technologies that both do and do not involve genetic modification of organisms.

Ruane and Sonnino (2011) describe how various techniques aside from genetic modification such as mutagenesis, interspecific hybridization, marker assisted selection, micropropagation and microbiologically based biotechnologies have been used for the genetic improvement of plant varieties, characterisation and conservation of genetic resources, diagnosis of plant diseases and other purposes in developing countries. Scientists who participated in this project engaged in research using many of these techniques. Although all the research concerned agriculture (including pests and other ecological factors such as drought) there was considerable heterogeneity in the work they performed (e.g. characterization, selection, optimization of techniques, development of tests, analyses of production of fruit, vegetables and other crops). None indicated they were engaged in bioprocessing, bioinformatics or nanobiotechnologies.

Twenty percent of the project participants had applied for or obtained a patent in Kenya or elsewhere. Seventeen percent had created intellectual property but not yet applied for a patent. Thus, the set of scientists surveyed included not only individuals actively attempting to create and commercialize new scientific knowledge but successful in developing intellectual property (new, valuable and useful).

Demand

The scientists were asked to estimate demand for the application of their research by end users and identify how they arrived at this estimate. Sixty percent indicated that demand for the application of their research was unknown. One scientist said demand was not possible to quantify at the moment owing to the stage and nature of the research – still at basic level. The remainder estimated demand as high and cited the following reasons for their estimate: feedback from farmers, expression of interest by consumers and enthusiasm by developers, other survey results, trial commercialization efforts or the fact that the products are staple foods for most Kenyans (e.g. cassava and sweet potato).

Shifts in Demand

Shifts in demand often stimulate innovation (Drucker 2006). A question on the survey asked scientists, “Has there been any shift in demand (rise/decline) for the nature of biotechnology research you carry out and potential application of it in the recent past or expected in the near future?” Several indicated that demand has been and is expected to be consistent in the future – no shift. Several said unknown. And the remainder (half) indicated they anticipated increased demand. They noted that any rise would depend upon: a) the performance of technology in the field, b) acceptance, interest in and perceived impact of the technology by stakeholders, and c) availability of funding and other resources.

The Hindi term “jugaad” captures the essence of frugal innovation – an innovative fix applied especially under severe resource constraints (Radjou et al 2012). Scientists indicated that available resources and access to these as well as other elements in the bioinnovation support system within Kenya are so meager that achieving even frugal innovation will be difficult in the future. One characterized the current situation as “bleak". According to the scientists who estimated *and* who did not estimate demand and shifts, there is a “short” in the connection between changes in demand and the social and economic benefits that can be derived from bioinnovation in Kenya. A diagram of the sequence they described is shown in Figure 1.

Scientists and managers commented on other factors that affect demand. These were:

- Increased acceptance around the world of biotechnology products in agriculture, industry and other areas (e.g. China, India and Europe)

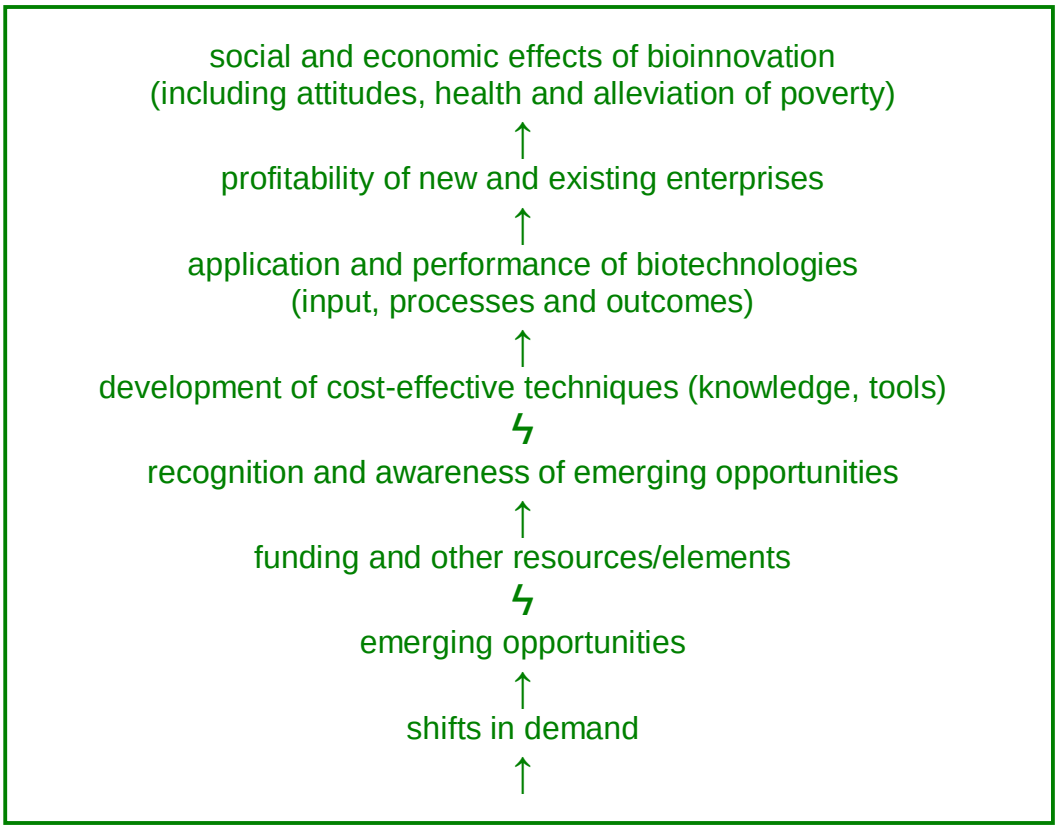
- Changes in biotechnologies including much more powerful and less expensive tools than in the past

- Increasing resource scarcity provoking the need for increased cost effectiveness

- Changes in the interests and behaviors of consumers (health and diet) revolving around positive living.
- Better understanding of regulation
- Development of policy frameworks

Figure 1

Diagram of "Short" in Connection between Changes in Demand and Social and Economic Benefits from Bioinnovation in Kenya



Valuable Resources Obtained at No Cost

The majority of scientists indicated that they received few, if any, "free" resources to supplement/substitute for resources unavailable to them. Resources obtained at no cost from others included: regulatory advice, open discussion and consultation, cooperation from different bodies, FTOs (genes) from companies and universities outside Africa and some diagnostic equipment. A couple indicated that they received substantial external support.

General Factors that Limit Biotechnology Research, Technology Development and Commercialization (RTD&C) in Kenya

Scientists identified four sets of factors that limit RTD&C. Summative content analysis indicated that thirty-five percent of the statements dealt with financial, human and physical constraints. These included:

- Inadequate equipment
- Lack of critical mass of experts
- Insufficient funding for research and for commercialization
- Lack of capacity (human and equipment)
- Inadequate personnel in biosafety and diagnostics for GMO
- Lack of sufficient modern molecular laboratory facilities
- Inadequate funding for upscaling and technology transfer
- Inconsistent funding throughout the life cycle of product development
- Lack of entrepreneurial skills among scientists
- Brain drain

Thirty percent of the statements dealt with policy and processes. Scientists cited:

- Lack of clear policy
- Regulation - not clearly articulated
- Institutional red-tape
- Lack of government and political goodwill
- Slow decision-making and bureaucracy
- Corruption, both perceived and not perceived
- Poor cooperation among stakeholders
- Government interference (manipulation of existing structures and institutions)

Thirty percent of the statements dealt with information. These included:

- Negative perception of biotechnologies
- Scientific myths
- Public unawareness of the importance of the technologies
- Disinformation from activists
- Scientists not aggressive in disseminating information
- Conflicting information from political players
- Lack of awareness of the economic potential of the technology
- Lack of awareness of the potential to commercialize products

Five percent dealt with demand. These comments addressed:

- International markets
- Lack of homegrown demand/low demand for biotechnology products

- Lack of incentives
- No clear indication of the actual demand for the technology once commercialized

Resource Constraints that Have Constantly Hindered Commercialization of Processes, Tools and Ideas Derived from Biotechnology Research in Kenya

Scientists. Scientists specified thirty-five resource shortages that have *constantly* (not episodically) thwarted commercialization of processes, tools and ideas derived from biotechnology research in which they have been involved. These constraints are listed in Table 1. Three respondents stated that they had overcome any resource shortages they had encountered but did not explain how, or, had encountered no constraints. Follow-up interviews are required to better understand how they surmounted any obstacles they met. One scientist described how s/he operated within the constraints. And the remainder indicated they were unable to overcome the constraints they faced.

Table 1

Specific Resource Constraints that Have Constantly Thwarted Commercialization of Processes, Tools and Ideas Derived from Biotechnology Research in Kenya

- Research databases
- Collaboration with colleagues outside own organization but within Kenya
- Access to information about business creation*
- Professional development*
- Business connections
- Proof of concept center*
- Bioincubator
- Bioaccelerator
- Links with suppliers (including burdensome procurement processes)*
- Tools/equipment
- Funding *specifically* aimed at enhancing biotech business development*
- Loan from bank or other source (debt)*
- Link with member of Kenya Diaspora*
- Professional/scientific organization

Table 1 (cont'd)

Specific Resource Constraints that Have Constantly Thwarted Commercialization of Processes, Tools and Ideas Derived from Biotechnology Research in Kenya

- Mentor
- Friendships formed in past
- Scientists who work in the same organization
- Business consulting*
- Competitive research grant*
- Collaboration with individuals in Africa
- Work with scientists in organizations *outside* Africa*
- Collateral (land) and/or bank credit*
- Private investor/investment group*
- Venture capital from large MNE in industry*
- Electricity, water (blackouts)
- Intellectual property created by others
- Rewards
- Time
- Staff
- Support from foundation(s)*
- Facilities*
- Patent application and enforcement assistance
- Technical assistance with national and international inspection, registration, certification
- Administrative assistance in contract/grant reporting

Managers. Each of the resource constraints identified by managers is denoted by an asterisk in Table 1. The number of respondents in this pilot study prohibits carrying out statistical analyses of differences between the responses of managers and scientists. It appears however, that the managers who participated in this project placed less

emphasis than scientists on collaborative relationships of all sorts as resources that are essential but in short supply. Their responses focused primarily on tangible and financial assets. They did not, however, mention rewards or lack thereof. Managers also cited fewer resource constraints overall – approximately half.

Effect of Resource Constraints Identified on the Advancement of Bioscience and Innovation in Kenya

Participants were asked to specify the impact of each or all of the resource constraints they identified on the population of Kenya, the organization at which they work and on themselves as scientists. Table 2 summarizes the effects that they identified. Duplicate ideas were collapsed together and listed as one (e.g." few individuals come out to participate in scientific biotechnological research due to perceived constraints"; "less researchers interested in conducting research").

Table 2

Effect of Resource Constraints on the Advancement of Bioscience and Innovation in Kenya

- Cannot do applied research so cannot innovate to improve technology so population cannot benefit from current technological advancements
- Less products rolled out in the market
- Level of scientific productivity and output is low; less research/scientific output
- Low level of appreciation of the power of research in the community
- Inadequate resources mean that scientists spend a lot of time looking for funding. This is time that could have been spent on research.
- Without funding nothing much can be done; Cannot carry out even basic research due to poor facilities (lab equipment)
- Scientists peg their research on the facilitation they get not the end product
- Lack of ownership of what scientists produce due to skewness in the proposal writing process

Table 2 (cont'd)

Effect of Resource Constraints on the Advancement of Bioscience and Innovation in Kenya

- Unviability of important projects that require complex but unavailable facilities
- Cannot carry out research using microorganisms with potential for respiratory transmission because existing facilities do not have adequate barriers to protect laboratory personnel and the environment from infectious aerosols
- Cannot carry out research with laboratory assistants owing to lack of space
- Scientists have to network at professional conferences and workshops at personal cost since only partial sponsorship is provided to participate
- Duplication of efforts; Incomplete research projects
- Few individuals come out to participate in scientific biotechnological research due to perceived constraints; Less researchers interested in conducting research
- The personal ambitions of scientists, expected achievements in the organization and contributions are constrained

Action to Increase Amount and Commercialization of Agbio Research in Kenya

Participants were asked to identify what *single* action is the fastest, easiest and least expensive method of enhancing the nature, amount and potential commercialization of biotechnology research that will have the largest social, professional and personal benefit. One third of respondents indicated "unknown" in response to this question. Two-thirds identified what they thought was the single most important action that should occur in order to accelerate commercialization of biotechnology research in Kenya. The ideas they offered are listed in Table 3.

Table 3

Action Recommended by Project Participants to Enhance the Nature, Amount and Potential Commercialization of Biotechnology Research in Kenya

- Establish a *country* vision on uses of biotechnology
- Increase public awareness on the importance of the technology and capacity building
- Involve every person in his or her capacity to help
- Establish policy that affects biotechnology that is in line with existing laws; Policy change
- Government and other institutions should take the lead in opening up biotech research and collaboration and implement policies that will not curtail the same.
- Formulation of research projects that incorporate all elements of the value chain
- Availing research funds
- Linking research to local needs
- Legislation of biotechnologically developed products which have been tested to full biosafety measures
- Remove prohibitive regulations like labeling
- Protecting intellectual property
- Greater use of electronic media to network with others

The survey distributed to project participants did not specifically ask scientists and managers about government policies, management practices in place to stimulate innovation within the organizations at which they work, or the capabilities (abilities, attitudes and preferences) of scientists. It focused only on demand, development, applications and resources available for biotechnology research and commercialization in Kenya. Nevertheless, project participants indicated that development of a country

vision as well as creation and implementation of government policies are key to bioinnovation in the nation. One suggested that it is essential to move forward to establish clear and coherent policies regarding bioinnovation congruent with the new Constitution so as to mitigate the possibility that scientists, politicians or others will begin to steer research in a direction that may not be consistent with the overall needs of the nation.

Discussion and Recommendations

The percentage of participants who indicated that demand for the application of their research is unknown is notably high. However, it is consistent with research that suggests that knowledge about demand is similar to technological knowledge in that it is frequently tacit -- difficult to codify and transfer to others (Fabrizio and Thomas 2011). Tacit demand knowledge is an important asset in identifying opportunities to create tools, processes, products and ideas. It can be a source of significant competitive advantage in the marketplace.

It is conceivable that understanding and anticipating local demand conditions is difficult given the rapid rate of institutional, political, technological and other changes that have occurred during the past several years in Kenya as well as changes on the horizon. It is also possible that links between scientists and other entities in the value chain are weak. Exactly why demand is unknown deserves further investigation.

Scientists indicated that that market demand is shaped by multiple factors such as policy frameworks, the need for increased cost effectiveness in agriculture and increased acceptance in the world of products, processes and tools derived from biotechnology research. Half anticipated a rise in demand in the future. They explained the bases for their estimate. None reported relying on systematic market research for purposes of estimating demand. This suggests that either market research assistance is unavailable, there is a lack of connection between business information and bioscientists and/or other factors supersede market information in estimating demand. Further research is required to test these possibilities.

The majority of scientists stated that they received few, if any, “free” resources to supplement/substitute for resources (un) available to them. This figure is surprising given well publicized accounts of various efforts from within and outside Kenya to better equip scientific and technology laboratories, well-publicized agreements between universities in Kenya and outside the country (e.g. Malaysia, China) and well-publicized efforts by foreign ngos and governments to aid in the development of the country (e.g. Sweden, Germany, UK, Canada, US). Perhaps these efforts focus on medical biotechnology rather than food security, deal with other domains of science, or, concentrate on the application of technologies in related fields such as computer science and/or engineering (Pankhurst 2011, Gachigi 2011, AFDB 2012). The reason(s) for this shortfall is/are a matter of speculation without more data. Research that investigates this issue is advisable particularly in light of the role that agriculture plays in the economy, increasing population anticipated in the country and the potential of

agbiotechnology products to assist farmers in growing more food, earning more money and feeding themselves.

The extent to which scientists themselves individually or collectively have pursued innovative methods to access “free” resources is not clear from the findings of this preliminary study. Since they work within the confines of what would be termed “bureaucratic” organizations, it is likely that operating as a “free agent” to access additional resources is not possible given their position. They may be able to channel efforts to obtain additional resources through external grants and contracts. Some no doubt have. Obviously, success in obtaining external grants and contracts depends upon at least three elements: existence of grants and contracts, a mechanism for obtaining them and a means for fulfilling the obligations inherent in receipt (including administration and contract/grant reporting requirements). Even those who obtained external funding through this route indicated that the latter is a stumbling block.

General statements made about factors that limit biotechnology research, technology development and innovation (RTD&I) fall into four sets: financial, human and physical constraints, policy and processes, information, and lack of incentives/ homegrown demand. Demand is addressed above. Policy and processes are addressed below. They are linked to information.

Scientists indicated that Information about and public attitudes toward biotechnology are important factors. The country has a biosafety law, biosafety regulations and a National Biosafety Authority (NBA). However, GOK leaders have not consistently voiced support for the development of agbiotechnology. This likely affects public opinion, perceived and actual demand as well as the availability of financial, human and physical resources. For example, a year after regulations were published governing the cultivation of GMO crops in open fields for research and commercial purposes, the President of the country directed the public health minister to ban GMO imports until the country is able to certify that they have no negative impact on people's health (Owino 2012). Further, this sort of action probably engenders considerable uncertainty for scientists engaged in research and commercialization activities designed to enhance food security by producing seeds that match climatic conditions and are resistant to yield-reducing pests. It probably makes them less attractive partners on international research teams (Obura 2012, 2013).

And it signals something about opportunity to young and aspiring bioscientists who may already be reluctant to pursue postgraduate agbiotech studies owing to a lack of perceived opportunities. See, for example, Waruru (2012). Notably, neither scientists nor managers indicated that there is a shortage of students preparing to enter the field. However, there appears to be a disconnect between number of students who might become agbioscientists versus the opportunities and resources available for them to create and commercialize intellectual property of strategic value to the country.

Several statements address human capacity/capital. Scientists indicated that there is a gap between the number and expertise of agbioscientists in the country vs. current and

expected demand for products and services developed through biotechnology research and commercialization. Despite the fact that scientific research is often carried out among teams of people with highly specialized expertise not co-located in the same site but virtually linked together, this shortfall poses a problem. It precludes the possibility of scientists even accessing resources available from sources outside the country to augment what is available (borrowing rather than acquiring them). Scientists are a critical, non-substitutable core requirement for advancing agbioinnovation within the country.

The findings of this preliminary study suggest that substantially more investment in building bioscientific human capital is called for. Kenya faces a shortage of agriculture scientists (Njagi, 2011). The extent to which investment in increasing scientific capability of human capital is occurring already within Kenya is unknown. However, based upon the responses of scientists and managers, it is clear that lack of human capacity has the potential to completely strangle indigenous agbioscience innovation (directly and indirectly). Whatever is now occurring (e-learning, importing talent, outsourcing doctoral education to universities outside the country, participation in international scientific conferences, regional research hubs/centers of excellence, etc.) is apparently not enough. Conceivably this is *not* the case in other domains of bioscience such as environmental biotechnology. Perhaps more advanced research and commercialization capacity enhancement activity is going on in medical and other applications of biotechnology (human and animal, marine, industrial, environmental). This pilot study focused only on the development of bioagricultural knowledge, tools, processes and products to feed the population of Kenya. Follow-up interviews would uncover any innovative advanced research and commercialization capacity-building activities about which scientists are aware but did not identify.

Scientists cited *thirty-five* resource constraints that have hindered commercialization of processes, tools and ideas derived from the biotech research in which they have been involved. In contrast to general accounts that report a need to build scientific capacity in the nation because science and technology innovation serve as a means to meet Vision 2030 goals (Republic of Kenya 2007), information derived from this pilot study is very specific. The degree of specificity makes scientists' needs obvious. The findings call into question the assumption that more efficient allocation of existing resources available for the development of agbio knowledge, tools, process and products by a central entity is likely to substantially enhance agbioinnovation in the country (Republic of Kenya 2012).

Managers who participated in this project placed less emphasis than scientists on collaborative relationships of all sorts as resources that are essential but in short supply. Their responses focused primarily on tangible and financial assets. They did not, however, mention rewards or lack thereof. Managers also cited fewer resource constraints overall – approximately half. Exactly why is not clear.

Collaborative relationships (social capital, knowledge networks, strategic alliances, etc.) have a significant impact on resource acquisition and the cost of resource acquisition as

well as a host of other phenomena (Lindstrand et al, 2011, Kayes and George 2012, Kim 2012, Maurer and Ebers 2006). A shortage of social capital means that post-doctoral and graduate students may not be able to easily link into an already established professional network. This may put them at a disadvantage relative to others who can. "Bootstrapping" by bioentrepreneurs becomes substantially more difficult and perhaps even impossible without a solid network of professional and personal relationships. In sort, there are myriad reasons why collaborative relationships are important. Consequently, the lack of collaborative relationships cited by scientists and relative emphasis placed on these by managers deserves further investigation.

Participants wrote many comments when asked to describe the impact of the resource constraints they faced on themselves, the organization in which they work and the social and economic development of Kenya. They indicated that resource constraints affect opportunity recognition. This is easy to understand in the sense that searching for resources can displace conducting research or the process of scouting for agbiobusiness opportunities and, the research one carries out may be defined by the nature of resources available rather than defined by local demand. Scientists identified these effects in addition to more than a dozen others. There were no apparent differences between the comments of scientists and managers in this regard.

Responses to this question about impact were straightforward but also appeared to reflect sadness, frustration, commitment to the development of Kenya, a sense of helplessness, hope, anger and longing. They pointed out that resource constraints cause fewer products to be rolled out in the market. They are unable to complete research projects. And they cannot carry out important research because complex facilities are not available. They also pointed out that there is a low level of appreciation of the power of research in the community. Other comments seem more negative in terms of effect on utilization and development of capacity. They said they cannot carry out research with laboratory assistants owing to lack of space. Few individuals come out to participate in biotechnology research. And the personal ambitions of scientists are constrained. The latter comment appears to predict the long term effect of existing resources on opportunity recognition and agricultural biotechnology innovation in Kenya. It identifies what lies ahead for young and aspiring agbioscientists right now.

Scientists were asked to identify a *single* action that they would recommend to enhance the nature, amount and potential commercialization of biotechnology research. One-third indicated "unknown" in response to this question. Exactly why they offered no opinion is unknown. Conceivably this is because they earlier indicated that demand is a function of multiple factors and/or actually do not know or have resigned from offering opinions about commercialization. Additional research is required to sort this out.

The remainder offered many ideas. Several comments dealt with policy, legislation and government action. They did not, however, specify exactly what policies need revision (regulatory, labour market, taxation, regional development, technology, social inclusion, financing, education, trade and investment, economic or even immigration). Policies to affect the supply of potential and future bioentrepreneurs, overcome finance

and information gaps, shape the values and attitudes of Kenyans toward bioinnovation, increase the attractiveness of pursuing bioentrepreneurial activity or enlarge the creation, survival and growth of new ventures are obviously important. The latter include policies that address accessibility of markets, property rights, the regulatory environment, demand, start-up and operating costs as well as other elements such as "patient" capital. Specific policies and the implementation of them to stimulate and support bioinnovation among scientists and others in Kenya merit in-depth research.

The suite of survey tools created incorporates questions concerning policies as well as questions regarding management systems and process that affect innovation and about scientists themselves. However, the portion of the suite of surveys that both scientists and managers completed as part of this pilot study did not. None of the recommendations scientists and managers offered dealt with methods to better manage innovation. Additional research is required to explore this issue since it is likely that innovation management systems and processes within the organizations where they work affect the motivation, performance, entrepreneurial aspirations of scientists and bioinnovation that occurs.

Similarly, none of the recommendations addressed scientists themselves (capability, social capital, etc.). It is conceivable that concern about resources overshadowed any recommendations they may have about the process of managing agbioresearch, entrepreneurship and innovation. There are many alternative explanations including the fact that the survey clearly dealt with demand, development, applications and resources.

The capabilities of scientists deserve attention (McEnrue, 2012). They play a key role in identifying significant research questions that bear on the social and economic well-being of Kenyans, the creation of intellectual property and the development of biobusinesses. Moreover, they play an essential role in educating and training the next generation of bioscientific minds that Kenya needs.

Additional Recommendations and Limitations

The small number of scientists who participated in this study calls for caution in drawing conclusions about opportunities and resources available to agbio scientists in the whole of Kenya. All of the scientists indicated that they operated in a team. This is consistent with studies indicating that the nature of biotechnology research and development requires teamwork (Oliver 2004). Thus, the answers they provided to the questions posed in the survey(s) probably represent reality for more scientists than the small number of respondents who participated in this pilot study. Secondary research suggests that the information scientists conveyed is externally valid. See, for example, Nganga (2010). Nevertheless, additional empirical research is necessary to support or refute these assumptions

Additional research is also required to examine whether the findings of this pilot study apply to other applications of bioscience such as medical, veterinary, industrial, marine

and environmental. Perhaps there are significant ongoing efforts to boost the capability, stimulate bioinnovation and encourage bioentrepreneurship in other domains of bioscience such as health. It is conceivable, for example, that opportunities to create value from biomedical research are more transparent, logistically easier, less controversial or more attractive to external sources of funding than agbioinnovation aimed at insuring that people have access to sufficient, safe and nutritious food.

It would be useful to carry out in-depth research on existing policies as well as the social capital of scientists. These issues surfaced among managers and scientists along with many other factors. Policies and the personal resources of scientists are obviously relevant. So too are cultural values regarding biotechnology (particularly among youth), the biobusiness knowledge and entrepreneurial attitudes of scientists as well as the specific nature of human resource shortages and assets available Each of these has a bearing on agbioinnovation and has implications for young and aspiring scientists.

It might also be valuable to compare future research and results obtained in Kenya with research carried out in other East African and SSA countries. This would provide scientists and others with a sense of the best way they can work together to address mutual needs. Moreover, it would provide baseline information with which to establish goals, evaluate progress, review existing policy and create an acceptable national vision for biotechnology in these countries.

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Conflict of Interest

This project was carried out independently without financial support from Jomo Kenyatta University of Agriculture and Technology and from California State University, Los Angles. The principal investigators declare no conflict of interest. They assume all responsibility for the accuracy of the results reported. Please report any errors found in this document to Dr. Aggrey Bernard Nyende and/or Dr. Mary Pat McEnrue.

Notes

[1] Statistical random sampling was unfeasible for purposes of identifying participants in this pilot project owing to the fact that reliable and up-to-date information on the population of scientists and managers engaged in agbiotechnology within Kenya was not available. The process of contacting potential participants was arduous. Difficulty in data-gathering is not uncommon in developing countries. See, for example, Bostoen and Chalabi (2006). The project team opted not to abandon the effort. The team sought to contact 162 individuals in Kenya and phoned, personally spoke with, attempted to visit and/or sent three follow-up messages to them over a two month period. This experience provides a basis for designing and carrying out a large-scale comprehensive examination of biotechnology research and commercialization by scientists and other entities in Kenya across multiple domains (agriculture, health, marine, industrial and environmental).