

# Thinking about local set-ups: Making sense of biotechnology in Kenyan agriculture<sup>1</sup>

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## Abstract

This paper is about an old systems' problem versus the challenges brought about by the new technological paradigm. It identifies challenges facing the existing National Agricultural Research Systems (NARS) in harnessing agricultural biotechnology for smallholders in Kenya. Modern agricultural biotechnology is being introduced into largely failed systems to effectively integrate needs of smallholders. The evidence from the case studies: *Rhizobium* inocula and transgenic sweet potato projects in the country reveal that there are fundamental problems with the existing agricultural knowledge systems irrespective of the technology characteristics. Addressing these challenges requires moving beyond biotechnology by looking at the problem from an evolutionary context and environment of the NARS in Kenya. Therefore, the paper attempts to move beyond the dominant and largely unsuccessful scientist-farmer type of linear innovation process that is typical of NARS towards identification of alternative small-scale innovation processes that employ a strategy of multiple actors and approaches to interface science and local production. This approach makes sense in our attempt to build National of Innovation Systems (NIS) from bottom-up.

**Key words:** NARS, NSI, user-producer interaction, agricultural biotechnology, scientists, smallholders, Kenya

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## 1. Introduction

This paper examines the capacity of National Agricultural Research Systems (NARS) in Kenya to learn, adapt and innovate given the challenges of globalisation of agricultural biotechnology. Modern biotechnology is being introduced into largely failed systems to effectively integrate needs and priorities of smallholder farmers in Kenya. This situation may get worse with new technological paradigm because modern biotechnology entails radical change in terms of new actors, new knowledge and new knowledge management practices. Addressing these challenges requires looking at the adaptive capacity of the systems from the evolutionary context and environment of NARS in Kenya.

The paper employs the framework of “National Systems of innovation (NSI)” and its building blocks of institutions, organisations, technology and their interactions to examine the adaptive capacity of the NARS in Kenya. It first reviews these concepts and especially sorts out the different types of institutions (informal, policies, rules, etc) embedded in the organizational cultures) to allow us to pin down the types of institutional reasons that are leading to systems failure. On the case study design, we focused on the interface of research and local production within a given research project and its producers of modern agricultural knowledge, the scientists and final users of the same, the farmers, to better understand how far, and in what ways, the diverse needs of farmers were identified by scientists and incorporated into the design and introduction of the two research projects”. This was informed by the fact that learning is best observed at the level of the task.

The rest of the paper is organised into seven sections. Section 2 extends the User-producer approach of the traditional NSI framework to examine scientist-farmers relationships by using sociological and anthropological inputs. The evolutionary and environmental context of NARS in Kenya is reviewed in Section 3. It identifies the challenges facing the NARS in harnessing agricultural biotechnology for smallholders. Section 4 provides an overview of globalisation of agricultural biotechnology. The section uses examples of plant biotechnology applications in Kenya to explore the role of institutions in influencing certain innovations. The analysis of the case studies; *Rhizobium* inocula and transgenic sweet potato projects—which respectively represent traditional and agricultural biotechnology innovation processes follow in Section 5. The limited success of these technologies shows that there are fundamental problems with the existing knowledge systems irrespective of the technology characteristics. This finding is also consistent with our view that there is an old systems problem versus the new challenges brought about by the new technological paradigm.

Section 6 highlights social interactions in agricultural biotechnology by reflecting on the challenges of new technological paradigm. It contends that the Kenyan NARS is characterised by the dominant scientist-farmer type of linear innovation process. The section reviews requirements for institutional change that might lead to the convergence of potential of agricultural biotechnology with societal needs—especially those of smallholders. Section 7 concludes the paper by stressing the need to move beyond the dominant and largely unsuccessful NARS towards alternative and successful small scale innovation processes. This conclusion is based on the case study findings that smallholders’ access to *Rhizobium* inocula and improved (non-GM) sweet potato varieties was largely facilitated by their relations to local actors including NGOs, local traders, farmers’ groups. Given that farmers and scientists are linked (or de-linked) by several actors, it makes sense to adopt a strategy of multiple approaches in an attempt to build National innovation systems (NIS) from bottom-up.

## 2. Extending National Systems of Innovation

National system of innovation (NSI) is defined as a set of organisations, institutions and linkages for the generation, diffusion, and application of scientific and technological knowledge operating in a specific way. The concept of national system of innovation had a well-defined meaning in the past when basic decisions concerning the science, technology, and innovation policies of a given country were taken essentially at the national level. Increasingly, international linkages are dominant in science as well as in innovation and diffusion processes leading to NSIs to become ever more open systems. Also, the national borderline is now less meaningful because of national power flowing partly upwards towards supranational institutions and partly downwards towards regional, and local institutions.

Nevertheless, the concept of NSI maintains significance not only because it is shaped by national characteristics, size, social and economic development, sectoral specialisation, endowment of resources, cultural traditions – but also since the required adaptation to the new paradigm is still largely done at national level. The components or building blocks of an NSI comprise groups of organisations sharing some common characteristics and institutions governing tile relations within the group (Galli et al, 1997). Thus, learning, especially interactive learning lies behind the NSI approach. Also, there might be an intimate relation between learning theories and evolutionary theories in the sense that learning is one mechanism through which diversity is created. Learning might even be an element in processes of selection. Therefore, theories of interactive learning together with evolutionary theories of technical change constitute origins of the systems of innovation approach.

The paper employs the framework of “National Systems of innovation (NSI)” and its building blocks of institutions, organisations, technology and their interactions to examine the adaptive capacity of the NARS in Kenya. The elements of adaptive capacity include competence and skills, habits and practices and linkages. There is justification for applying NSI framework to the study of biotechnology and smallholder agriculture in developing countries such as Kenya. In particular, initiatives in biotechnology transfer to Kenya include donated proprietary technologies, training of personnel, capacity building in the formulation and implementation of patent and environmental laws and regulations from the international organisations. This means that we are still focused on radical aspects of some biotechnological systems in the upstream (international-national) research networks as opposed to links in the downstream (national-local) research and farmer adoption. In particular, modern biotechnology involves shifts from conventional plant breeding to genetic engineering, free exchange to market exchange of knowledge via IPRs and from public to private goods research. These are characteristics associated with shifts in technological paradigm. Under such circumstances, the national characteristics and its adaptive capacity will deal with challenges of modern biotechnology.

While useful for national institutional analysis, traditional NSI framework was less likely to help us assess the nature of interactions in the smallholder agriculture. We adopted an analytical framework of user-producer perspective that focused on interactive learning in the process of innovation. Many different kinds of actors and agents in the system of innovation are involved in these learning processes; the everyday experiences and activities of engineers, sales representatives, and other employees matter a lot. In the words of Lundvall (1992:xx):

Such activities involve learning-by-doing, increasing the efficiency of production operations (Arrow 1962), learning-by-using, increasing the efficiency of the use of complex systems (Rosenberg 1982), and learning-by-interacting, involving users and producers in an interaction resulting in product innovations (Lundvall, 1988).

The economic role of learning currently seems to be increasing rapidly, and there is much talk about “the knowledge based economy” and 'the learning economy. Lundvall argues that knowledge is the most fundamental resource in the modern economy and, accordingly, that the most important process is learning (Lundvall, 1992:1). This means that it is vital, from the viewpoint of encouraging economic growth and employment, to analyse the knowledge and learning aspects of systems of innovation, including the formal R&D system, the education and training system, as well as processes of learning embedded in routine economic activities.

However, literature on traditional (industrial) innovation systems tends to place more emphasis on a firm as learning and innovating unit, but in developing countries, traditional agricultural innovations for the majority smallholders are largely generated in the public sector. In applying the framework to biotechnology and smallholder agriculture, we needed to extend the traditional NSI framework. The extension process entailed employing sociological and anthropological inputs. Sociological inputs included the concepts such as “participation”, “gender relations”, etc in the assessment of farmers’ needs and priorities in agricultural biotechnology. Meanwhile, the anthropological inputs included incorporating the concept of “culture” to understand how smallholders within specific ethnic and geographical locations interact among themselves and with outsiders in their farming practices. We believed that the latter would help us to examine how culture might support farmer interactions with scientists and/or intermediaries --and consequently the acceptance of emerging agricultural (bio)technologies by smallholders. In moving from the traditional User-producer interaction to farmer-scientist relations, **the** analysis takes as its points of departure from two important characteristics. First is applying the user-producer perspective on the early stages of agricultural biotechnology innovation process to understand relationships between farmers and scientists especially with respect to priority setting and technology introduction in the local production systems. Second is taking farmers as final users of technology produced by scientists in the public sector.

From the farmer-scientist relations perspective, we therefore, characterise the nature of technical change and innovation in agricultural biotechnology in terms of two categories (Table 1). The first category that involves traditional innovation process is characterised by simple, incremental change and low learning costs. The second category that entails modern innovation process is characterised by complex, radical change and high learning costs.

**Table 1 Analytical schedule of innovation processes**

Case/Variable	Traditional innovation process <sup>a</sup>	Modern innovation process <sup>b</sup>
Learning and Innovation	Simple/incremental/cheap	Complex/radical/expensive
Organisation of knowledge	Universities, public sector	Public-private partnerships
Knowledge intensity & costs	Low	High
Regulations	Unregulated	Regulated
Farmer access and control	High	Low

Source: Author

Notes: a = represented by *Rhizobium inocula*; b = represented by *transgenic sweet potato*

We identify learning and innovation as the linking elements of traditional and modern innovation processes. The other elements are: organization of knowledge, intensity of knowledge and costs, regulations and knowledge access and control...

### 3. Context of NARS in Kenya

The changing contexts of NARS in Kenya can be traced to three phases of agrarian systems in the country namely: the pre- and the post-independence and the structural adjustment periods. The change can further be linked to the imperatives of modernisation strategies of the post World War II period. The Kenya NARS (then NARIs) assumed a highly political role before and after independence. The state enacted legislation that established the NARS constitute organisations and especially provided legal support for compulsory recognition and the check-off systems of some commodities (Beynon, et al. 1998: 57-80). Notwithstanding this support, a major constraint faced by the NARS is the historical role of the state policies in supporting some actors while restricting others from agricultural innovation process. For instance, the colonial settlement policy since 1902 contributed to the creation of the two farming systems: that of European Settlers and that of indigenous communities. The exclusive European farming systems, state policies and increased polarisation in the native reserves fuelled the Mau Mau in the Kikuyu region. The ensuing “Swynnerton Plan”, significantly shaped the post-independence agrarian policies and institutions in Kenya (Bates, 1989). At the independence in 1963, the Government retained policies and institutions inherited from the colonial era, while attempting to balance between liberal and social state paradigms. It adopted supportive policies for foreign capital and favourable taxation for business and redistribution policies as means of modernising the subsistence sub-sector (ibid).

The period since mid 1970s was characterised by the rapid expansion of public agricultural research and extension (R&E) programmes –and the corresponding increase in smallholder production due increased public investment from bilateral donors. The main source of public investment in agricultural development came from bilateral and multilateral donors. This period was also marked by the proliferation of international research organisations in the country. Kenya has the highest number of international agricultural research centres (IARCs) in Africa. In a sense, due to the integration of Kenyan agriculture into the global system as well as local political patronage, the NARIs ignored the traditional knowledge systems.

Since mid 1980s, International Monetary Fund (IMF) and the World Bank’s prescription for economic stabilisation and adjustment have influenced the performance of Kenyan agriculture. Although the reform was effective in terms of reducing government expenditure and regulating trade in manufactured goods, it did not bring about meaningful improvement in agriculture. Many African NARS are still in the process of re-organisation for a meaningful assessment of the impacts of SAPs on their performance in terms of knowledge creation, diffusion and utilization. But it is important to point out that following the introduction of SAPs in mid 1980s, there has been a shift away from state-dominated NARIs to a much wider concept of the National Agricultural Research Systems (NARS). NARS comprise the traditional public and private R&D sectors and an emergent a third sector involving civil society. The contemporary structure of NARS in Kenya follows the five broad categories: academic, public, private, civil society and government regulatory agencies.

In the post-adjustment period, the improved performance of the NARS is a priority of the state since it has an impact on the high incidence of rural poverty. While the state either maintains or increases efforts to manage the macroeconomic condition and provide social security, all other forms of intervention are reduced or redirected towards the private sector (Gibbon, 1992). This gives rise to the conventional thinking that the state is rolling back. But the state continues to influence the outcome of agricultural research policy and planning through the Five-Year Development Plans, Policy papers and Commissions. For instance, in keeping with this interventionist role of the state, the government appointed the National Committee on Biotechnology Acquisition and Their Applications (NACBAA) in 1989. The Committee comprising of policy makers, researchers and academia, was an attempt by the state to fully integrate modern biotechnology into the existing livestock and agricultural

research and development (R&D) activities. NACBAA adopted a framework that did not address issues of declining public funding and linkages between research and local production. During our fieldwork in 2000 we found that inadequate funding affects the performance of agricultural research in Kenya (Odame, 2003).

Although the NACBAA findings, which mainly prioritised traditional biotechnology applications, were not implemented, the Committee recommended guidelines for the development and safe introduction of modern biotechnology in the country. Some of the research priorities and recommendations were later implemented through donor-supported programmes. This means that agricultural research priorities and funding continue to emanate from scientists and donor agencies that increasingly draw knowledge management away from local to national and international agenda. Such an approach has its genesis in the recent globalization and international governance structures (Friedheim-Bonte and Sheridan, 1997). We now turn to globalization-localization interface of agricultural biotechnology in Kenya.

#### **4. Globalisation of Agricultural Biotechnology**

The term “biotechnology” entails a wide range of techniques. Some of the techniques such as fermentation have been used by farmers for centuries in food processing and preservation. The evolution of modern biotechnology began in the post World War II era and was based in part on molecular biology, and its twin science, molecular genetics. It initially contributed to advances in plant tissue/cell culture and soil microbial research (Sasson, 1993). These traditional biotechnologies also known as ‘non-transgenic biotechnologies’ are developed in the public sector and considered appropriate for smallholders in developing countries. It is the so-called transgenic biotechnologies emerging in the private sector and involving genetic modification which are the most controversial phase of biotechnology evolution. A genetically modified (GM) crop (also known as genetically engineered crops or transgenic crops or biotech crops) could result in increased productivity, more diverse products and better quality in existing products. But GM crops and traits developed so far have been targeted at the needs of large-scale commercial farmers, particularly in North America.

The crops grown by smallholder farmers in developing countries are not targeted. Equally not targeted are marginal conditions (including drought, declining ground water levels, high temperatures, salinity) in which a majority of the resource poor live. Many of these problems require multiple genes unlike the current GM crops, which have single genes or traits like *Bacillus thuringiensis* (Bt) technologies as well as herbicide tolerance. So far, there are no patents for drought tolerance; hence, we are far away from realising transgenic crops that are drought tolerant. At the same time, genomics or emerging science of mapping genes can help us to screen a large number of plants and select useful traits especially for tropical crops.<sup>1</sup>

This situation raises the immediate need to look for alternatives to transgenics including ecological agriculture and organic agriculture, integrated pest management, participatory plant breeding, tissue culture, marker assisted breeding etc. These non-transgenic biotechnologies are considered cost-effective and do not involve controversies including Biosafety concerns. Aaron DeGrassi (DeGrassi, 2003), for example, argues that the Kenya Agricultural Research Institute (KARI) and Monsanto could have saved a large amount of money and time on transgenic sweet potato research had they considered virus resistant varieties of sweet potato developed in Uganda through participatory plant breeding.

The critics of alternatives to transgenic biotechnologies are point out that “a cost-effective way does not always imply one better way”. During an international conference on “Can

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<sup>1</sup> At [http://www.redbio.org/portal/encuentros/enc\\_2001/conferencias/C-22/redbio2000.pdf](http://www.redbio.org/portal/encuentros/enc_2001/conferencias/C-22/redbio2000.pdf) (01-11-04)

agricultural biotechnology be pro-Poor” organized by FIELD/IDS Sussex on 1-2 October 2003<sup>2</sup>, Michael Lipton argued that there has been a decline in yields of staple food for the last ten years and wonders what really conventional breeding is going to change. He added that at least, transgenics have three opportunities. First is the increase in caloric yields of staple crops especially for food deficit areas. This may lead to surplus production and suppression of market prices but at least farmers will have their own food and avoid the question of distribution, which has failed in the first place. Also cheap food prices are good for consumers. Second is the improvement of micronutrients or bio-fortification in golden rice and Beta-carotene in potatoes. Third is the ability to use the knowledge of genomics to produce transgenics under moisture stress and in combination with the knowledge of farmers.

The challenge is how to translate the potential transgenics into reality given that crops and traits of interest for smallholder farmers are not given consideration. Apparently, the private business sector that dominates much of modern biotechnology is motivated by profits. It has resources to invest in modern biotechnology which it controls through intellectual property rights (IPRs). In doing so, the sector has been buying patents and other companies as well as forging all kinds of partnerships to control the technology and benefits accruing from its use (Glover et al, 2003). This makes the development path of modern biotechnology less likely to improve the smallholder agricultural production in developing countries.

The international regulatory regimes which are supposed to mediate the potential of modern biotechnology and societal needs are accused of being allied to interests of technology and partnerships. For instance, the WTO Agreements promote trade over other social interests. The urge to harmonize the international regulations also support the interests of Multinational corporations (MNCs) and their sponsoring countries. Therefore, developments in modern Biotechnology are oriented towards interest of the private sector in developed countries. As a developing country, China has, however, followed a different path of development given that the state uses enormous resources to develop agricultural biotechnologies that are considered more affordable to its majority smallholder farmers (See Box 1.1).

#### **Box 1.1 An overview of development path of biotechnology in China**

The Chinese biotechnology is supported by strong public policy. The state uses enormous resources to develop biotechnology in the public sector domain. As a result, it has developed and field-tested many crops --but only commercialized four crops including peppers, tomatoes, petunias and cotton. Of these crops, Bt cotton is the most important crop grown – accounting for 35 per cent of all cotton grown in China. The large public investment in the agricultural biotechnology has reduced the influence of MNCs in the large Chinese economy. Although it is now implemented with caution, the Chinese regulatory framework has reduced the IPR and biosafety concerns. This coupled with extensive seed delivery systems has made the technology available and more affordable to its majority smallholder farmers. For instance, Bt cotton seed produced by the Chinese Academy of Agricultural Science (CAAS) is cheaper than that of Monsanto. However, China is a large economy which can domestically commercialise biotechnology without fear of MNCs and WTO. It has also unique political and organizational culture which make the public sector-driven modern biotechnology a viable option (Huang and Wang, 2003, Keeley, 2003).

In most developing countries, the public sector lacks resources and capacity to generate appropriate agricultural biotechnologies for smallholder farmers. For instance, Kenya as a small and poor country remains at the mercy of international organizations and institutions such as MNCs and WTO Agreements. The country’s public investment in agricultural biotechnology is very small and all modern agricultural biotechnology research projects are

<sup>2</sup> At [www.field.org.uk/PDF/IDS%20biotech%20conference%20summary.pdf](http://www.field.org.uk/PDF/IDS%20biotech%20conference%20summary.pdf) -

donor-funded which raises the question of their sustainability. Although the country has an expanding modern biotechnology programmes in terms of training opportunities and other types of collaboration with regional and international agencies, it is still in the phase of non-transgenic biotechnologies such as biological nitrogen fixation (BNF) and tissue culture. Table 2 shows that many of the country's modern biotechnology applications, including transgenic sweet potato, Bt. Maize are yet to reach farmers (Bolo, 2004).

**Table 2: Status of GM crops research in Kenya, 2004**

Transgenic crop	Desired trait	Institutions involved	Status
Bt Maize	Insect resistance	KARI/CIMMYT with financial support from Syngenta	Contained trials
Bt Cotton	Insect resistance	KARI/MONSANTO	Contained trials
Transgenic sweet potato	Viral resistance	KARI/MONSANTO/DANFORTH CENTER (USA)	Contained trials
GM Cassava	Cassava Mosaic Virus	KARI/DANFORTH CENTER (USA)	Contained trials
Rinderpest vaccine	Disease control	KARI	Contained trials

Source: Bolo, 2004

Also, Kenya is still in the process of developing specific national policy and legal frameworks on biotechnology. The international forces and interests have influenced the development and introductions of a few donated transgenic crops and associated intellectual property (IP) laws and biosafety regulations in the country --without considering the country's implementation capacity. For instance, Kenya faces problems of poor extension service, non-availability of quality seeds and inappropriate production technologies especially for smallholder farmers (Bolo, 2004). Also, the fact that the Kenyan scientists have not produced transgenic crops of their own has led critics to question its competence as well as whether the motivation of MNCs was to use a few token transgenics as market openers for other transgenics

The Chinese and Kenyan examples justify the need to rethink a public policy approach that strengthens the appropriateness of agricultural innovations for smallholders. For this to be realized, the process ought to be placed in the public domain and receive adequate funding. Of particular importance are the IARCs and the CGIAR centres and their collaborations with the NARS. IARCs may be seen as neutral arbitrators but unfortunately this is not happening because they lack resources to address the needs of poor farmers, and companies will continue to concentrate on high-value GM technologies that meet the needs of wealthy markets in developed countries. Resources in the public sector are under great pressure. This also raises the question of whether public sector research is a panacea for developing and deploying appropriate and profitable technological innovations for poor.

This question is apparent given that there is continuity and change between GR technologies which were developed in the public sector with modern biotechnologies now emerging the private sector. Unlike GR technologies, transgenics involve new actors, new knowledge and new ways of managing knowledge. During GR era, most technologies were developed in the public sector but they "bypassed" certain countries, regions and groups of farmers --especially in Sub-Saharan Africa (Richards, 1985, Lipton et al., 1989, Conway et al., 1990). Does this mean that if transgenics are developed in the same failed system, the process will lead to appropriate agricultural innovations for smallholders? In the next section we present the results national institutional analysis and of two case studies: *Rhizobium* inocula and transgenic sweet potato projects—which respectively represent traditional- and modern-agricultural biotechnology innovation processes to show that that there are fundamental problems with the existing knowledge systems irrespective of the technology characteristics.

## 5. Synthesis of field results

The synthesis of field results summarized in Table 3 follow the analytical framework conceived in Table 1 in Section 2. These include learning and innovation, organization of knowledge, intensity of knowledge and costs, regulations and knowledge access and control.

### 5.1 Learning and innovation:

The general finding from analysis of national institutions and cases studies suggests that the typology of “producers” and “users” of knowledge is indeterminate because the so-called users of one type of knowledge are themselves producers of another type of knowledge in the innovation process. It also defies many definitions and conventional categories of traditional and modern agricultural knowledge management practices. For instance, despite the complex and radical nature of technical innovation, scientists in the transgenic sweet potato project were combining modern knowledge and farmers’ traditional knowledge and landraces in upstream research to generate CPT560 variety of sweet potato for smallholders. The project was, however, primarily concerned with generation of virus-resistant sweet potato variety to increase crop yields of smallholders. In the case of *Rhizobium* inocula project which involved simple and incremental type of technical innovation, the development of Biofix and Prep-pack were restricted to the scientific knowledge in the upstream research. The innovation process was still characterised by weak scientist-farmer interactions in the context of priority setting and technology development. Also, the transgenic sweet potato project, which involved relatively a modern innovation process, was likewise characterised by weak scientist-farmer interactions in the upstream research.

**Table 3: Summary of Case study field results**

Case/Variable	Rhizobium inocula <sup>3</sup>	Transgenic sweet potato
Learning and innovation	Traditional biotechnology <sup>a</sup>	Modern biotechnology <sup>b</sup>
Organization of knowledge	public university	Public-private partnerships
Intensity of knowledge & costs	L-research, H-production	H-research, L-production
Regulation	Unregulated	Regulated
Knowledge access and control	Formal: S-control upstream	Formal: S-control upstream
	S-control downstream	Informal: F-control downstream

Source: Author

Notes: *a* = simple/incremental/cheap;  
*b* = complex/radical/expensive  
*L* = low; *H* = high;  
*S* = scientist; *F* = farmer

The innovative features in the upstream research of transgenic sweet potato project include public-private partnerships through technology donations by the private sector. It is also apparent that promoters of transgenic sweet potato project showed an adoption of ToT model with “adaptive organisation” in the downstream research networks and some aspects of the “innovative organisation” in the upstream research. In both *Rhizobium* and transgenic sweet

<sup>3</sup> Rhizobium inocula or Biofix are interchangeably used to refer to biological nitrogen fixation (BNF) technology.

potato projects, we noted multiple knowledge relationships including policy makers, regulators, local traders and NGOs/CBOs. This means that farmers are linked (or de-linked) from scientists by several actors. In turn, this has practical and policy implications for interactions. The transgenic sweet potato research project, for instance, entailed a dual strategy (Wambugu, 1995), in which KARI, a public sector, was licensed-free-of-charge by Monsanto, a private sector, to generate a technology for subsistence farmers in Kenya.<sup>4</sup> Thus, it exemplifies a combination of agricultural knowledge management practices characterised by public-private partnerships in the upstream and predominantly public sector research and extension in the downstream.

Scientists in both case studies had established upstream research linkages but were limited on the downstream linkages. Yet, the two research projects were expected to shortly develop and deploy appropriate agricultural innovations for smallholders. In this context, the activities of participating NGOs were considered peripheral to technology development but core to its deployment. In doing so, the scientists made little attempt to directly involve farmers and their supporting organisations and culture in identifying and prioritising problems they face in the production of sweet potato. Therefore, a research organisation can simultaneously display characteristics of innovative behaviour in upstream research networks and inertial behaviour of the conventional TOT model in downstream research linkages.<sup>5</sup>

## 5.2 Organization of knowledge

The market-oriented economic re-structuring and the advent of biotechnology R&D innovation process challenge the traditional role of the state and the livelihoods of rural people. In this process, the state is largely a spectator. The effective response to needs of farmers at the local level appears to come from other sources other than the state. This limits public support for the NARS to build bridges with subsistence producers.

A survey of synergy of organizations conducted by Odame, Mbote and Wafula (Odame et al., 2000) reveals that the highest number of ties is with (IARCs) (Table 4).

**Table 4: Organisational synergy**

Organisation category	Number of ties to sector	Average score of tie performance <sup>b</sup>
University	50	3.20
NARIs <sup>a</sup>	52	3.04
NGOs	19	3.37
Private	14	3.37
International	56	3.37
Government	36	2.83
Total	227	

Source: Odame and Mbote, 2000

**Notes:** a: KARI (ties =32 and score = 2.96), Other NARIs ( ties =20 and score = 3.15); b: 1= poor; 2= fair; 3= good; 4=very good; 5=excellent

<sup>4</sup>Monsanto philanthropically contributed to the technology transfer to small farmers. However, this is a controversial issue because it has been argued that beyond philanthropic reasons, Monsanto's motivation was purely strategic –in the sense that the gesture would facilitate its ease of entry into Kenya and East Africa as well as set the stage for the introduction other protected transgenic crops.

<sup>5</sup> This means that a supportive policy in the upstream linkages does not necessarily translate to farmer access to technology. There is need for downstream linkages too.

These include the International Livestock Research Institute (ILRI), International Centre on Research and Agroforestry (ICRAF), International Centre for Insect Pest and Ecology (ICIPE) or having regional offices (CYMMIT, CIP, ISAAA, etc) in Nairobi. Approximately 158 (70%) of all the ties are linked to the three public research organisations namely, international agencies (56%), NARIs (52%) and universities (50%). Ties to other organisational categories were 36 (16%) and 33 (14%) for the government agencies and NGOs/private sector respectively. These figures demonstrate the dominance of research networks in S&T policy. It further confirms the prominence of upstream institutional linkages in the production of public goods research.

In terms of tie performance, with the exception of ties to the government agencies --which are rated fair at 2.83 (fair to good), most of the scores fall within the range of good (3.04- 3.37). The ties to KARI were rated fair at 2.96 and to the other NARIs were rated good (at 3.15).

### **5.3 Knowledge intensity and costs**

Global trends show that scientists in modern biotechnology research are increasingly using science-intensive knowledge. This is a serious constraint for many researchers in developing countries given that much of this knowledge requires high-tech labs, specially trained personnel and adequate funding. It also makes it difficult for people in the laboratory to communicate with those on the ground (viz. donors, policy makers, scientists, farmers, etc). This problem is exacerbated by the history of research scientists denigrating the knowledge of smallholders. For instance, theory informs us that setting of research agenda is often restricted to scientists while the information generated first diffuses upwards in the form of reports and conference papers to national and international organizations (Vitta, 1992).

Based on results of the 11 laboratories we surveyed in mid 2000 (Odamo, et al, 2003), a majority were using tissue culture techniques. With the exception of international centres such as ILRI and ICRAF, it appears that funding and reagents and personnel are the respective acute and serious constraints for laboratory capacity in Kenya. The most affected were universities are universities, national agricultural research institutes (NARIs) and government regulatory agencies. Again, with the exception of the IARCs and the private sector, the other actors reported that funding was an acute problem.

While traditional biotechnology capacity building involved plant breeding, soil science, etc, modern biotechnology has since the early 1990s focused on research training in areas related to molecular science, IPRs, and Biosafety regulations. At the same time, the role of public sector in modern biotechnology was limited as the government budget for agricultural research was declining. With increasing proprietary knowledge in R&D inspired innovations, the public research sector could only access the technology and the relevant human resource capacity training through collaboration with the private sector and donor funding.

During our fieldwork, some respondents suggested that such collaboration was limited to a few scientists and short courses. As one respondent pointed out "...there was limited contribution to the long-term strategy for achieving a critical mass of human resources needed to effectively engage in modern biotechnology". The country is currently facing a crisis of training and retaining scientists. The few scientists that are highly trained leave the country for better career opportunities in Europe, North America and Southern Africa. For instance, it was reported that of 14 scientists who had qualified with Ph.D. in molecular biology and genomics, only one was still in the country by the end of 2001 (Daily Nation, 2000-2001). This problem stems from under-utilization of existing capacity --mainly as a result of poor scientific infrastructure. Much to the deficiency in modern biotechnology capacity is also related to intensification of science and costs. This practice challenges the public sector researchers. For instance, scientists recalled that they are being increasingly

required to upgrade their scientific knowledge and skills. They feared that such a policy while intending to expand the range of skills for scientists, it has potential to displace some traditional disciplines or fields.

In key informant interviews, a former plant breeder said that modern biotechnology "radically induced cross-crafting, which required scientists to have a wide range of skills". The intensification of scientific knowledge and costs in the recent past seemed to further polarise the public sector and created a possible mismatch between technology and society. Many key informants expressed the view that the promoters of modern biotechnology tended to treat local knowledge with contempt and also lacked respect for the conventional agricultural research. According to one respondent: there was: "an air of superiority from the so-called biotechnologists feeling that their knowledge competence and skills were more important in overcoming the obstacles of cross-species transfers which was the main constraint of traditional breeding techniques".

These pro-modern biotechnology scientists were further accused as being "technology-supply oriented and ignorant of the real needs and knowledge of local people". Some of the alleged bad habits and practices of agricultural biotechnology scientists during the interviews with some key informants –especially NGO respondents may not represent deliberate neglect for the local knowledge and disrespect of conventional plant breeding by the scientists, but rather it is consistent with the changing knowledge management practices. Also, this behaviour is not unique to modern biotechnologists. As we noted in the previous sections, the GR technologies, which were developed by scientists in the public domain and through free exchange of materials, tools and knowledge had not effectively engaged local knowledge system. But as we discuss in the next section, the international regulations that govern modern knowledge are likely to exacerbate the gap between scientific knowledge and traditional or local knowledge systems in Kenya.

## **5.4 Regulations**

Modern biotechnology involves new international regulatory regimes including intellectual property rights (IPRs) and Biosafety regulations. IPRs mediate market exchange in modern biotechnology. This contrasts with conventional agricultural technology development process, where knowledge management is characterised by free exchange of information, materials and tools. Even where biotechnology transfer to developing countries involves donated technologies, there are still post-release IPR concerns with respect to generating appropriate innovations and accessing them to smallholders. This problem is likely to get worse with the proliferation of international trade regimes which require removal of subsidies in agriculture. Apart from access to modern biotechnology, there are concerns over Biosafety-related issues. International regimes require the establishment of national regulations for risk assessment and management in the governance of modern biotechnology. But many developing countries lack the technical and legal capacity to implement and enforce Biosafety regulations.

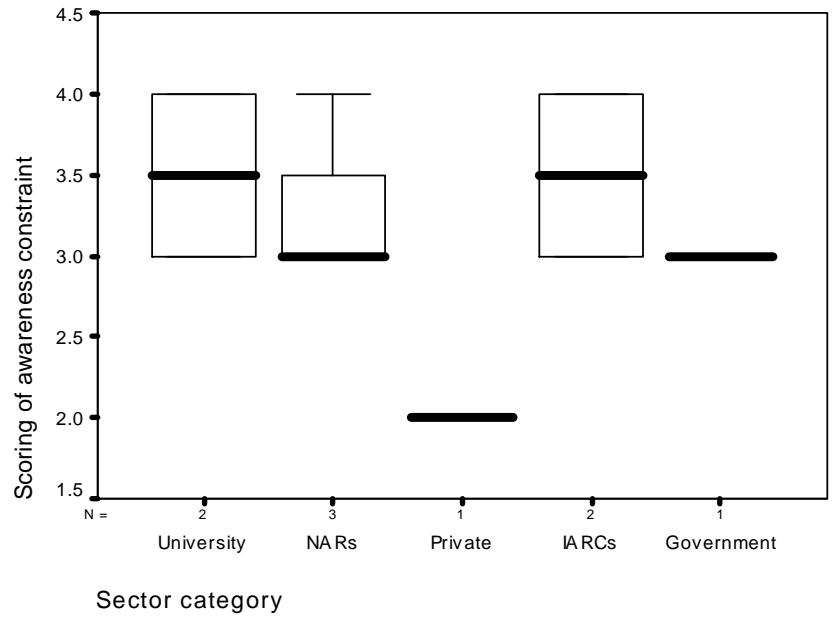
### ***Intellectual property rights***

In Kenya, non-market transactions characterise much of the traditional agricultural (bio) technology transfer. A large number of ties in the predominantly public researcher sector are reported to be informal or based on personal relationships. Even where respondents indicated an existence of a research contract or memorandum of understanding (MOU), they were not conversant with the details of these agreements. This situation had implications for institutional arrangements and researcher performance. For instance, lack of legal framework, restricted the privatisation of some aspects of *Rhizobium* innovation. Also, the unspecified IPRs were a disincentive for the performance of scientists in the public research sector. Since acceding to TRIPS agreement in 1991, the Kenya government has revised her laws to

comply with the agreement --and developed regulations to guide the use of laws (Odame, et al. 2003: 18). However, there are several challenges to the development and implementation of IPR policy in the country. It appears that the Industrial Property Act of 2001 was swiftly enacted to conform to the requirements of TRIPS.

Based on national institutional analysis in Figure 1, a majority of Kenyans including researchers, policy makers, manufactures, farmers, etc. remained unaware and were less likely to benefit from these developments (*ibid*: 19).

*Figure 1: Box plots of perceived awareness constraint on access to and use of modern agricultural biotechnology in the Kenyan NARS*



Source: Field data

**Note:** 1= not a problem; 2= a least problem; 3= a moderate problem; 4= a serious problem; 5 an acute problem.

In the case of transgenic sweet potato project, Monsanto donated the technology to KARI for public goods research. However, KARI may also protect the arising transgenic sweet potato varieties through Plant Breeders Rights (PBRs), which raises the question of post-release IPR implications for researchers and farmers. The exclusion of farmers from PBRs encourages commercialisation and privatisation of plant breeding activities (Brouwer, et al. 1992; Kameri Mbote and Cullet 1999:10). This impinges on utilisation of farm saved seed –with the potential for long-term household food insecurity.

**Biosafety**

In Kenya Health and safety regulations are traditionally enforced through several mechanisms and regulatory agencies, which may lead to some degree of uncertainty. For instance, the country has several regulations and mechanisms enshrined in different Acts and Principles of laws of Kenya. Many such regulations are based on international conventions and recommendations (Bolo, 2004). One important observation arising out of national institutional analysis and the two case studies is the weak capacity of the government to enforce some of these regulations. This is due to a number of constraints including awareness, lab facilities, incoherent policy, funding and personnel. These constraints were

serious in the public sector. At the national level, the National Council of Science and Technology (NCST) received donor support to develop Biosafety Guidelines/Regulations but its capacity to implement them still remains uncertain (Odame, et al. 2003). Historically, health and safety regulations are used in a precautionary manner under uncertainty. This raises the question of the extent to which these regulations are supportive or restrictive of particular agricultural biotechnology innovations in Kenya.

In the *Rhizobium* project, general plant quarantine procedures were used to allow cross-border transfer of bacteria isolates for *Rhizobium inocula* research at the University of Nairobi (Prof. Keya, Person:Comm in 2001). In the transgenic sweet potato project, the existing general procedures were inadequate to allow the safe transfer of transgenic plantlets from the Monsanto lab in St Louis USA to KARI laboratory in Nairobi, Kenya --for the purpose of field trials. In accordance with the requirements of Article 19 of the Convention of Biological Diversity (CBD) (Biological Diversity, 2000), NCST was pressured to develop Biosafety Guidelines/Regulations and to establish the National Biosafety Committee (NBC) in order to allow the transfer of transgenic sweet potato plantlets into the country.

### **5.5 Smallholder access and control**

The genes or trait of interest, type of crop of crop and farmer characteristics (including location, farm size, family size, gender and marital status, wealth, group membership) will determine how farmers receive and use agricultural innovations in their local production. Agricultural production in Kenya is dominated by small-scale farmers. In terms of land size, the concept “small scale farmer” may refer to a family who lives and farms on 2 ha or less, especially in the high potential areas. This definition is changing due to subdivision of land.

Based on our field data, small farmers on average owned respectively 3.7 acres and 3.2 in Mathira and Kieni East division of Nyeri District --and 6.8 acres in Butula division of Busia District. Women agricultural producers dominantly manage this sub-sector. For instance, we noted that out of 230 farmers surveyed in Nyeri and Busia districts, 156 (68%) women managed the farms --which were legally owned by their husbands. These women managers had access to land but less control over it. They account for the largest proportion of farm labour because they remain on the farms as men leave for urban areas in search of employment opportunities. Indeed, women were the majority members of farming groups. The groups were in turn the main channels through which individual farmers gained access to technology and extension services. But many farmers cited poor extension services, which reduced their access to existing technologies. This implies that farmers are likely to be marginalized by the advent of new knowledge. The evidence from the case studies shows that differences may arise from the ability of farmers to access and control a given technology.

In the case of *Rhizobium* case study, the limited farmer control over inocula restricted their ability to domesticate the technology. This was in spite of the fact that *Rhizobium inocula* project involves simple technical change or innovation due to low intensity of science and upstream research costs. In the case of transgenic sweet potato project, subsistence farmers were likely to have more control over the technology once it is distributed despite its radical nature in terms of high intensity of science and upstream research costs. This evidence suggest a close look at the production constraints that need to be addressed including improving soil fertility and extension services. In the *Rhizobium* case study, the size of Biofix package had a negative impact on the available land and labour. For instance, in Kieni East division, this led to splitting of the inocula package among groups of farmers --which upset farmers. Although the Pre-Pack package was small, farmers in Butula division reported that it impacted negatively on the available family labour because children were not allowed to apply it for fear that it would harm them. In general farmers reported that the inocula increased yields of common bean but they could not report the actual yields because of not wanting to appear to reject the technology. It seems that when asked about the advantages of

using the inocula, farmers merely repeated what they had been taught by the extension workers. The farmers' true responses were captured when they listed the disadvantages of using the inocula and suggested the needed changes in the Rhizobium technology.

Regarding sweet potato production, Table 5 shows that in the order of seriousness of problem, the main constraints were soil fertility (49%) , extension service (29%), land size (24%) and labour (21%). The same table shows that at 4%, markets are not considered a serious problem under the current production practices.

**Table 5: Percentage subjective scoring of production constraints**

	Not a problem	Not a serious problem	A moderate Problem	A serious problem	An acute problem
Land size	11.3	21.3	33.8	23.8	8.8
Soil fertility	3.8	5.6	33.1	48.8	8.1
Pests and diseases	8.8	34.4	33.8	20.0	1.9
Planting material	48.1	19.4	23.1	8.8	0.0
Labour	6.9	26.3	40.0	21.3	5.0
Extension service	20.6	16.9	19.4	29.4	13.1
Markets	55.6	31.3	6.9	3.8	0.0
Moles	20.0	.6	3.1	6.9	.6

*Source:* Field data

At present, food security is more important than income generation in sweet potato production because farmers produce only enough for home consumption and hence very little for market. Therefore, the findings from the case studies confirm the fact that there was limited farmer participation in priority setting and technology introduction.

Regarding production relationships, the state directly intervenes in rural development programmes in terms provision of subsidized credit and farm inputs, although this is now seldom because of the advent of SAPs. Evidence shows that past state interventions in Kenyan agriculture particularly in commodity trade distorted market conditions in the sense that it stifled the interests of the majority smallholders.<sup>6</sup> In the unorganised smallholder production sub-sector, the institutions that matter are indigenous organisations and culture. During pre-independence era, these local institutions were relatively strong in the rural areas. But from independence period, many of them were neglected and/or co-opted by the state, thus, weakening the social fabric of rural communities. In return, the state organs became pervasive. With the advent of SAPs and the subsequent withdrawal of the state, there was a formal institutional void in rural areas.<sup>7</sup> This void is being filled by informal institutions. For instance, each of 230 farm households studied belonged to at least one farming group. Farmers in Kieni East division had formed groups which were relatively stronger because of their linkages to market agents of the export-oriented horticultural sub-sector. Even within these market linkages farmers complained of exploitation by “middlemen”. Consequently, they called upon the state to re-regulate the sub-sector. Therefore, from the analysis of national institutions and the material from the case studies, a complex picture of production and marketing relations emerge in the process of structural change. In particular, SAPs have left the farming communities in a state of confusion due to the proliferation of NGOs/CBOs, whereas the state withdrawal has left a void in rural markets for subsidized credit and farm inputs (Kabuga, 2001). This situation is further complicated by advent of modern biotechnology and its underlying regulations.

<sup>6</sup> For example, large scale farmers who only account for 20 percent of the total maize produced used 80 percent of subsidised fertilisers in the country (Johnson et, al, 1980)

<sup>7</sup> This is a direct result of policy advice from the World Bank. See World Bank (1995c:31).

## **6. Social interaction in agricultural biotechnology**

### **6.1 Challenges of new technological paradigm**

Although, innovation can be defined as new knowledge or combinations of existing elements of knowledge<sup>8</sup>, technologists and economists within NSI framework often focus on changes knowledge --with economic significance. Here the innovators are firms and more recently technical universities. The alternative is the incremental technical change or adaptation aimed at improving production methods or processes. Defining innovation this way recognizes the contribution of farmers and farming communities in agricultural knowledge systems. However, this emphasis changes when one looks at innovations from the perspective of radical change or paradigmatic shifts in technological systems. For instance, modern biotechnology involves radical change given that it is removed from the normal practices of relevant people (donors, policy makers, scientists, farmers, etc). As such, it is difficult for people in the labs to communicate with those on the ground, thus, requiring new ways of interactions between them.

This implies a need to identify and improve the capacity of intermediaries and supporting institutions to select and adapt new technologies to the needs of smallholders. The existing institutions can be supportive as far as innovations are incremental but restrictive in dealing with radical innovations and vice versa (Sunding and Zilberman, 2000; Zilberman, et al. 1997). For instance, the legal exclusion of smallholders from R&D-inspired innovation process is exacerbated by path-dependent culture of research scientists. Smallholders are neglected because they are mainly subsistence producers, who cannot afford to pay for technology adjustments. Also, they are spatially dispersed and lack effective organisations to represent them. In past two decades, the policy of organising rural communities has received more attention as an aftermath of rolling back of the state. Sustainable measures are required to prepare subsistence farmers for new technological innovations.

Many evaluation studies on agricultural innovations often suggest the need for the NARS to shift from the traditional narrow focus on formal research organisations to incorporate other sources of knowledge. The imperative of change in patterns of behaviour and culture of technology-supply oriented researchers is at the heart of policy framework. Such change implies a prerequisite for better institutional arrangements (Janssen, et al. 2000; Lundvall and Christensen, 1999; Nelson, 2000). Therefore, our extended NSI model should interface research and local production in order to simultaneously transform technology and society.

### **6.2 Requirements of institutional change**

The existing African NARS and their constituent organisations are at crossroads. The past failure of African NARS to effectively respond to needs of smallholders has been weakened by the implementation of SAPs (Kherallah, et al. 2000). However, the new knowledge management practices have the potential to further widen the knowledge gap between research and local production. The evidence from the two research project settings, in which we examined interactions between scientists and farmers, confirm this pattern. There were no direct scientist-farmer interactions in the research design phase.

In the case of *Rhizobium inocula*, the project staff attempted to diffuse the technology to farmers through traditional extension channels such as agricultural shows and government extension services. But government extension has become weak and even non-operational in some areas of Kenya due to reduced public funding (DeGrassi, 2003). Therefore, the link between research and local production has been further weakened by the implementation of SAPs (Kherallah, et al. 2000). This situation leads to the question of how prepared the existing

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<sup>8</sup> See, for example, Schumpeter 1939)

systems are in dealing with radical innovations such as modern biotechnology. In the introduction of transgenic sweet potato varieties, there will need for extension service.

The emerging picture across the national institutional analysis and the two case studies show that the existing systems are expending their energies on the traditional reactive strategies of promoting ‘technology-as-is’ –rather than shaping it to the benefit of subsistence farmers. At the same time, there is continued preference of some systems’ leaders to make rhetorical statements about the potential of modern agricultural biotechnology to alleviate poverty, hunger and malnutrition. This leads to the question of whether the existing systems should be transformational or inert? In this respect, this study raises more questions than answers. Despite the position taken, the existing/new systems ought to respond to the societal context. This includes considering the reality of agrarian systems in Kenya. We have already raised the question of the potential impact of new knowledge management upon the prospects of transforming the NARS in Kenya. We return to this concern in the next section.

## **7. Conclusion and recommendations**

In paper we have attempted to stress the need to move beyond the dominant and largely unsuccessful NARS towards alternative and successful small scale innovation processes. From the synthesis of field results in Section 5, the major actors in the local production systems are small-scale farmers and traders (i.e., smallholders) as opposed to innovative firms of the industrial or commercial production assumed under NSI. Smallholders have a history of limited participation in technology development, which is likely to be exacerbated by R&D inspired agricultural biotechnology innovation process. This process limits farmers’ ability to adapt new technologies to existing practices. In particular, due to the impacts of SAPs, farmers are returning to the traditional farming practices despite the proliferation of new technologies. The regulatory frameworks associated with new technologies are likely to improve the ability of actors to place claims on intellectual assets and to consistently enforce rules on sanitation and protect against risks associated with GMOs. However, such regulations are likely to limit free exchange of knowledge and materials between (and among) scientists and farmers. They may also affect the ability of farmers to save and sustainably use their own local seeds.

The traditional NSI framework is characterized by rapid technological changes and interdisciplinary and inter-organizational relationships in technology deployment. In Kenya, the labs are small, isolated and ill equipped and staffed to effectively to engage in high intensity and costly knowledge management. At the local level, there are few farmer-managed on-farm trials and limited efforts to engage traders and NGOs that support farmers.

In terms of organization of knowledge, the Kenya NARS are characterized by incoherence in priority setting and funding agenda as well as political authority. Although there is an increase in agricultural R&D investments by the private sector and public-private partnerships (PPPs), but priority setting through 5-year development planning is still dominated by the public sector. This is done in a top-down approach with limited ability of the government to coordinate research activities. This has led to divergence in priorities of scientists and farmers—which may be exacerbated by modern biotechnology since the current efforts in PPPs are restricted to upstream linkage as opposed to being extended to building the capacity of farmers and local institutions that support them. Therefore, NARS faces a major challenge of translating existing agricultural technologies to farmers.

DeGrassi (2002) warns that the historical weakness of African NARS in transferring technology from research to farmers may impact negatively on the deployment of modern biotechnology. This is partly due to the legacy of colonial and post-independence model of

technology transfer. This model of NARS needs to be transformed. The challenge remains how to do it. The starting point for the NARS is to build or strengthen their local and global knowledge networks. This will improve their capacity to effectively participate in accessing and translating modern biotechnology into socially acceptable innovations for subsistence farmers. In doing so, there are at least two emerging issues to consider within the changing context of NARS. First, in the future, it is possible that there will be expansion of both public and private sector collaborations in agricultural research and extension services. As such, the NARS should respond to this challenge by sharpening their IPRs, business and negotiation skills. Apparently, the advent of modern biotechnology has placed pressure upon the NARS to respond to new knowledge management practices.

Second and most important is that unlike in old era, today the public sector in developing countries does not have monopoly over agricultural knowledge. There are many other players in knowledge management including local traders and Nongovernmental Organizations (NGOs). Some of them have global networks in this area. These NGOs include women groups, consumer groups, environmental groups, etc. The expanding space of farmers' (viz. women) groups, local traders, Community Based Organizations (CBOs) and NGOs in both case studies, reflect a shift from reliance on government to other service providers. Apparently, extension service by NGOs is limited in terms of scientific knowledge and coverage. In the case of sweet potato, the extension work of a local NGO, Appropriate Rural Development Agriculture Programmes (ARDAP) was confined to a radius of 3-5 km. Responses from farmers located 5-15 kilometres away from the project site were not aware of the provision of improved sweet potato varieties and training. However, as the state extension service declines in Kenya, no comprehensive market or civil society extension service seems to emerge to strengthen the links between research and local production.

Notwithstanding increased fragmentation and sub-divisions of land in the study areas, it was still owned by the majority smallholder farmers. What we also noted was not the full-time and the predominantly married male farmer of the traditional production system, but rather a full-time female-farmer and often part-time male farmer. Therefore, the rural people in Kenya are smallholders and predominantly female and typically resource-poor. In particular, they have limited access to modern inputs, credit and extension service. In *Rhizobium* project, farmer access and use of *inocula* was facilitated by their farming group memberships. The groups interfaced farm households and formal research and extension agents. The formal extension agents helped to organize and train farmers' groups in Mathira and Kieni East divisions of Nyeri District. The strength of some farmers' groups in Kieni East was bolstered by capacity training and their linkages to the markets of horticultural crops. In contrast, farmers' groups in Butula division in Busia District were relatively weak and not effectively linked to external markets. This means that without much of community mobilisation and access to productive assets and markets, attempts by agricultural scientists to graft farmers' groups at the pipe-end of the innovation process may be unproductive.

Even more unproductive may be assumptions that existing NGOs, CBOs, and their collaborating farmers' groups can effectively help farmers to manage environmental risks resulting from the possible use of genetically modified (GM) crops. Rather, for farmers in sweet potato case study, reciprocity and trust are the main desirable characteristics of mediating and supporting organisations. This implies that civil society groups need to build trust and strengthen inter-personal relationships before they can be expected to play an important role in the delivery of services to the rural communities. This challenge is more apparent with the advent of modern biotechnology and may exacerbate the already weak interactions between research and local production. Therefore, we need to build from bottom-up National Innovation Systems (NIS) that can co-ordinate diverse interests within the framework of social and economic development. The proposed NIS should be well placed to organise, represent and protect farmers from possible supplantation of their traditional knowledge and risks associated with globalization of agricultural biotechnology.

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