

CAPACITY DEVELOPMENT FOR AGRICULTURAL BIOTECHNOLOGY IN DEVELOPING COUNTRIES: AN INNOVATION SYSTEMS VIEW OF WHAT IT IS AND HOW TO DEVELOP IT

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Abstract: There are divergent views on what capacity development might mean in relation to agricultural biotechnology. The core of this debate is whether this should involve the development of human capital and research infrastructure, or whether it should encompass a wider range of activities which also include developing the capacity to use knowledge productively. This paper uses the innovation systems concept to shed light on this discussion, arguing that it is *innovation capacity* rather than science and technology capacity that has to be developed. It then presents six examples of different capacity development approaches. It concludes by suggesting that policy needs to take a multidimensional approach to capacity development in line with innovation systems perspective. But it also argues that policy needs to recognise the need to develop the capacity of diversity of innovation systems and that a key part of the capacity development task is to bring about the integration of these different systems at strategic points in time. Copyright © 2005 John Wiley & Sons, Ltd.

1 INTRODUCTION

There is no doubt that if developing countries are to prosper they must build the capacity to take advantage of new technological paradigms such as biotechnology. However what is much less clear is what capacity development might actually mean in a contemporary sense. Building skills in frontier areas of science will of course be part of this process. However it is now becoming increasingly apparent that there is a generic problem with capacity development approaches that focus solely on competencies to produce knowledge—i.e. research. The failure to develop complementary competencies and structures to put that

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knowledge into use and the need to take account of how scientific resources integrate with the rest of the economy and respond to society as a whole is now a major concern in the science, technology and innovation debate (Hall, 2002, Chataway *et al.*, 2005).

In the case of agriculture much of this problem relates to historical patterns of capacity development in science and technology (S&T) and the concepts that informed good practice 40–50 years ago. At that time it was thought desirable to create specialist agricultural research organisations that would produce scientifically validated technologies that farmers and others would subsequently use. Of course what is now realized is that while these ‘centres of excellence’ are important, what is equally crucial is the way the work of these organizations integrates and interacts with other sources of knowledge in a sector or country.

The required process of integration goes much beyond the often rhetorical calls for scientists to work with farmers. Instead it involves the development of an intricate web of interactions through which knowledge is shared and exchanged in different arenas—task, sector, state, region. This is the process through which individuals and organisations learn and put into use new ways of working and new methods of production. It is this process that leads to innovation in a technological, institutional and organizational sense. In the past working practices, routines, norms, policies (referred to here as institutions) that governed the extent of interaction and learning were not thought to be connected to the question of the effective deployment of S&T resources. However contemporary thinking on the production and use of knowledge suggests that institutional factors are a central component of capacity (Edquist, 1997; Oyelaran-Oyeyinka, 2005). To make the same point differently, the suggestion is that capacity is an embedded concept that can neither be understood, nor developed, without an understanding of contextual settings and particularly the institutional dimensions that these imply. A related observation is that since these contextual settings evolve over time, capacity and what it might entail is an ever-changing entity.

These sorts of perspective are emerging from a large body of literature dealing with the way countries and firms have developed and sustained the ability to innovate. Grounded in an evolutionary economics tradition (Nelson and Winter, 1982) and building on empirical observations at the national level (Freeman, 1987; Lundval, 1992) and at the firm and sector level (Bell and Albu, 1999; Mytelka, 2000) these ideas have found coherence in the concept of an innovation system. (The transition to a new, more embedded mode of knowledge production put forward by Gibbons *et al.*, 1994, makes a similar point). This concept is increasingly being used to tackle policy questions related to agriculture in developing countries (Hall *et al.*, 2001). The purpose of this paper is to use this perspective to explain what the nature of capacity and capacity development might be in this contemporary sense and its implications for biotechnology. The central message of the paper is that policy should recognize that capacity development in a contemporary sense is a multidimensional concept. It requires skills or competencies of both a scientific and non-scientific kind; it requires linkages between producers and users of knowledge; it requires the types of relationships and institutional setting conducive to knowledge sharing and interactive learning; it requires a policy environment that is sensitive to the need to create the conditions needed to make productive use of knowledge rather than focusing solely on the creation of that knowledge; and it needs the S&T and innovation policy foresight to prepare for the future. The paper illustrates this with some examples of the challenges developing countries face and a critique of recent capacity development approaches.

Section 2 below begins by briefly reviewing the concept of capacity development in agriculture and then Section 3 presents the innovation systems perspective on this.

Sections 4 and 5 present recent empirical cases from East Africa and India. Finally, Sections 6 and 7 discuss and conclude policy on innovation capacity development.

2 CAPACITY DEVELOPMENT IN AGRICULTURAL SCIENCE AND TECHNOLOGY: FROM RESEARCH CAPACITY TO INNOVATION CAPACITY?

For the last 40 to 50 years agricultural science and technology has been viewed as a critical driver of technological and socio-economic transformation in the predominantly agrarian economies of most developing countries. Building national and regional capabilities to conduct agricultural research has been at the forefront of these efforts. This has included training scientists and the establishment of research infrastructure to create national public sector research programmes. It has also included providing operational funds to conduct research and technology development, often in collaboration with the international centres of the Consultative Group on International Agricultural Research (CGIAR).

Yet despite the fact that financial support for agricultural research has declined and the mechanisms for sustaining support have failed to materialise (Rukuni *et al.*, 1998; Echier 1989) there are more serious concerns about the appropriateness of traditional agricultural research arrangements and the apparent inability of these to adapt to the changing agricultural scenario (Hall *et al.*, 2000; Byerlee and Alex 2002). In many senses the contemporary scenario is markedly different to earlier eras. The agenda has shifted from increasing crop (usually) food productivity, to explicit attempts to reduce poverty and protect the environment. The private sector has emerged as a much more important player in the sector—both in terms of research and product and service delivery. The role of the State has altered, often radically and new trends in governance—participation, decentralisation, consensus building and intellectual property protection—are impacting on many areas of research and development practice. Globalization (of markets, of knowledge, of regulatory and trade regimes) has also had major implications for agricultural research. Defining features include the following.

- New technological paradigms—biotech, information technology and communication (ITC).
- Increased private investment in research and development (R&D).
- Increasing knowledge intensity of production and competition.
- New modes of professional behaviour in development practice—participation, professional self reflection, partnership.
- New patterns of accountability to society (e.g. public debate on biotechnology).
- Changing patterns of ownership of knowledge and the technological and institutional changes that have supported it.
- Incremental learning about the nature of knowledge production and use.
- Changing views on the proper roles of the state, private sector and civil society.
- Changing views on the value of local knowledge, but also of knowledge systems more generally—particularly in the health sector.
- Opportunities and threats arising out of globalization (for both knowledge and trade systems).
- Changes in rates of change and stability of economic systems.

The emergence of biotechnology has been a typical example of recent trends whereby the broader framework conditions in which agricultural science and technology sit has been

altered in fundamental ways. The critical features of biotechnology are discussed in length in the specialist literature, but they include the following.

- Technological paradigm shifts whereby whole new trajectories of technological possibilities exist.
- Institutional changes, including a greater degree of proprietary ownership of knowledge and materials; and new patterns of partnership between scientific disciples and between public and private sectors.
- Science and society controversies surrounding ethical, environmental and health risks and uncertainty particularly with regard to genetically modified organisms.

These developments raise important questions for biotechnology capacity development: is it just a case of providing technical assistance to developing countries in the old sense—i.e. mainly as a matter of training and the development of human resources? Or as some have argued, is it a case that capacity building has to address instrumental issues such as the development of procedures, management, organizational structures, or strategy formulation (*Biotechnology and Development Monitor*, 1999)?

While there is an apparently inescapable logic to the view that capacity development in frontier technical field such as biotechnology should focus on training scientists, contemporary views on the production and use of knowledge suggest that this is only part of a larger task. There increasingly calls for capacity development in Southern countries to be concerned with strengthening the systems that interface between research and society which can promote learning and innovation (Hall, 2002), and that recognizes the importance of institutional development in this process (Fukuda-Parr *et al.*, 2002). This contrasts with the earlier knowledge transfer perspective that left unquestioned the way new knowledge or new skills would fit into existing systems and agendas in national settings and how these settings would impinge on the effectiveness and outcome of these transfers. Underpinning this contemporary view is the growing appreciation that, in agriculture and economic development, innovation is the central ingredient to transformation and that innovation concerns both the production of knowledge and putting that knowledge into use.

This perspective suggests that in areas like agricultural biotechnology it is not science and technology research capacity that is required alone, but instead a more broadly conceived notion of *innovation capacity*. To understand what this concept might mean, it is useful to revisit the concept of an innovation system and explore what its implications are for building the capacity to innovate.

3 INNOVATION SYSTEMS

The origins of the innovation systems concept lie in the concept of a national innovation system (Freeman, 1987; Lundval, 1992). This concept emerged because conventional economic models had limited power to explain innovation, which was viewed conventionally as a linear process driven by research. The innovation systems framework sees innovation in a more systemic, interactive and evolutionary way, whereby networks of organizations, together with the institutions and policies that affect their innovative behaviour and performance, bring new products and processes into economic and social use (for example, Freeman, 1987; Lundval, 1991; Edquist, 1997). The framework is now being used to understand and strengthen innovation at national, regional, and sectoral levels (OECD, 1997; Mytelka, 2000), including in agriculture (Hall *et al.*, 2001).

The framework provides a number of key policy and analytical insight that have relevance to the nature of capacity development.

3.1 Focus on Innovation

In contrast to most economic frameworks, which focus on production (output), the framework focuses on innovation processes. Innovation is often confused with research and measured in terms of scientific or technical outputs. However, the innovation systems framework stresses that innovation is neither research nor science and technology, but rather the application of knowledge (of all types) to achieve desired social and/or economic outcomes. This knowledge may be acquired through learning, research or experience, but until applied it cannot be considered innovation. These processes of learning and acquiring knowledge are interactive, often requiring extensive links among different sources of knowledge. The implication is that capacity development needs to focus not just on enhancing the ability to produce knowledge, but also the ability to put it into productive use.

3.2 The Role of Institutions

Institutional settings play a central role in shaping the processes critical to innovation: interacting, learning and sharing knowledge. Again, the meaning of institutions is often misunderstood. The innovation systems framework distinguishes institutions from organizations. Organizations are bodies such as enterprises, research institutes, farmer cooperatives, and government or non-government organizations (NGOs), whilst institutions are the sets of common habits, routines, practices, rules or laws that regulate the relationships and interactions between individuals and groups (Edquist, 1997). Because institutions shape innovation, institutional change is a large element of capacity development.

3.3 The Role of Policies

Policies are also important in determining how people behave. However, an environment that supports or encourages innovation is not the outcome of a single policy but rather of a set of policies that work together to shape innovative behaviour. Furthermore, habits and practices interact with policies: so to design effective policies it is necessary to take into account the habits and practices of the people affected (Mytelka, 2000). For example, the introduction of more participatory approaches to research is often ineffective unless the habits and practices of scientists are also changed. Capacity development therefore needs both the clusters of policies need to support innovation, but also the interaction of these with institutions also needs to be considered. This hints at the embedded context specific nature of capacity.

3.4 Stakeholder Involvement and Demands

The framework stresses the importance of including stakeholders and of making organizations and policies sensitive to their agendas and demands. Demand shapes the

focus and direction of innovation. It is articulated not simply by the market but also by non-market drivers, such as collaborative relationships between the users and producers of knowledge. Demand for certain sorts of innovation can also be stimulated by policy, for instance by providing incentives to adopt a certain technology or management practice. This can be especially important where key stakeholders are poor and have limited social and economic power or where the negative environmental impact of development needs to be addressed. Skills and institutional setting needed to create stakeholder involvement are thus part of capacity.

3.5 The Dynamic Nature of Innovation Systems

The habits and practices that are critical to innovation are learnt behaviours that may change either gradually or suddenly. They are often enshrined in institutional innovations, such as farmer field schools or participatory plant breeding, that emerge through scientists' experimentation and learning. These new approaches to research and development often require not only new ways of working but also new partners. Thus capacities develop in incremental ways through learning. But a key element of capacity is the ability to reconfigure approaches and patterns of partnership to deal with changing circumstances.

3.6 Changing in the Face of Change

One of the characteristics of successful innovation systems is that their component organizations tend to create new partnerships and alliances in the face of external shocks. Examples of such shocks might be: a new pest problem, requiring collaboration between a different set of scientific disciplines; the advent of a new technology, such as GM crop varieties, requiring the formation of partnerships between the public and private sectors; or changing trade rules and competitive pressure in international markets, leading to a need for new relationships between local companies and research organizations. It is not possible to determine the kinds of networks, links and partnerships that will be needed in the future, as the nature of future shocks is by definition unknown. The way to deal with this is to develop capacity that creates the flexibility in working habits and institutions that allows dynamic and rapid responses to changing circumstances.

There is as yet no accepted definition of the term *innovation capacity*, but it captures the creative and non-linear events that sustain the change process. In a similar vein, more than a decade ago Bell and Pavitt, (1993) used the narrower term *technological capacity*. They contrasted research capacity and technological capacity stating that the former concerns the resources needed to conduct scientific research. In contrast technological capacity concerns the resources needed to manage technical change including skills, knowledge and experience (scientific, but also entrepreneurial), institutional structures and linkages or networks connecting science, consumers, entrepreneurs, intermediary organizations and policy bodies.

The innovation capacity concept recognises these same broad set of skills, links and structures, but in relation to the total process of producing accessing, diffusing and, most importantly, putting into use knowledge in socio-economically useful ways. It stresses that institutional settings (including the policy environment) are a critical part of this capacity and that capacity development is often an issue of institutional and policy change.

Innovation capacity is thus an embedded capacity that can not be understood or development without considering its contextual setting. Furthermore innovation capacity is a dynamic capacity not just concerned with systems, linkages and institutions as they exist today, but also about the ability to reconfigure these arrangements in response to changing demands and circumstances. As Clark (1995) points out, the need is to understand capacity in terms of holistic evolutionary systems of learning and change, where future states were unknown and unknowable.

The nature of biotechnology is such that its utilization is embedded in a range of institutional and other factors which are themselves evolving rapidly. The innovation capacity perspective therefore seems to have much to offer.

4 EXAMPLES OF DIFFERENT FORMS OF CAPACITY DEVELOPMENT

Given the complexity of the capacity development task and recognizing that there are divergent views about how it should be achieved, it is hardly surprising that it has been tackled in different ways by different agencies and different countries. The following examples illustrate some of these different approaches. Not all of these examples have been designed specifically with capacity development in mind, although many have. Similarly not all of these examples have had the outcomes that were intended. All these cases, however, have been included to illustrate what on the one hand innovation capacity might mean in operational terms and on the other the short comings of some existing interventions.

4.1 Building Capacities in Basic Sciences: The Millennium Science Initiative in Uganda

The Millennium Science Initiative (MSI) is a joint project of the Ugandan Ministry of Finance Planning and Economic Development and the World Bank. The project, which is yet to enter full implementation, is based on diagnosis of the state of science and technology in Uganda which highlights the following.

- A sociological bias against science which is viewed as 'useless and irrelevant'
- Poor science education at primary and secondary levels
- Low investments in science disciplines in both public and private universities
- Static or obsolete university science curricula
- Few career opportunities for scientists in Uganda
- Low critical mass of entrepreneurs able to turn science talent into business ventures.

Despite the absence of a strong and coherent policy to develop S&T capability, Uganda has managed to create pockets of high quality S&T often with funding made available through donors. Agricultural science has been a good example of this. Recent developments at the main public university, the referred to as Innovations at Makerere Programme, have made strenuous efforts to re-establish the relevance of academic work as a key quality criterion. The MSI is an attempt to build on these advances, recognising the need for capabilities in both basic and applied, responsive research.

The proposed project has two main components.

4.1.1 *Component One (85 percent of project cost)*

The core of the project is a competitive grant fund (the 'MSI Fund'). The MSI Fund would have three 'windows' to support (i) advance research connected to graduate training. This is aimed at the top research groups in the country in the hope of giving them the ability to work at similar levels to richer countries of the OECD; (ii) strengthening or creation of undergraduate degree programmes in S&T disciplines; (iii) research activities defined by the private sector.

4.1.2 *Component Two (15 percent of project cost)*

This component will support involvement of the science and technology community in policymaking and related activities. A main set of activities would involve 'social marketing' of science by high profile researchers to primary and secondary school students. The goal would be to catalyze greater attention to and action for improvements in primary and secondary level science education (curriculum reform, strengthen teacher qualifications). The social marketing of science would seek to overcome the anti-science biases that have developed in the education system after years of neglect and under-investment.

In a sense the MSI is a combination what are old ways of developing scientific capacity (i.e. providing funds for research to be carried out) and contemporary thinking about the need to integrate this into capacity into the rest of the economy and society. The initiative clearly recognises the needs to build an acceptance of science and a scientific orientation through its focus on primary and secondary education curricula. It also recognizes that resources need to be spent to increase interaction with the private sector. However, the focus is still pre-dominantly on developing capacity of the science and technology system and not the wider innovation system. The issue of integration with the private sector is given relatively minor attention and is discussed, for example, in terms offering small initial grants to industry associations/entrepreneurs to create problem-focused research agendas in collaboration with researchers. The development of relevant policy capabilities seems to be absent from the project.

4.2 **Creating and Strengthening Regulatory Frameworks**

USAID has supported a series of programmes to assist countries in Africa to develop biosafety arrangements. These programmes include the African Biosafety Programme I managed by Michigan State University and ABSP II managed by the Cornell University Programme for Biosafety. More recently USAID has launched a global programme on biosafety—the *Program for Biosafety Systems (PBS)*. This programme is managed by the International Food Policy Research Institute. PBS focuses on the development of regulation protocols for biotechnology-related activities through stakeholder consultations, technical training in environmental and food risk assessment, communication and outreach, as well as providing grants for research into environmental risk issues. In 2003 and 2004, PBS focused on enabling the authorization and safe conduct of confined field trials of genetically modified organisms in a number of countries.

This type of approach is clearly important in developing capacity in developing countries in risk assessment and risk management. It is an important element of innovation capacity helping create the necessary institutional framework needed for the deployment of biotechnology. However it is less clear how these efforts relate to creating relevant

policy capacity as many of these programmes seem to focus on protocols rather than policy *per se*. Also unclear is the way these programmes link with the policy process and this will certainly be required if bio-safety is to become an integrated part of science and technology and innovation policy.

A more broad based approach has been East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN). BIO-EARN was launched in 1999 with support from the Swedish International Development Cooperation Agency (SIDA) and the Biotechnology Advisory Centre of the Stockholm Environment Institute. BIO-EARN aims to build capacity in biotechnology research and policy in Ethiopia, Kenya, Tanzania and Uganda. It has three programme areas: biotechnology, biosafety, and biotechnology policy development. BIO-EARN capacity building activities target scientists, regulators, the private sector, special interest groups and policy-makers and include training through short courses and workshops, for instance, in:

- biosafety (biosafety assessment and risk management, field evaluation of transgenic crops, case studies of industrialised country experiences); and
- policy (biotechnology policy formulation, analysis and implementation, intellectual property rights, technology transfer, technology assessment, public-private partnerships).

BIO-EARN also aims to facilitate greater dialogue amongst these actors through its training activities. Examples of courses that BIO-EARN has been involved in include 'Biotechnology and public policy' and 'Building national biotechnology innovation systems: new forms of institutional arrangements and financial mechanisms'. This focus of policy capacity development is an important feature of this programme.

4.3 Networked Centres of Excellences

In 2000 John Mugabe, the then director of the African Centre for Technology Studies, prepared a strategic document for the United Nations Conference on Trade and Development (UNCTAD) outlining capacity development consideration relation to biotechnology in developing countries (Mugabe, 2000). He argued that on the one hand the capacity to search, assess, acquire or develop and utilize new technologies and new knowledge for science and technology policy making is one of the most important prerequisites for sustainable development. But that on the other hand international science and technology organisations under the UN and the Consultative Group on International Agricultural Research had neither satisfactorily addressed the needs of developed countries nor built adequate linkages with research organisations and research within these countries. The remedy for this, it was suggested, was to create networked centres of excellence, replacing the trend towards concentration of resources in single locations. Instead the idea would be to build the capacity of a number of centres that would collectively constitute a centre of excellence. These could then be linked to regional and international public research institutes. By creating capacity in locally based units of the network, opportunities for local involvement in agenda setting, for local outreach activities and for a stronger scientific base for policy are created (Mytelka, 2001).

This vision of networked centres of excellence is being operationalised through the establishment of Bioscience for Eastern and Central Africa (BECA). Then the centres of

excellence concept was further developed in 2002, through collaboration between the New Partnerships for African Development (NEPAD) and the International Livestock Research Institute (ILRI), and the Doyle Foundation, which facilitated consultations within Africa and with potential partners internationally. The concept identified capacity building as a key component in any biosciences initiatives in Africa. The focus is on biosciences as they relate to health and agriculture with the recognition that research focus at the gene level has allowed much scientific convergence between the two sectors, including the following areas.

- Marker assisted selection as an aid to breeding programmes
- Genomics as an aid to gene discovery
- Plant transformation
- Molecular diagnostics
- Bioinformatics

There are three key elements in operationalising the initiative. The first is the creation of scientific infrastructure hosted at the ILRI Nairobi. This has involved updating laboratory facilities, mainly in the ILRI Nairobi campus with the financial support of the International Development Research Centre (IDRC) of Canada. The second is mobilisation of further operational funds to ensure that African scientists have access to research funds on a competitive basis. The third element is the establishment of a governance/partnership structure. This is particularly critical for a shared and networked facility. For the facility to operate effectively it needs to partner with key scientific and developmental stakeholder in the region. It is important that different stakeholder groups are involved in priority setting and foresight exercises. There are also issues about the ownership of facilities and how recurrent costs will be paid. In addition there is a need to address the integration of the initiative into other capacity development initiatives in the bioscience in the region needs to be addressed. And perhaps most fundamentally of all, the question remains as to how the scientific agenda and outputs can be linked to those who are going to need to use these technologies particular poor rural communities. Only if the latter can be successfully resolved will the initiative be able to succeed where so many others have failed to fulfil the promised of science delivering equitable and sustainable development in Africa.

The initiative is at an early stage of development and it is probably fair to say that the governance/ partnership element of the initiative is proving by far the most difficult to operationalize. But this is an important part of the process of capacity development as it will create skills and lessons on how to establish and operationalize this type of networked biosciences facility in the context of sub-Saharan Africa. As Carlos Sere, the Director of ILRI pointed out after lessons from the establishment of the BECA will provide lessons about how capacities can be created to use science more effectively in the development process. This will not only provide lessons for how to establish biosciences centres of this type in other regions of Africa. But it will also provide lessons on how capacities can be built to exploit the technological paradigms that succeeds biotechnology, for example nano-technology (personal communication, 2004).

4.4 Partnerships

Two forms of partnerships are widely discussed in relation to capacity development in biotechnology. The first is North–South partnerships and the second is public private

sector partnerships. In both cases the logic is that partnerships give developing country research organizations access to materials and advanced techniques that these organizations can then master. Even if developed county research organisations can not master new techniques because of for example infrastructure reasons it can take advantage of its networked capacity which would include that of its new partner. Another additional benefits arising out of these partnerships is that it exposes research organizations to new ways of working particularly when working with organizations with contrasting cultures such as private firms. Organizations like the International Service for the Acquisition of Agri Biotechnology Applications (ISAAA) have played an important role in brokering partnerships between developing country research organization and both public and private organization from Europe and North America. (Verástegui (1999) and Velho (2004) provide useful summaries of examples in Latin America and East Africa respectively.)

In general the partnership approaches have often been quite successful in developing clusters of organizations capable of developing new technology—examples are presented in Table 1. However as Velho (2004) points out a generic weakness, particularly for North-South

Table 1. Examples of capacity development biotechnology partnerships

Focus	Private sector partner(s)	Public sector partner(s)	Observations
Bt maize (insect resistance)	Pioneer Hi-Bred (USA)	Agricultural genetic engineering Institute (AGERI), Egypt	Training for AGERI scientist. Gave pioneer access to evaluate Bt proteins and genes patented by AGERI. IPRs provide for market segmentation
Papaya ring spot virus	Monsanto (USA)	Research organizations in South East Asia Universities in USA and UK	Network of public and private partners. Arrangement brokered by ISAAA.
Golden rice (vitamin a enhanced)	Zeneca plant science (now part of Syngenta) Many including Greenovation, Zeneca (now part of Syngenta)		License is free for production for local domestic markets. Involved 70 patents belonging to 32 companies and universities and difficult IPR negotiations Board established to help deliver to developing countries
Virus resistant sweet potato	Monsanto (USA)	USAID's ABSP Kenyan Agricultural Research Organization and Vegetable and Ornamental Plants Institute (South Africa)	Brokered by ISAAA. IPR allow unrestricted use in Africa. Yet to be commercialized and concerns exists about weak links to local private sector, NGO's and farmers.
Apomixis	Pioneer Hi-bred (USA) Syngenta (Switzerland) Limagrain (France)	CIMMYT L'Institut de Recherche pour le Development (France)	
Insect resistant maize for Africa	Novartis (Switzerland)	Syngenta foundation (Switzerland) Kenyan agricultural research institute, CIMMYT	Use limited to Africa

partnerships is the failure of the Southern research organisation to build local partnerships and networks with firms, NGO's and other stakeholders. Without these the uptake of new technologies becomes difficult and identification of priorities becomes skewed.

Perhaps the most graphic example of this is the much cited case of the partnership between the Kenyan Agricultural Research Institute and Monsanto in the development of virus resistant sweet potato (see Ikiara, 2004). This was a very effective scientific collaboration. Monsanto had the virus resistant gene and trained Kenyan scientists in genetic transformation techniques. The gene was then transferred into Kenyan sweet potato germplasm. However this virus free material is facing the same struggle of getting out to farmers fields as any new technology coming from the Kenyan public agricultural research system. That is to say that commercialization and dissemination has been weak. Without down stream partners the capacity to bring about innovation in farmers fields is compromised. More worrying in this case is that the lack of connection with farm reality may have been responsible for selection of a gene conferring resistance to the wrong virus—it appears that the gene does not give protection against the commonly occurring sweet potato virus in Kenya.

This is clear a case of an intervention that has helped develop important technological capacities, but has not fully addressed the need to strengthen the capacity of the innovation system as a whole. Ikiara (2004) argues that this wider systems failure in Kenya includes a lack of a bio-safety framework, lack of effective intellectual property rights regime; lack of trust between public and private sectors; poor political and economic governance; lack of coordination between the national agricultural research organisation, donor agendas, farmers and national and international research collaborators.

4.5 Building Policy Capacity in Innovation Systems Perspectives

Despite the growing recognition of the importance in development of biotechnology and science and technology more generally in the development process, efforts to build science technology and innovation policy (STIP) skills have been extremely limited. A recent review (Clark, 2004) of the demand for STIP training in relation specifically to agricultural biotechnology in Africa highlighted not only the clear need for policy skills with an innovation systems perspective, but also the almost complete absence of organizations providing this training in the region. Exceptions include the African Technology Policy Network (ATPS) which has been active in promoting these policy perspectives. Similarly The African Centre for Technology Studies (ACTS) in Nairobi pioneered a capacity development programme for policy actors using a systems perspective (Clark and Mugabe, 2004). ACTS has recently renewed its efforts in policy capacity development, piloting a new course in 2005.

In the international arena CTA¹ of the Netherlands and the United Nations University, Institute for New Technologies (UNU-INTECH) have been running a regular annual training programme on Agricultural Systems of Science and Technology Innovation (ASTI) for researchers and policy-makers since 2003–04. The purpose of this programme is to provide policy makers practical tools to analyse and plan with in a framework of a system of innovation. In a related development UNU/INTECH has proposed the establishment of the East African and South Asia Regional Hubs in partnership with the

¹The full form of CTA is The ACP-EU Technical Centre for Agricultural and Rural Cooperation.

International Livestock Research Institute.² These hubs will act as focal points to link policy research relating to innovation in agriculture and rural development with researchers and policy actors. Underpinning this is the desire to contribute to building the capacity of policy-makers to tackle issues such as the deployment of biotechnology in a more holistic systems of innovation sense. The International Food Policy Research Institute is also pursuing capacity development activities in this area of policy.

Although these efforts at building policy capacity are rather thin on the ground, there does seem to be a growing recognition that building better integrated capacities to deploy technical advances such as biotechnology will require policy capacities that embrace these perspectives (Clark, 2004). This is important because it is these policy perspectives that will create the enabling environment to allow innovation take place. The donor community should note that policy capacity of this sort is part and parcel of innovation capacity and therefore must be an integral part of capacity development approaches that seek to exploit science and technology.

4.6 Pro-Poor Biotechnology Capacity Development through Institutional Innovation

The Andhra Pradesh–Netherlands Biotechnology Programme (PNBP) is a donor assisted programme in India designed to develop biotechnology capacity.³ Unlike many programmes it recognized that this task was as much about institutional change as it was frontier skills. This perspective was particularly relevant in the case of India because the country already had well trained scientists and scientific infrastructure. The programme therefore viewed the capacity development task not as one of creating disciplinary excellence in science, but as one requiring the integration of conventional laboratory-centric research arrangements with farm-centric activities and process. This required both alliances between the scientific and NGO communities as well as a process of learning to work in new ways.

In essence the programme which had two five-year operational phases was a series of collaborative research and development projects related to initially traditional biotechnology (tissue culture, microbial inoculants and bio-control of pest) and latter advanced biotechnology (including genetic transformation, for example Bt castor). While at one level the core of the programme was the provision of research funding to help build biotechnology capacity, the project was organised in such a way that it was tackling a much bigger set of issues than research funding alone. Important features were the following.

- The programme made a conscious decision to focus on using biotechnology to create solutions to real problems faced by poor farmers in the rain-fed areas of Andhra Pradesh. This was embodied in an approach called an integrated bottom up approach (IBU). The IBU involved undertaking detailed needs assessment exercises with farmers to set overall guiding priorities for the programme. Latter on the IBU meant that farmers were active participants in projects.
- NGOs rather than research organizations were chosen to undertake the needs assessment work because of their greater familiarity with rural communities. As part

²Beginning in April 2004 UNU-INTECH began a programme of work addressing the question of the nature of agricultural innovation system capacity and how, within the framework of sustainable development this capacity can be developed to cope with changing technological, institutional, policy and social contexts.

³See Clark *et al.*, 2002 for comprehensive review of this programme.

of the IBU, the NGO then became partners with research organizations in the projects that the programme sponsored.

- Right from the start the Dutch donor gave control of the programme to an Indian steering committee and programme office. This was critical because it was recognised that as a capacity development programme it needed local ownership and needed to be shaped by locally appropriate ways of doing things.
- The programme office was hosted by part of a public university, but one which was totally unrelated to biotechnology. The logic behind this was that since the programme recognized that a large element of the capacity development was changing the culture of scientific research (making more client focused, learning to work with NGOs), it needed to have the autonomy to provide the institutional space for scientists to experiment in different ways of working. This would have been much more difficult if it had been a classic research programme house in an agricultural research organization.

This last point is critical as a defining feature of this programme was its attempt to put in place a process which would allow scientists and development workers to create and experience the institutional innovations necessary to allow biotechnology to be brought to bear on the problems of poor farmers. By definition this process has to be a very contextually specific and so the approach of allowing this capacity development programme to be locally owned and embed in local systems was very important.

It would be wrong to portray the APNBP as an un-reserved success. There are, however, two points about the nature of capacity that this case highlights. The first as already mention is the idea of institutional innovations as part of capacity development. To be specific, in this case what this meant was that it started to become both acceptable and desirable for scientific research organizations to work interactively with NGO's and farmers. This came about through a long process of collaborative projects in which it became apparent to scientists that they had much to gain from working in these ways. This was particularly in terms of seeing the uptake and use of their research findings. In India where strong hierarchies tend to separate scientists from farmers, this is a significant institutional innovation.

The second point that emerges from this case is the way that social capital emerges as an important element of capacity. In this regard social capital refers to the ability to form relationships of trust, cooperation and common purpose. One of the outcomes of this programme is that social capital has been built up between the scientific and the NGO community. This does not mean that permanent linkages have been formed. However, once having worked together, a relationship exists that can be used as the basis for potential collaboration in the future. This type of capital not only increases the likelihood of linkages forming, but it also increases the rate at which new patterns of linkage can be established in response to changing challenges and opportunities.

5 TOWARDS AN UNDERSTANDING OF INNOVATION CAPACITY DEVELOPMENT

The conceptualization of innovation capacity as developed in the early part of this paper refers to the understanding of knowledge production and use in a systems sense where innovation is embedded in and shaped by contexts, relationships and actor groupings that include but go beyond formal scientific organisations. While the capacity development efforts discussed above had to varying degrees of success in addressing this broader task, one senses a lingering tendency to compartmentalize the capacity development task. To

make the same point differently, capacity development perspectives which tackle biotechnology in a piecemeal fashion (human capital and research infrastructure; bio-safety; public private sector partnerships; IPR) without understanding the need to deal with (and often strengthen) the overall system for producing and using knowledge are going to continue to encounter 'second order problems'.

Having said that the examples presented above do provide insights in the range of components that would encompass the concept of innovation capacity. This capacity could be defined as *the context specific range of skills, actors, practices, routines, institutions and policies needed to put knowledge into productive use in response to an evolving set challenges, opportunities and technical and institutional contexts*. While it is impossible to be definitive about what a context specific and adaptive capacity would entail, the broad elements of agricultural biotechnology innovation capacity may include the following elements, arrangements and skills.

- National culture appreciative of the value of the scientific knowledge in enterprise and development.
- A critical mass of scientists trained in frontier area of biology and the scientific infrastructure and funds to productively employ them in research and development roles in the public and private sectors. (This would include the training organizations needs to create this human capital.)
- A range of actors with different types of agricultural knowledge, codified and tacit, in the public, private and NGO sectors.
- Linkages between key sources of knowledge and the social capital need to allow new linkages to be brought into play when needed.
- Relationships and institutions (including habits and practices) that support dialogue, knowledge access, sharing, and learning between different sources of knowledge; between different interest groups including the poor; and between policy actors, practitioners and researchers.
- A range of skills in research, entrepreneurial organizations including: scientific, technical, managerial entrepreneurial skills and skills and routines related to partnering, negotiating, consensus and learning.
- Clusters of supportive policies that allow both the production of knowledge (i.e. science and technology policy) as well as the productive use of that knowledge (i.e. market and trade policy, investment incentives, regulatory regimes, bio-safety protocols; IPR).
- Change management competencies and mechanism to help predict and cope with evolving innovation environments (i.e. technology foresight). This will include the ability to link scientific knowledge to policy, problem solving and long-term planning.
- Coordination and facilitation mechanisms (i.e. sector associations, development authorities or boards) and incentive and support structures (i.e. subsidies, credit) to strengthen systems coherence in the absence of market signals.
- Policy capacity to plan and promote innovation as a systemic phenomenon.

6 POLICY TOOLS FOR CAPACITY DEVELOPMENT— MULTIPLE EVOLVING INNOVATION SYSTEMS

The innovation systems framework certainly does help reveal the breath of the capacity development task in the contemporary sense. However the discussion of an innovation systems and ways of building its capacity seems to suffer from precisely the flaw that its

critics level at it: namely that is a theory of every body working with everybody on everything. In other words, is it sufficiently policy relevant to be operationalised in science, technology and innovation planning? Also at this level of conceptual discussion one senses something counter intuitive about it. So, for example, we can see that farmer participatory research with local grouping of actors will be necessary to develop innovations in complex agro-ecological environments. But we can also see that the development of biotechnology solutions is going to require quite different grouping of actors, where scientific agencies and perhaps the private sector are going to have to play a lead role. Furthermore these different innovation systems can not be thought of as static entities as they are all embedded in evolving contexts with which they interact and respond to.

To address this shortcoming it is perhaps more useful to further develop the innovation systems concept and recognize that there are in fact families of connected but distinct innovation systems. These would involve clusters of organizations producing and using knowledge in ways that are appropriate to specific agendas and goals, technological settings, and competencies and of course specific contextual settings.

The empirical cases that have been presented seem to support this in a number of ways. For example it seem quiet correct that the capacity of biotechnology innovation systems needs to be developed around clusters of scientific organizations. The examples of the networked biotechnology capacity concept and the partnership model of capacity development are probably of this type. Despite the critique of these, particularly the partnership model, of having failed to build the linkages with local and down stream actors, one can not detract from the fact that these sorts of capacities are important when viewed as part of a bigger endeavor. Similarly, and perhaps at the other end of the spectrum, the APNBP in India was a case of developing and innovation capacity that was more participatory and farmer centric.

A key theme that is common to all these types of cases is that a major task is not just about creating the linkages in the particular innovation system, but about integrating different groupings of linkages. The APNBP chiefly concerned integrating the scientific network of Indian agricultural research organization with the NGO's and farmer networks working rural development. The short coming of the Kenyan sweet potato virus case was again about the need to better integrate the scientific network developing new varieties with the commercial, NGO and farmer networks involved in diffusing and using the technologies. It was also not that these clusters all had to be working together all the time, but that there needed to be interaction at strategic points in time, such as problem identification.

The innovation systems concept predicts that these different systems will both emerge spontaneously around new themes, or will evolve through incremental change as systems interact with their changing contexts. Some of these systems already exist while others its is probably safe to predict are likely to emerge (or need to be put) in place in coming years. This would include the following agricultural innovation systems typologies:

- **Old CGIAR.** Network of international centres of scientific excellence developing agricultural production technology.
- **New CGIAR.** Network of international centres acting as brokers of agricultural science for development.
- **Entrepreneurial led Agri-businesses.** National and international companies with linkages to both public and private sources of technical expertise.

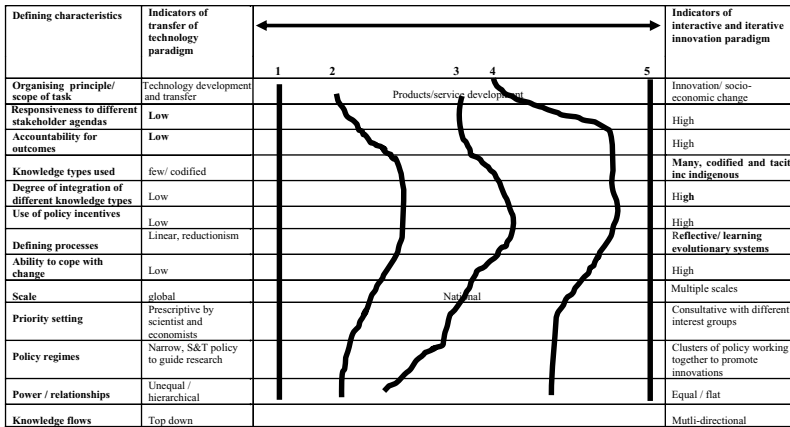


Figure 1. Typology of agricultural innovation systems

Notes: 1 Old CGIAR; 2 New CGIAR; 3 R&D led Agri-business; 4 Public private sector partnership; 5 Pro-poor participatory innovation for complex agro-ecologies.

- **R&D led agribusiness.** National and international companies with advanced R&D capability in the biological sciences.
- **Public private sector partnerships.** Alliances of public research organisations to develop and deliver products with high social returns.
- **Coping and competing in international agricultural markets.** Sector based groupings of farmers, agri-business and public and private research organisations interacting to innovation in response to changing markets conditions.
- **pro-poor participatory innovation for complex agro-ecologies.** Localised and well integrated groupings of farmers, agri-business and government and non-government development agencies with strategic links to research organisations.

Figure 1 presents these different typologies by placing them at different points along a continuum between two innovation paradigms. The first on the left is the technology transfer paradigm and the second on the right is the interactive and iterative innovation paradigm. Institutional characteristics of each paradigm are given in the left- and right-hand columns. The lines representing the different typologies are shaped to map the different institutional features which characterise them. Figure 1 is not intended to indicate an evolutionary progression from the technology transfer paradigm to the interactive iterative paradigm. Rather it represents a branching genealogy where new types of innovation system emerge through adaption in response to new tasks and other changes in the research and development environment. Its not that one is better than another, rather than different systems are suited to achieving certain outcomes.

This recognition of diversity is important for a number of reasons. Firstly it allows policy and capacity development activities to recognize and support the co-existence of different types innovation capacity. This helps break out of the false dichotomy whereby old practices are vilified at the expense of new without recognizing synergy. Secondly, it allows emphasis to be given to ways of strengthening the strategic, purpose-oriented interaction of these systems at various points of intersection. This shifts attention to complementing and integrating different ways of producing and using knowledge rather than arguing for homogeny and, for example, insisting that all approaches having to

become participatory or partnership based or that all approaches have to be science-led. Clearly neither of these propositions is workable and could undermine well intentioned capacity development efforts. This perspective is important for biotechnology as it helps understand how agriculture biotechnology innovation systems might be situated and integrated with respect to other systems or indeed whether biotechnology is not a new innovation system in itself but an aspect that has to be integrated into other systems.

7 CAPACITY DEVELOPMENT: WAYS FORWARD

This paper has a number of messages about the ways biotechnology and other innovation capacity can be developed in developing countries. The first is that policy should recognize that capacity development in a contemporary sense is a multidimensional concept. It requires skills or competencies of both a scientific and non-scientific kind; it requires linkages between producers and users of knowledge and between scientist and policy makers; it requires the types of relationships and institutional setting conducive to knowledge sharing and interactive learning; it requires a policy environment that is sensitive to the need to create the conditions needed to make productive use of knowledge rather than focusing solely on the creation of that knowledge; and it needs a policy capacity with the perspectives to deal with innovation as a systemic phenomenon.

Secondly, at a general level the innovation systems approach is a useful policy tool for thinking about how capacities can be developed. However, this alone maybe too simplistic an analysis to be policy relevant. Nor indeed does it reflect the diversity of knowledge production arrangements that already exist, only one of which might be focused on biotechnology. Instead policy should recognize that there are in fact multiple innovation systems operating in the agricultural sector; all have different rules and different players appropriate to the themes and incentives to which these are responding to. Agricultural biotechnology capacity has to been seen in both this broader innovation systems sense, as well as recognizing that it is only one in a series of related innovation systems. The corollary to this is the importance capacity development in a diversity of these systems.

Thirdly, policy should look at ways of strategically integrating different innovation systems; for example how can biotechnology innovation systems be brought to bear on farmer participatory innovation systems. And fourthly, it is noted that these sorts of perspectives are yet to penetrate the policy community dealing with developmental aspects of agricultural science technology and innovation in national and international organizations. Building the skills of policy actors to conceptualize innovation capacity in this way will be essential for putting in place supportive frameworks for capacity development in this broader embedded sense. Only when this happens will biotechnology start to significantly impinge on the development process in the poorest countries and deliver the potential that its advocates have promised for so long.

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