Preface

The origin of this book is the work of a group of science, technology and innovation policy analysts working in India – all of whom are editors of the book. In 1997 this group started exploring issues about partnership and institutional contexts of post-harvest research projects (some of this history is detailed in Hall et al. (Paper 8, this volume). In their search for more-inclusive ways of thinking about these issues they started to use and adapt an idea that that their counterparts were using in relation to industrial innovation in developed countries. The idea was that of a **national system of innovation** – in the book most authors use the shorthand **innovation systems** when discussing the principles implied by this concept.

The main thrust of this policy research has been to develop and apply the innovation systems concept in relation to agricultural innovation in developing countries. The context in which the group carried out this work needs to be explained because it shaped the way the concept was used and the sorts of empirical case that were explored. The initial work explored partnership in the post-harvest sector – initially public–private sector partnership and latter more general partnerships. More specifically these were partnerships and post-harvest issues associated with a donor-sponsored research program – the UK Department for International Development (DFID) Crop Post-Harvest Programme (CPHP).

At the time DFID and other international development assistance agencies were making high-profile attempts to improve the impact of their programs on poverty reduction. Significant resources were being spent on agricultural research, and yet it was unclear how this was leading to a reduction in the level of poverty. Responding to this policy imperative, the research team was not only interested in trying to apply the innovation systems concept as a way of more effectively deploying agricultural research and development (R&D) in a general sense, but also doing so in ways that had an explicit poverty focus. As a result of this emphasis most of the papers in this book discuss the pro-poorness of certain innovation processes and ways of making innovation systems more socially responsible – as it turned out this proved to be the most difficult aspect of the research on which to provide definitive answers.

The post-harvest theme has obviously been a major influence on the sorts of empirical case that have been investigated. This is notable perhaps only because the host for much of this work has been the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) whose main interest has been on crop improvement and not on post-harvest issues. The work conducted at ICRISAT was a true 'special project' in the sense that it explored an approach (and a sector) in which the Institute probably would not have invested; but recognized the value of the general topic. In fact, when the research on innovation systems began it was a time when not only was ICRISAT trying to explore ways of improving its own impact, but was also grappling with the idea of partnership as a key implementation strategy. One of other results of the work's being hosted at ICRISAT was that it exposed the research team to the impact assessment traditions of the Institute and indeed to those of the rest of Consultative Group on International Agricultural Research (CGIAR). At that time – 1997 – the CGIAR as a whole was under intense scrutiny from its sponsors to demonstrate value for money. A critical response by many of the centers in the Group, including ICRISAT was to conduct a series of impact assessments studies that sought to demonstrate the economic rates of return to investments in international agricultural research. While the research team respected the need to make scientific research organizations more accountable (in this case to its sponsors), it sensed that this was necessary but not sufficient. The feeling was that if the impact was to be improved, the diagnostic content of economic analysis needed to be supplemented with perspective that could provide insights into ways of improving research as a process. This was clearly an area in which the innovation systems idea had much to offer.

The research team participated in a number of high-profile international conferences focusing on the impact of international agricultural research and on ways to improve it. As a consequence, a group of social scientists emerged from these meetings with a shared interest in promoting institutional change as a way of improving impact. This initiative is starting to take to shape in the form of the CGIAR Institutional Learning and Change Initiative that uses the innovation systems concept as an underpinning framework.

Elsewhere there are also signs that the innovation concept is starting to spread. For example, the new International Service for National Agricultural Research (ISNAR) program at the International Food Policy Research Institute (IFPRI) has an explicit focus on capacity development and institutional change in innovation systems. The research team is happy to see that others are finding merit in these ideas and hopes that this book and its companion volume *Post-harvest innovations in innovations,* published in 2003 by CPHP, will provide others with a useful summary of their experiences of using this idea. The team also worries about the bandwagon effect of new concepts and hopes that it will not be used cynically to re-badge old approaches.

On behalf of the research team I would like to thank those have made this research and hence this book possible. Firstly, the sponsor of the work, DFID's CPHP and particularly the Manager Tim Donaldson who was willing to extensively fund a largely untested idea. Next, we would like to thank the Directors of the Indian National Centre for Agricultural Economics and Policy Research (NCAP) and ICRISAT, Drs Murthnja and Dar for providing their support and the support of their staff for the research. And finally, the team would like to thank Sue Hainsworth and her editorial team for pushing us to get the book finished – it simply would not have happened otherwise

Personally, I would like to thank Norman Clark for his guidance and support, as a mentor, colleague and friend over many years. I would like to thank Dr Jha, former director of NCAP for having the foresight to insist that I work with Rasheed Sulaiman, and I would like to take this opportunity to let Rasheed know how much I have enjoyed working with him as a research partner and as a friend, and hope that we have many more joint papers ahead of us. All those other mind-expanding influences are also acknowledged here.

I would also like to the Natural Resources Institute, University of Greenwich and particularly their director Dr Guy Poulter for sending me to ICRISAT and for letting me stay there for so long.

And finally, I would like to thank my family for putting up with my constant absenteeism whilst I worked on the book.

Andy Hall

Foreword

ICRISAT – an innovating organization in a changing world

W D Dar[1]

At ICRISAT, we recognize and accept that change and evolution are central characteristics of modern human society. If science and technology is to be effectively used to combat poverty in this changing world, one cannot stand still. Organizations like ICRISAT and our development partners must adapt, innovate, and evolve. I would like to share with you some of the innovations within ICRISAT that have been introduced to cope with this changing world, and the core principles and values of partnership, trust, and excellence that the Institute uses to keep pace with the developments which surround it.

As ICRISAT has now passed its 30th anniversary it is useful to reflect on the way the semi-arid tropics (SAT) and indeed the wider world have changed. When the Institute was established in 1972, the successes of the seed-based technologies of the Green Revolution were just starting to become apparent to all. Food shortages in both Asia and Africa were still a major concern for the international development community. There was still a critical need to build capacity in public-sector plant breeding programs and in seed production and distribution systems – particularly for crops grown and consumed by the poor. These imperatives were reflected in the establishment of ICRISAT as an international center of excellence in the crops of the SAT – sorghum, pearl millet, chickpea, pigeonpea, and groundnut – with a core competence in plant breeding and genetic enhancement.

In the intervening years much has changed. Eight features stand out:

1. In the world's SAT, increasing food production, while still necessary, is no longer sufficient to reduce poverty. The rural poor have developed diversified livelihood strategies to cope with their vulnerability and to exploit new, often market-driven, opportunities
2. International development goals have widened from merely increasing food supply to include poverty reduction and environmental sustainability. As a consequence, international support for agricultural science and technology has now to compete with a wider set of development objectives
3. Shifts to a development paradigm that seeks to build stronger stakeholder participation, partnership, and governance, are now exerting a major influence on approaches and priorities
4. The public sector as the main source of technological innovation has been supplemented by the private sector, in both the seed industry and related areas of biotechnology in particular and in life sciences in general
5. The role and sophistication of the non-governmental organization (NGO) sector has emerged as a major force for rural change and innovation

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6. As the rural sector is drawn further into market-based economies, the distinctions between pro-poor development agendas and the priorities of enterprise and industry have started to blurr
7. The emergence of new generic technologies, particularly information technology and biotechnology, and the possibilities and controversies that these present
8. The emergence of global markets and technology systems and the threats and opportunities these offer to the poor people of the SAT.

Perhaps the only thing that hasn't changed is the scourge of poverty that continues to blight the lives of millions of men, women, and children in the SAT – 40% of all those living in South Asia and 46% of those living in sub-Saharan Africa. In the SAT alone this currently amounts to a staggering figure of nearly 450 million people.

ICRISAT has coped with this changing world by re-orientating two key features of its operation – its programs and its approach to partnership. The first has involved the restructuring of the entire research portfolio away from disciplinary programs – breeding economics, pathology and so forth – by creating broad thematic areas, the Global Research Themes. These themes focus on some of the major developmental drivers of the SAT:

1. Harnessing Biotechnology for the Poor
2. Crop Improvement, Management and Utilization for Food Security and Health
3. Water, Soil, and Agro-biodiversity Management for Ecosystem Health
4. Sustainable Seed Supply Systems for Productivity
5. SAT Futures and Development Pathways.

This new structure has shifted the focus of the Institute to a forward-looking, opportunity-driven agenda. This agenda is still based on excellence in science, but in a totally new framework, moving away from disciplinary contributions alone to include developmental goals and agendas.

The second key shift is also concerned with the framework of scientific excellence, but this time in terms of our patterns of partnership. The Institute has always had very strong partnerships with national programs in the countries of the SAT. During the recent past, however, ICRISAT has adopted a much broader-based partnership approach. Both NGO and private-sector organizations are now core partners in ICRISAT endeavors. This has been a direct response to the need to have more intimate relationships with the users of technology, particularly farmers, and the need to partner with organizations that have complementary skills and resources. And this response has not just been about new partners; it has been about new types of partnership and participation with stakeholders.

These generic shifts are exemplified in a number of key institutional innovations in ICRISAT. One of my first tasks on assuming my position as Director General was to sign an agreement with a consortium of private seed companies to fund hybrid development research here at ICRISAT. At that time this was an almost unique innovation in the whole of the CGIAR.

More recently ICRISAT has entered into an agreement with a major rural development project – the Andhra Pradesh Rural Livelihoods Project (APRLP) supported by DFID. This project is helping to cement an entirely new type of relationship between scientific research on watershed development and natural resource management at ICRISAT and the developmental activities of APRLP. Such a linkage between an international agricultural research center and a major, long-term rural development program is a key institutional innovation, embedding science in a new framework of stakeholder governance.

A new innovation that is still at an early stage is an initiative to develop an agri-business incubator facility for small and medium-sized companies. This will create a new dynamic between ICRISAT and the life-science industry, and is expected to generate enormous amounts of creative synergy for both us and our partners.

These are just some of the more high-profile innovations that have taken place. I share them with you to illustrate the way we at ICRISAT have responded to our changing world. We have done so in ways that reflect our own history, our core expertise in science, and our long-term commitment to reducing world poverty. There is no blueprint for responding to the challenges of the changing world around us – what we see today at ICRISAT is the result of a truly evolutionary process in which we have adapted and are continuing to adapt to fit our niche in international development.

Our partners have all adapted to the changing world in different ways, and each brings with them their own history and their own evolution. The main things that we at ICRISAT can share with others are the principles and values that have shaped our evolution and innovation. These include: the centrality of partnership in our approach; the need to develop mutual trust, respect, and transparency with our partners; and the need to maintain excellence in our science. But we have not left the development of these principles and values to chance. In our partnerships and teamwork we have made explicit effort to emphasize, develop, and build awareness of our philosophy and approach. These values will take us forward and ensure that science continues to play its role in supporting the livelihoods of poor people in the SAT. This is the core of our credo of ‘Science with a human face’.

Overview

Innovations in innovation: reflections on partnerships, institutions and learning

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Introduction

This book explores the nature of innovation processes associated with socio-economic change in rural areas of developing countries. It brings together a collection of empirical and conceptual papers that discuss contemporary experiences and perspectives. Most of the papers explore these issues with a view to providing lessons for the agricultural research community and in particular lessons on ways of more effectively deploying agricultural science and technology as part of the socio-economic development process. This emphasis responds to the growing sense that, while agricultural science continues to be an important policy instrument in rural development and poverty reduction, research efforts need to be less isolated and more closely linked to social, economic, and policy domains in which they seek to bring about change. This mirrors other shifts in development practice where processes are becoming more inclusive, consultative, and participatory and where the roles of the State and other players in the development process are being revisited. While these developments offer great opportunities for progress, they also bring challenges. Not least of these challenges is the need for agricultural research to respond reactively to a wide range of interest groups and agendas. And, given the rapid pace of change of modern economic systems, new arrangements need to be nimble and responsive as agendas, priorities, and opportunities are likely to evolve very quickly indeed.

While no clear consensus exists on how to deal with this emerging situation, it is now widely recognized that conventional agricultural research arrangements need to be reconfigured in significant ways. The idea that it is effective to conduct scientific research independent of related areas of economic and policy activity is simply no longer a viable proposition. Even the most conservative of agricultural research organizations are responding to this realization. Terms such as 'partnership', 'participation' and 'demand-driven' are now commonly found in mission statements and strategic plans – although practice has often not caught up with promise. Of course the reality is that these terms suggest a fundamentally different way of doing business, and institutional change is therefore part and parcel of ways of developing more effective

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modes of agricultural research. And since this often challenges deeply held professional norms and conventions, institutional change is seldom rapid.

The papers in this book address this theme of institutional change. Common to all of them is the use of innovation systems as an underpinning conceptual framework. This is used as a way of understanding the institutional context of agricultural science and technology initiatives, situating them in the web of actors, relationships and activities associated with innovation and socio-economic change. This introductory paper begins by locating the innovation systems concept in the historical context of its emergence in policy fields unrelated to agriculture, but in response to exactly the same challenges that agricultural research policy faces today – namely the desire to make more effective use of science and technology for economic and social development.

This introduction to innovation systems also discusses how this concept has been adapted and applied to the agricultural sector at a time when notions of partnerships, plurality, and diversity are becoming guiding forces in development practice. Of course, there have been many parallel and formative conceptual developments leading in the same direction as the innovation systems concept – some of which are highlighted later. The attraction of the innovation systems idea seems to be that it draws together some of these ideas into one framework. In doing so it focuses attention on issues of partnership, institutions, and learning at precisely the time when these topics are emerging as major areas of policy interest for the agricultural research community. The aim of this book, however, is not to suggest that the concept should replace all that has gone before it. Instead the purpose is to argue for it merits and illustrate its use as a complimentary tool to improve the planning, execution, and evaluation of agricultural research and related interventions in the development process.

The other purpose of this introductory paper is to provide some orientation to the rest of the papers in the book, presenting a brief synopsis of each and drawing out some of their key messages. This is done by illustrating important features of innovation using the examples that are detailed in the rest of the papers. Emphasis is given to the operational significance of these features for national and international research organizations, donors, and planners.

Unpacking the innovation process

There is now a wide recognition that the constraints faced by many agricultural research organizations and systems around the world are institutional in nature (Byerlee and Alex 1998). However this need for an emphasis on institutional change, and the consequent need to understand institutional arrangements and contexts is the point where many widely used agricultural research policy perspectives come unstuck (Hall et al. 2003; Watts et al. 2003). For a number of historical, and probably very valid reasons, policy analysis of these issues by the agricultural research community, particularly in the Consultative Group on International Agricultural Research (CGIAR), has relied heavily on neo-classical economics rationality. Here the logic is that some research themes give greater returns to research investment and that by selecting these ex-ante, or reviewing comparable ex-post cases, the performance of research can be improved overall. While there are merits to this, the assumption that the research process is a 'black box' that is the same in all cases, irrespective of specific contexts, and which remains constant over time, clearly does not bear empirical scrutiny.

Conceptual roots

These sorts of conceptual problems are nothing new in the field of science and technology policy outside the agricultural sector. The origins of these debates go back more than 20 years. A major point of departure came when policy analysts such as those from the Science Policy Research Unit at the University of Sussex in the UK, pointed out that rates of technical and economic change did not relate only to levels of national investment in research and development (R&D). Instead it was suggested that qualitative differences in the way research and economic production were organized and practiced seemed to be equally, if not more, important. This institutional dimension of science and technology policy subsequently emerged as a major focus of analysis. And, because this concerned the role of R&D in economic development, the scope of the analysis expanded from exploring research to looking at the wider innovation process – usefully defined as the production, diffusion and use of new knowledge of socio-economic significance. (The way policy analysis in the area of science and technology has evolved and the way emphasis has shifted towards institutional development is summarized in Hall et al. (Paper 5, this volume).

On the nature of innovation

Based a large number of empirical cases and drawing inspiration from evolutionary economics perspectives, a picture began to emerge of the true nature of the innovation process. This suggested that innovation emerges from interaction and knowledge flows between research and entrepreneurial organizations in the public and private sectors. And it certainly wasn't the case that research organizations simply produced new knowledge that others used. Rather, innovation involves an interactive learning process involving a variety of scientific and economic agents. Not only did this mean innovation had multiple sources, not just formal research organizations, but it also suggested that learning caused much iteration and evolution to take place in innovation processes and approaches. A related observation was that technical and institutional changes were often interdependent. For example, technical developments associated with biotechnology have been stimulated by and have in turn stimulated such institutional developments as intellectual property right (IPR) regimes, new alliances between scientific disciplines and public and private sectors, the development of bio-safety protocols, and so forth. As evidence about the innovation process built up, institutions (in their various forms) were identified as a critical determinant of the rate and direction of innovation because they are the conventions and routines that pattern processes of learning and change.

Complexity

Taken together these observations suggested that innovation is a complex systems phenomena. Here, the concept of **complexity** refers to the characteristics of systems in which many elements interact with each other to create cumulative and unpredictable outcomes. For example, when the Internet was first conceived as a military application, nobody could have predicted the emergence of e-commerce. So in this case a technological innovation (unwittingly) created an opportunity for an institutional innovation in the way business is conducted. The power of the Internet continues to advance because there is an iteration between the potential applications that it presents and the technological advances needed to make these a reality. This is a classic characteristic of complex systems where the interactions of many players (in this case businesses, technology developers, hackers, customers, and governments) continuously throw out new possibilities and challenges and different players address these with fresh advances. It is simultaneously driven by both technology and user demand and so continues to evolve. Shambu Prasad (Paper 2, this volume) presents an example of just such as case where *Spirulina* algal technology was developed originally as an organic fertilizer and subsequently was found to have a much better application as a food supplement. As can be seen, the development of such complex systems is driven by feedback loops and learning processes, that enable them to respond to emerging needs and circumstances that cannot be fully predicted in advance.

Systems of innovation

The idea of innovation, as a complex system phenomenon whereby networks of research, entrepreneurial, and other actors interact to produce and use new knowledge was articulated by Freeman (1987) and Lundvall (1992) in their discussion of 'national systems of innovation'. A number of the papers in this volume discuss this original idea of national system of innovation in detail (see Hall et al. Papers 1 and 5, this volume). A simple definition of an innovation system would be the system of all the actors and their routines and habits that in a given policy context produce, use, diffuse and adapt knowledge in socio-economically significant ways.

Lundvall (1992) identifies learning and the role of institutions as critical components of such systems. He considers learning to be an interactive and thus socially embedded process, which cannot be understood without reference to its institutional and cultural context, usually in a national setting. Underpinning this concept is the idea that organizations develop new knowledge and capabilities through their interactions with other organizations and that it is this new knowledge and capabilities that lead to innovation. The value of interaction is also that it assists flows of knowledge – this might be old knowledge that then reaches players who can use it in new ways, or it might be new knowledge, the spread of which represents the diffusion of an innovation. These learning and knowledge-sharing processes are governed by routines or conventions and this is why institutional issues have such great analytical importance in understanding innovation.

Dynamic, evolutionary characteristics

The other important point to note is that because innovation is a social process (ie, it involves people who are influenced by their experiences of participating in that process), learning inevitably takes place. As a result, capabilities, linkages, networks, and institutional arrangements are continuously changing. In other words, these systems are continuously evolving. This means that in the planning and particularly the evaluation of intervention it is not sufficient to explore the inputs and outputs of such systems. Processes and systems invariably evolve and change because the actors involved in innovation learn along the way and modify their behavior accordingly. It is this process that causes these systems to exhibit the complex characteristics discussed above. One manifestation of this is that these systems are evolutionary in nature

Take the simple example of the experience a researcher builds up through a series of research projects. These could be thought of as 'tricks of the trade'. They might include which organizations to partner with, how to communicate results to client groups, or how to present results so that they are accepted for publication by certain journals. It might result in the researcher deciding to work with the private sector, or to develop learning alliances with NGOs. Hall and Yoganand (Paper 4, this volume) provide an example of just this type of learning process at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) whereby partnerships with non-traditional partners became a major strategy. A related feature is the way an innovation trajectory builds up over time. Themes of work build up through a series of projects as researchers build competencies in certain areas.

There are a number of analytical implications of this evolutionary tendency. Most significant is the difficulties it raises for conventional economic analysis, because rather than being a fixed, constant parameter, the innovation process is constantly changing. The innovation system does not optimize and reach equilibrium, but continuously learns, changes and – in a sense – reinvents itself. The way policy approaches have dealt with this is to shift emphasis away from research resource allocation – although clearly priority setting remains important – and to concentrate on the policy and institutional environment and other ways in which the ability of these systems to learn and innovate can be improved. In other words, the emphasis has shifted to capacity building in a total systems sense. As a result of this shift, understanding the nature and behavior of innovation systems is now a central concern of science and technology policy in many of the Organization for Economic Co-operation and Development (OECD) countries (OECD 1997).

Agricultural innovation systems

Until recently the concept has not been widely applied to developing-country issues and certainly not in agriculture and the rural sector. Indeed, there are those who argue that the innovations systems concept are really a theory of how private companies behave in market-driven economic systems and therefore it has limited relevance to development issues. While there are clearly qualitative differences between the innovation context in developed and developing-country settings, there is great attraction to using innovation systems concepts as a broad heuristic for thinking about innovation as a complex systems phenomena. Clearly the actors in such systems in developing countries are going to be very different – for example, the private sector is often far less well developed. (Some of these differences are illustrated in Table 1.) But as a framework for exploring partnership, institutions, and learning processes associated with innovation, the concept would appear to provide a unique lens (Hall et al. 2001; Clark 2002).

Since 1999 there are been a number of policy analysts who have started to explicitly use the innovation concept in relation to developing-country agriculture. This includes many authors of papers in this book and indeed the last paper (Hall et al. Paper 8, this volume) provides a summary of their work (see also Hall et al. 1998; 2000; 2001; Clark

Table 1. Qualitative differences between developed country industry-based innovation systems and developing agriculture-based innovation systems.

	Developed/ industrial	Developing/ agricultural
Technology users	Firms and firms	Farmers, consumers and firms
Production contexts	Uniform	Variable, complex
Main location of research activity	Often present and strong in firms	Mainly in public sector research organizations. Strong in Trans National Corporation (TNC), but often absent or weak in local firms
Sources of tacit knowledge	Firms	Farmers, but also NGOs and firms
Role of the public sector	Co-ordination and capacity development of innovation systems. Independent scientific authority	Conducting the majority of R&D and delivering technology
Role of the market in articulating demand	Strong	Weak
Nature of intermediary organizations	Consulting firms, industry associations	NGOs, government programs, farmer operated enterprises, and co-operatives
Objectives	Economic growth	Socially responsible economic growth
Wider institutional environment	Well developed and supportive	Often unsupportive and slow to change
Dominant innovation paradigm	Increasingly systemic	Strongly linear

et al. 2003). Other applications of this idea can be seen in Ekboir and Parellada 2001; Douthwaite et al. 2004; Clark 2002; Byerlee and Alex 2003; Biggs and Messerschmidt 2004; Temel et al. 2003.[1] In the same vein, although not explicitly using the innovation systems concept, Douthwaite's important and widely cited book *Enabling Innovation – a practical guide to understanding and fostering technical change* (2002), deals with similar issues. The importance of Douthwaite's book is that he demonstrates that the underpinning innovation principle to which he refers as 'learning selection', can be observed to be at work in technology contexts ranging from rice harvesters to computer software. And that networks or partnerships of users and technology developers are important for all the technologies he investigates and in cultural contexts in both the developed and the developing world.

Other bodies of thinking that develop similar and underpinning concepts also need to be acknowledged here. The work of Biggs on the institutional context of research (1978) and on multiple sources of innovation (1990) anticipated the innovation systems concept by many years. Chambers' critique of the transfer of technology model (Chambers and

Ghildyal 1985) similarly draws attention to institutional arrangements in agricultural R&D. Roling's (1990) idea of an agricultural information and knowledge systems embodies similar systems principles, as does Echeverría's 1998 discussion of innovation systems comprised of intersecting and multiple research providers and sources of funding.

The attraction of the innovation systems concept seems to stem from the fact that a number of critical issues have arisen for agricultural research, all of which embody institutional aspects of research and innovation capacity. These include:

- The growing realization that the old national agricultural research systems (NARS) model is obsolete as a organizational focus for capacity development; and that while financial resources have declined, many of the constraints faced by research systems are institutional in nature (Byerlee and Alex 1998)
- The search for more pluralistic arrangements for funding and execution of agricultural research, with a greater role envisaged for the private sector (Pray and Umali-Deininger 1998; Echerverría 1998; Byerlee and Echerverría 2002)
- A recognition that civil society and other non-research organizations, including farmers, have an important role to play in innovation, and that rather than just acting as conduits for technology they can actively participate in research, often innovating with alternative modes of practice (Biggs and Clay 1981; Biggs 1990; Clark et al. 2003; Shambu Prasad Paper 2, this volume)
- The commitment (and coercion) of many organizations to pursue a partnerships-based approach to research and development
- Changing paradigms in development practice where participation, diversity, and self-reflection are becoming the expected modes of professional behavior (Chambers 1983; Watts et al. 2003)
- The broadening of the policy agenda of agricultural research to include poverty reduction and environmental sustainability (Hall et al. 2000) and the increasing calls for socially responsible research and development interventions, particularly with regards to the degree of poverty focus (Berdegue and Escobar 2002; Biggs and Matsaert Paper 7, this volume).
- Concerns about the impact of agricultural research and worries about economic impact assessment approaches as a way of dealing with this, coupled with the recognition that approaches are required that engage with processes and institutional contexts of research, and that institutional learning could be an important tool for improving performance (Hall et al. 2002; Hall et al. 2003; Horton and Mackay 2003; Watts et al. 2003).

The innovation systems concept offers a way of understanding and dealing with these issues in the following ways:

An inventory of innovation actors. It provides a framework for identifying the range of actors relevant to a particular innovation system or to a particular task with which that innovation system is dealing. So, for example, an innovation system dealing with creating new markets for sorghum by introducing its use in poultry feeds will require scientific actors from crop and animal disciplines, entrepreneurial actors from the feed and poultry industry, farmers or farmers' organizations, and actors involved with procurement transport and commodity trading. All of these will have to be involved in creating innovations in the use of sorghum.

System competency. Once an inventory of actors in a particular innovation system has been established it is then possible to examine the extent to which links and relationships exist among actors. The existence of relationships will depend on the policy and institutional context. For example, strong public–private partnerships may have emerged through a liberal policy towards germplasm access. Alternatively, weak linkages may be a result of restrictive personnel polices for public-sector scientists undertaking contract research for the private sector. The innovation system acts as a framework to focus on linkages that need to be developed and the changes required in policy and practice to allow this to happen.

Actor roles. Part of the relationship analysis concerns the importance of multiple roles of some actors and the different types of relationship these roles imply. For example, an agricultural university may be both a source of information on regional variety trials, as well as a recipient of improved breeding lines from a crop improvement center. Both these types of role are important and the innovation system concept recognizes this. Similarly, it provides a framework for identifying actors with important roles that are excluded from existing arrangements, but should be included. These might be sources of particular types of knowledge, or actors with political importance.

Cultural and institutional context. The types of relationship that develop in a particular innovation system reflect both the national context and different organizational cultures. The innovation system recognizes this and provides a framework for its investigation. For example, the national context may, for historical reasons, have a strongly paternalistic public-sector culture with a mistrust of private-sector enterprise. Another scenario may be that the public sector has a strongly hierarchical culture, whereas the non-governmental organization (NGO) sector may have a more decentralized, participatory culture. Partnerships between public agencies and NGOs will not necessarily lead to more participatory approaches because of the organizational culture of the former. The innovation system concept provides ways of accounting for these contextual features in evaluation and planning processes.

Relationship dynamics. Having built up a picture of the actors (and potential actors) and existing patterns of relationship, the innovation system concept can then provide a framework for exploring the nature and dynamics of these relationships. The importance of this from a systems perspective is that it often reveals that relationships are strongly asymmetrical, preventing information flows and interactive learning. For example, partnerships between international and national agencies are often skewed by more favorable access to resources on the part of the former, by historical patterns of interaction, and by professional and cultural norms that value 'outsiders' at the expense of 'locals'. Local political processes, interest groups, ethnic communities, and social hierarchies will all contribute to the *political economy* of the innovation process. The innovation systems concept provides a framework for revealing some of the dynamics and addressing the problems they cause.

Reflection and institutional learning. The innovation systems concept identifies reflections on process and institutional learning as key elements for success. For example, systems in which there is clearly a gulf between policy rhetoric and research practice have a weakness in institutional learning. Other indicators of this may be a reluctance to admit mistakes and confront failure and its causes, or even to revisit key assumptions about roles or ways of working. In contrast, organizations that regularly undertake self-evaluation, and where senior management encourage and reward reflection and learning tend to have a higher capacity for institutional learning and innovation. The innovation systems concept provides a framework for exploring and promoting learning, particularly institutional learning, and this has the potential to strengthen performance and impact.

To conclude this introduction to agricultural innovation systems, Table 2 presents the differences and similarities between an agricultural research system and an agricultural innovation system. A useful way to visualize an agricultural innovation system is to contrast it with an agricultural research system. The later is the group of scientific organizations involved with the creation of scientific and technological knowledge related to agriculture. In contrast an agricultural innovation system is all the actors involved in the production, diffusion, adaptation and – most importantly – use of new knowledge in the agricultural sector. Our aim here is not to vilify research systems and those who work in them. Instead our aim is to highlight the essential characteristics of an agricultural innovation system, and at the same time to draw attention to the sorts of institutional changes that need to take place for agricultural research organizations to better locate themselves in the wider innovation systems in which they seek to participate. A final word of caution. The agricultural innovation system concept is not presented here as a something that should take on administrative and bureaucratic form – although it does have implications for existing bureaucracies. It is not being suggested that a national agricultural innovation systems organization or council should be established. The concept is being presented as a policy tool, ie, as a way to organize thinking on the analysis and understanding of how innovation can be nurtured and how socio-economic change can be accelerated.

Aims of the book

It is the idea of an innovation system that forms the underpinning conceptual framework for this book and is discussed in detail in many of the papers. One of the critical policy insights that this perspective brings is the recognition that the innovation process is not a fixed parameter that converts research investment into economic change. Instead it is an ever-evolving set of processes and institutions. In other words, it is a dynamic concept that only assumes meaning in relation to specific contexts and points in time. The policy question is therefore not how should the innovation process be organized per se; rather, it is how can existing innovation processes in a specific setting be continually improved upon in order to respond to current and emerging challenges and opportunities. And of course, these innovations in the ways innovation takes place concern institutional change in the sense of changes in the conventions and routine governing how things are done. This book's title and its emphasis on **innovations in innovation** allude to this constant intuitive and purposeful search for, and the emergence of, new ways of generating, promoting, and using new knowledge. It is thus at the heart of questions about how institutional change can improve the performance and impact of agricultural science and technology interventions.

The purpose of drawing together the papers in this book is to:

- Generate a critical mass of empirical and conceptual explorations of this theme; to share these with policy and practitioner audiences at a time when agricultural science is trying to reinvent itself as part of a larger development agenda

Table 2. Similarities and differences between agricultural research systems and agricultural innovation systems.

Institutional features	Agricultural research systems	Agricultural innovation systems
Guiding agenda	Scientific	Developmental
Relationships involved	Narrow, hierarchical	Diverse, consultative
Partners	Scientists in other public agencies	Various combinations of scientists, entrepreneurs, farmers, development workers and policy actors from the public and private sectors
Selection of partners	Predetermined by institutional roles defined by the arrangement of the research system	Coalitions of interest. Determined by the nature of task, national institutional context and skills, and resources available
Role of partners	Fixed. Predetermined by institutional roles defined by the arrangement of the research system	Flexible. Determined by the nature of task, national institutional context and skills, and resources available
Research priority setting	Fixed. By scientists	Consensual by stakeholders and depending on the needs of different task.Technology foresight and technology assessment approach
Work plans and activities	Fixed at beginning of project	Flexible, iterative
Mandate for research/task approach adopted	Fixed by institutional norms of the research system	Negotiated through coalitions of interest
Knowledge produced	Technical/scientific	Technical/ scientific and institutional
Indicators of performance	In scientific terms to other scientists	In development terms to donors. In terms of fulfilling role in task network to other partners
Responsibility for achieving impact	Other agencies dedicated to extension and technology promotion	Scientists and their partners in task networks
Capacity building	Trained scientists and research infrastructure	Collective capacity of task networks, social capital, partnership skills

Note: This table polarizes the differences between these two paradigms which have been exagerated for illustrative purposes.

- Try to distil out some general principles about the nature of agricultural innovation processes
- Comment on the challenges and next steps in operationalizing an agricultural innovation systems perspective.

The remainder of this overview takes the opportunity presented by this collection of papers to draw some inferences across multiple cases of innovation. The paper concludes with a discussion of implications for national and international agricultural research organizations and for planners and donors who wish to deploy agricultural innovation as a rural development strategy.

Organization of the book

The papers in the rest of the book are divided into two main sections. The first section – Innovation in Innovation – contains papers that present empirical cases. The second section – Reflections on Partnerships, Institutions and Learning, contains review and methodological papers.

Innovations in Innovation

1. Post-harvest innovations in innovation: a synthesis of recent cases – *AJ Hall, B Yoganand, RV Sulaiman and NG Clark*

This first paper presents and analyzes three cases of innovation from the post-harvest sector in India. The first discuss the Kerela Horticulture Development Programme (KDHP), an initiative linking farmers to markets with a combination of technology support and market systems development. An interesting feature of the case is a failed attempt to partner with the local agricultural university – mainly due to the mismatch of university conventions with the need to work interactively with farmers on technology development tasks. The second case describes the way an NGO, International Development Enterprises India [IDE(I)] employed a total systems approach to design, production and distribution of post-harvest technology. The third case describes the activities of a science and technology voluntary organization, and details its approach to developing the capacity of local techno-economic systems.

The main argument of the paper is that instances of successful innovation certainly do conform to a set of general principles that the innovation systems framework suggests. However, the way this is operationalized is usually very specific to the physical, institutional, and political contexts of a particular intervention. Developing context-specific approaches often involves a high degree of experimentation and learning. It is these case-specific innovations in the innovation process that lead to success. One conclusion is that the growth of diversity in approaches is necessary and should be valued over general blueprints. Rather ominously the paper highlights the fact that many of these innovations in innovation have been brought about by the need to find alternative research support because of the nature of institutional arrangements in public research organizations. A related conclusion is that in order to take better account of the institutional context of research, planning and management protocols need practical tools to reveal and manage these contexts. The paper by Biggs and

Matsaert (Paper 7, this volume) provide considerable detail on how that might be achieved.

2. The innovation trajectory of *Spirulina* algal technology – *C Shambu Prasad*

This paper explores a case of innovation led by a civil society organization. The case documents the historical evolution of the innovation trajectory of *Spirulina* algal technology in India over a period of about 30 years. The paper argues that civil society initiatives have an important role in scientific initiatives in developing countries and often follow an alternate paradigm of learning and innovation that holds many lessons for research project design, management, and practice. Central to the *Spirulina* story is the involvement of the civil society organization, Murugappa Chettiar Research Centre (MCRC) and its eclectic leader Dr CV Seshadri. The institutional setting of MCRC was such that even through *Spirulina* began as technology for soil fertility, research and development efforts were able to take a sharp change of direction when it became apparent that the use of *Spirulina* as a food supplement was a more promising option. This entailed changes in scientific disciplines, the development of new networks and partnership in the food and health sector, and simultaneous involvement with strategic, applied, and marketing activities. All this was necessary for the innovation process to proceed successfully – the paper details specific lessons and the extent to which the technology has spread. But the central point of the story is that all of this was possible only because of the organizational culture/institutional setting of MCRC. Thus, the case suggests modes of operation that formal research organizations might emulate if they wish to enhance their contribution to innovation and impact.

3. Technological and institutional innovations: a case study of pomegranate production and marketing – *Rajeswari S Raina*

The third paper in this section also presents the historical evolution of an innovation trajectory over a considerable period of time. In this case the focus of the paper is the development of dryland horticulture in part of the Indian state of Maharashtra and particularly the role of pomegranate cultivation, production technologies and marketing. The case is interesting not just because of the dramatic changes that have taken place in livelihoods of poor people – rural migration during the dry season has virtually stopped – but because of the range and diversity of processes, relationships, and interconnected events that have brought about these innovations.

The paper's exploration of the pomegranate innovation system illustrates the way innovations arise from a variety of different sources, including formal research settings, but also field-level operations, and how these innovations can be both technological and institutional. The author argues that there is no predetermined sequence of discovery, diffusion, and adoption, and, perhaps most importantly of all, the learning process of all those involved in interventions is a critical way of driving technical and economic change. The paper presents a useful example of why partnerships and linkages are important. Using the case of promoting mirco-irrigation technology, the paper describes the relationship between the different actors related to this activity – farmers, retailers, and manufacturers. The paper details the way this operates as a system built on mutual dependencies – each actor needs the others, although for different reasons. Like a number of other papers in this book, this one stresses that successful interventions are those that avoid blueprints and instead concentrate on shepherding progress through the complexities of the innovation maze.

4. New institutional arrangements in agricultural research and development in Africa: concepts and case studies – *AJ Hall and B Yoganand*

The last paper in this section discusses the need for institutional change in agricultural research in sub-Saharan Africa and provides some case studies of recent developments. Over the last decade the national agricultural research systems (NARS) of many African countries have struggled to fulfill their operational mandate. This paper argues that while declining financial (and political) support has certainly not help this situation, there is now broad agreement that to a large degree the problem is institutional in nature and that interventions must focus on institutional change. Issues to be addressed include:

- Involving a wider set of actors from the research and non-research sectors in the research process
- Defining a new role for the public sector, and evolving new types of relationship with partners relevant to the agricultural sector, including partners as sources of funding
- Establishing priority setting and technology development and testing approaches that broaden the participation of stakeholders, particularly poor technology users, but also the enterprise sector
- Establishing mechanisms to improve the accountability of publicly funded research and to explore and demonstrate impact, specifically on the poor but also on more general economic development
- Responding to and contributing towards a more broad-based vision of rural development that goes beyond increasing agricultural productivity and includes developing wider livelihood opportunities, including those in the rural non-farm sector and the development of wider market opportunities
- Defining the most appropriate organizational focus for capacity building, given the broader patterns of participation being sought and the expanded objectives that are being addressed.

While it is all too easy to be prescriptive about institutional change, this paper presents three case studies of recent institutional innovations, detailing how these have emerged and what their significance is. The cases are: the partnership approach of ICRISAT's Sorghum and Millet Improvement Program (SMIP) in southern Africa; a banana tissue culture initiative from Kenya that employs both national and international partners from the public and private sectors; and the case of the establishment of the National Agricultural Advisory and Development Service (NAADS) in Uganda. The paper summarizes the types of institutional change that have been important in each of the cases. The central message from these cases, however, is that successful institutional change is rarely an externally driven phenomenon. While institutional change does take place in response to external and internal stimuli, what is important is that it is an indigenous process of change that is shaped by local circumstances, resources, capabilities, priorities, and political realities. The paper suggests that reform policies should concentrate on developing a nurturing environment for this change process and providing opportunities for institutional experimentation, reflection, and learning.

Reflections on Partnerships, Institutions and Learning

5. The evolving culture of science in the Consultative Group on International Agricultural Research: concepts for building a new architecture of innovation in agri-biotechnology — *AJ Hall, B Yoganand, JH Crouch and NG Clark*

The second section of the book begins with a paper that explores the evolving culture of science in the CGIAR and investigates the way the emergence of biotechnology is hastening the need for institutional change. The main argument of the paper is that CGIAR centers were set up for an arguably simpler world where public research organizations addressed issues of food security by developing higher-yielding varieties and transferring them to farmers. The contemporary scenario is markedly different, and in particular the emergence of biotechnology as a potentially powerful force for change raises a series of dilemmas and challenges for the CGIAR. These include questions on how the CGIAR:

- Initiates and evolves relationships with the private sector and advanced research organizations?
- Ensures public access to proprietary technologies and processes?
- Maximizes the public good nature of innovations jointly owned with the private sector?
- Negotiates new partnerships that ensure that all stakeholders including the poor stand to gain?
- Constructively engages in issues of public acceptance of biotechnology, simultaneously promoting new technology and protecting society from the unknown?
- Reaches consensus with stakeholders on research priorities?
- Engages and builds capacity in national and international policy processes relevant to exploiting biotechnology for pro-poor development?

The paper explores these issues through the lens of innovation systems by presenting a case study of recent development at ICRISAT. Like many CGIAR centers, ICRISAT has evolved considerably since its establishment in 1972. Nevertheless, as the paper explains, the on-going process of institutional change is often slow and contested and raises new questions that have to be dealt with. A critical dilemma is the need to balance the financial and technological benefits from an increasingly close relationship with the private sector with the pro-poor, developmental mandate of the Institute. The paper concludes by explaining the way a consultative foresight process could be used to set priorities in a way that addresses the multiple agendas of different stakeholders, while at the same time capitalizing on the technological possibilities presented by recent scientific advances.

6. Strengthening science and technology policy in the field of environment and development: the case of the African Centre for Technology Studies Capacity Development Programme — *NG Clark and J Mugabe*

The second paper in this section documents experiences of the African Centre for Technology Studies (ACTS) gained during the development and implementation of a Capacity Development Programme (CDP) for science and technology (S&T) policy in the area of environment and development. The paper begins by arguing that modern notions of technological capability go beyond physical infrastructure and a skilled labor force. Instead technological capabilities are now viewed as the resources needed to generate and manage technical change, including skills, knowledge, and experience, and institutional structures and linkages. A large element of this capability to manage technical change is a policy capability that can engage with S&T issues in a systemic way. It is precisely these policy skills which the CDP described in this paper sought to address.

There are a number of important features and lessons that emerge from this experience: 1. the direct introduction of policy analysis to both the recipients (government officials) and the providers of knowledge (research sector); 2. the focus on the problem as the unit of analysis rather than the academic discipline; 3. the combination of broad orientation lectures and seminars (to bring participants up to speed with basic issues and agendas) with field research project work (to show participants that there is a lot to be gained by interacting directly with those at the receiving end of public policy; 4. training in basic communications skills (verbal and written); and 5. the focus on a specific set of policy issues. The paper has been included in this volume for two reasons. Firstly, it represents an innovation in capacity development in the area of policy. Secondly, it is an example of a consortium of organizations getting together for a common purpose and then learning how to do things better as the project proceeded. The paper thus provides reflection on this type of approach from which others who address capacity development in S&T policy might like to learn.

7. Strengthening poverty reduction programmes using an actor-oriented approach: examples from natural resources innovation systems — *Stephen Biggs and Harriet Matsaert*

This paper introduces some social science tools that can help operationalize the innovation systems concept and that specifically focus on promoting poverty reduction. The tools discussed are actor-oriented in nature. The paper explains why the institutional context of natural resources interventions is so critical to the types of outcome achieved and why it is necessary to reveal and manage the agency role of different actors in projects. Actor-orientated approaches are defined by the paper as those concerned principally with mapping relationships and flows of information to provide a basis for reflection and action. The paper explains the use of three main types of tool. Firstly, actor time lines as a way of revealing competing interpretations of past events and providing an opportunity to reanalyze the reasons behind key changes. Secondly, actor mapping and linkage matrixes as a way of systematically reviewing the range of actors associated with a project and the extent and nature of their relationship. The matrix exercise can be used in conjunction with a third tool, an actor determinates diagram. This tool is similar to problem tree analysis used in participatory rural appraisals; and is used as a way of exploring particular linkages and how these might be strengthened. The paper explains how these tools can be used to underpin actor learning and response analysis, and argues that they can provide the basis for monitoring project progress and introducing mid-course corrections to patterns of partnership and relationships. Although not specifically mentioned in the paper, these tools may also be useful in building up institutional and process knowledge that, once synthesized, could be of value to others.

The second half of the paper presents illustrative cases from Bangladesh and Nepal where actor-oriented tools have been used. The authors conclude that the use of the tools have helped them:

- Visually map a given innovation system and analyze strengths, weaknesses, and opportunities in the system in terms of its key actors and their relationships
- Encourage technology users to look at existing (often unexpected) strengths in an innovation system and analyze their institutional implications
- Provide a framework whereby actors in a specific innovation system have been able to change their perceptions of their role and relationships to other actors in the system
- Provide tools for planning, monitoring, and evaluating coalition building and information flows
- Provide tools that are appropriate for use by groups (as part of coalition building).
- Keep a pro-poor, socially responsible orientation to the work of the group.

The paper concludes, however, by cautioning that innovations systems concepts and actor-oriented tools will only introduce pro-poor activities into natural resource projects if key players are willing to use them to promote socially responsible professional behavior and monitor it consistently. One suggestion by the authors is that strongly disciplinary based social science skills be strengthened within natural resources innovations systems and that social scientists use actor-oriented tools to promote socially responsible innovation processes.

8. Institutional learning and change: towards a capacity-building agenda for research – a review of recent research on post-harvest innovation systems in South Asia — *AJ Hall, RV Sulaiman, B Yoganand, Rajeswari S Raina, NG Clark and Guru C Naik*

The final paper in the book provides a review of a policy research project exploring the use of the innovation systems framework as a way of improving the planning and evaluation of post-harvest research. In fact, it was this project that gave rise to the book. The paper is an attempt to synthesize a large body of work and make suggestions about future avenues of research. It outlines the background to the project; the scope of the case study work conducted; and provides a useful summary of lessons learned on the nature of innovation processes in the post-harvest sector. It also reflects on the nature of the research approach adopted and makes suggests about how shortcomings could be rectified in future research.

Two sorts of broad conclusions emerge from this paper. The first concerns insights into the nature of the post-harvest innovation systems in India. While new patterns of partnership and other institutional innovations are certainly emerging, it was found that in many areas, particularly (but not exclusively) in the public sector research system, much institutional change is required before system approaches to innovation can be adopted. Often this is an issue of integrating and linking research organizations into the wider context of other sector stakeholders including the private sector – non-governmental and community-based organizations. Client orientation is something that many research organizations are going to have to work hard to achieve.

The second broad conclusion of the paper is that learning and institutional learning in particular is critical to successful innovation processes and arrangements. Paradoxically while this finding was evidenced by the way successful organizations adapted approaches incrementally, few insights were gained about how the learning process took place and could be promoted. The authors make a very strong case that future efforts need to focus on understanding institutional learning and change. They advocate that this should be pursued in an action or interactive policy research mode whereby a coalition of researchers, policy actors, and practitioners investigate and experiment with institutional learning in operational contexts.

Lessons and emerging issues

As can now be appreciated, the collection of papers in this book present a valuable opportunity to draw lessons and general principles from a wide selection of empirical cases. The following discussion highlights some of these lessons and observations. In discussing these points emphasis is given to what might be the operational significance and implications of these issues for agricultural research organizations and for planners and donors seeking to enhance the contribution of science and technology to agricultural innovation systems.

Partnerships

The importance of partnerships in both development practice and agricultural research and innovation is increasingly becoming a truism. As such it is easy to lose sight of why partnerships really matter. All of the empirical cases presented involved partnerships and all illustrate why they are important. See, for example, Shambu Prasad's discussion in the *Spirulina* case of the way in which MCRC partnered with health research because it had no expertise in this area, but needed to run a feeding trial if *Spirulina* was to be accepted as a nutritional supplement. Raina's Paper 3 on pomegranate innovation systems stresses the fact that partners have mutual dependences. Often this is about needing knowledge from each other, but it might also be market dependencies where user knowledge helps retailers sharpen product performance and thus improves sales. The pomegranate case also illustrates that because partnerships help knowledge sharing and flows – innovations spread very rapid through a partner network. The ICRISAT case discussed by Hall et al. (Paper 8) suggests that partners can bring both financial and intellectual synergies and that both have importance.

Hall et al. (8) and Biggs and Matsaert (7) both point to the idea of partnerships being important as coalitions of interest. This might be an interest in, for example, a task such as introducing new packaging technology described by Hall et al. (Paper 1). But it might also be a coalition of mutual support where coalition members believe in a certain approach and seek ways to collectively promote this approach. The case of the People's Science movement and the experience of applying innovation systems concepts described by Hall et al. (Papers 1 and 5) suggests that coalitions are particularly important where advocacy for institutional innovations or policy change is key. This implies that bringing about changes in overarching policies and institutional frameworks that govern agricultural innovation systems will require policy coalitions and partnerships.

The example that Biggs and Matsaert give of a constructive partnership between the World Bank and the Nepal Agricultural Research Council perhaps illustrates this sort of coalition of interest in policy change. Of course it also highlights the importance of recognizing that donors are also partners.

The operational significance of these findings is self-evident in the sense that partnerships do need to be embraced as a core methodology in efforts to improve the effectiveness of agricultural research and innovation systems more generally. To put this into practice, researchers, managers, and development practitioners must arm themselves with new tools. The challenge is to find ways to plan and execute their work as a part of an innovation system wherein they are part of the whole intervention and not just external, neutral, and apolitical observers. Biggs and Matsaert (Paper 7) provide some very timely and practical tools on how this might be achieved. It is not only physical scientists who need to adopt such approaches. Policy researchers must pay particular attention to this and need to be more inclusive in their research partnerships and more reflective about their own professional conduct. Hall et al. (Paper 8) suggest ways have to be found to network and partner with policy actors and to adopt interactive methodologies akin to the action research tradition.

Multiple knowledge bases

The idea that innovation has multiple sources is not new – see Biggs 1990. Case studies in this book provide a useful illustration of the way particular innovations require the use of different knowledge bases or sources. For example Hall et al. (Paper 8) describe a project in which partnerships are used to address quality management issues for mango export. Dealing with this issue required: post-harvest scientists to work on transportation conditions; horticulturalist to work on fruit production issues; pathologists to work on anthracnose - the disease problem affecting fruit; soil scientist to develop improved agronomy practices; private equipment suppliers to establish cold storage facilities; and packing house specialists to develop fruit-handling protocols. And, last but not least, it needed mango farmers and laborers who worked in mango orchards for their knowledge of local conditions, production, and harvesting practices. As the case explains, the intervention actually failed precisely because it failed to include this last, but critical knowledge base.

The *Spirulina* case presented by Shambu Prasad suggests that civil society organizations – in addition to being a knowledge base about grassroot conditions, are also a knowledge base about alternative approaches and the institutional innovations that these embody. The work of IDE(I) described by Hall et al. (Paper 1) is just such a case. IDE(I) had developed an approach to establishing irrigation technology production and supply systems, the activities described by all Hall et al. were the result of a donor asking IDE(I) to try out this approach in a new technology sector, ie, post-harvest.

Again the operational significance of these observations is to a degree self-evident. Multiple knowledge bases underpin successful innovation systems and partnering is the main strategy for achieving this. But there are two points that are worth making. Firstly, the concept of multiple sources or bases of knowledge suggests that the old dichotomy of scientists' and farmers' knowledge represents only a partial understanding of innovation. Instead knowledge bases and thus partnerships need to include a much more diverse set of organizations and individuals from the public, private research, and non-research sectors – and even donors. Clark and Mugabe (Paper 6) illustrate the way training organizations also need to partner to bring together different sources of knowledge. Clearly the range of knowledge bases will be specific to a project or other intervention, but the message is nevertheless that planners and researchers need to include a large range of partners that may have relevance to a particular task. Furthermore, some of these partners may need to be intermediary organizations who can mediate between different knowledge bases. For example, NGOs can often articulate the agenda of poor stakeholders.

Innovation triggers

Many of the papers illustrate the way that to some event, change, constraint, or opportunity triggers innovation and the consequent (re)clustering of partners and activities to bring about innovation. For example, the improved packaging innovation in the case of the IDE(I) intervention described by Hall et al. (Paper 1) was triggered by changes in environmental policy that it was predicted would stop the supply of wood for making wooden boxes. The mango quality management case discussed by Hall et al. (Paper 8) was triggered by anthracnose –a disease problem. In Shambu Prasad's story of *Spirulina*, new uses were found for *Spirulina* in disaster relief and this was triggered by a serious earthquake and the resulting nutritional needs this presented. In Raina's story of the pomegranate innovation system, it was the decision of the State government to introduce and popularize pomegranate production. In Hall et al.'s (Paper 5) discussion of the evolving culture of science at ICRISAT, the emergence of a new generic technology has triggered a series of institutional innovations to cope with and better utilize it. Clark and Mugabe (Paper 6) illustrate the way the emergence of new global environmental legislation brought about the need for new types of policy capability and new approaches to their development.

In all of these cases it is quite clear that the triggering event started off a series of activities and new alliances in an attempt to solve a problem or grasp an opportunity. What is less clear, however, is what the operational significance of this might be. Perhaps those planning and promoting agricultural innovation need to be sensitive to the periodic emergence of these triggering events, and to recognize that they signal the need to revisit and probably reconfigure alliances, partners, and approaches.

Innovation champions

A number of the papers allude to the fact that projects or innovation trajectories have only succeeded because certain organizations and often individuals have played a champion's type of role. For example, Shambu Prasad explains the importance of the organizational culture of MCRC in allowing it to develop *Spirulina* technology in the ways discussed. Central to the way MCRC work was its Director, an eclectic thinker and visionary who was willing to challenge convention and experiment with new approaches. The *Spirulina* innovation trajectory would not have proceeded as it did without him. In the case of the packaging technology story discussed by Hall et al. (Paper 1) it was the NGO, IDE(I) that was the guiding force. In fact, it was one particular individual from IDE(I) who had the vision, skills, and energy to knit together a total system for the development, production, and distribution of the new technology.

In some way that these champions have emerged in projects and other interventions and have become critical to the success of the whole endeavor, Biggs and Matsaert (Paper 7) also point to the role and importance of individuals and cite the work of Bode (2002) and Tendler (1997) who make similar observations – Bode discusses the role of 'good kings' among local elites. Biggs and Matsaert suggest that the actor-oriented approach that they advocate enables one to move beyond structural linkages to unique opportunities, which may depend on a particularly innovative or a dynamic personality. They go on to suggest that the actor event time line exercises often reveal the important role that a key individual has played in past innovation processes.

Again it is difficult to be definitive about ways of making operational use of this observation about the importance of champions. Perhaps, as Biggs and Matsaert allude, the existence of champions represents an opportunity to make change happen. Research organizations might, for example, seek out particularly motivated or dynamic individuals or organizations that are working (and succeeding) in allied fields and jointly explore projects or other interventions on which they could collaborate. A strategy of building on success in this way would be a refreshing change from the convention of first identifying constraints and working from there.

Diversity and innovations in innovation

The range of case studies presented in this book illustrates the great diversity of different approaches and arrangements for innovation. Many of the papers highlight the fact that innovation processes have emerged in very context-specific ways. All are unique stories with their own triggers and circumstances, outcomes and groupings of partners. While many similarities can be seen in the underlying principles, the tendency is towards diversity and away from uniformity. Many of the papers draw the obvious conclusion from this observation that blueprints should be avoided. A central message from the book is that if performance of research and innovation processes is to be improved, these context-specific innovations in the innovation process need to be facilitated and nurtured. As is discussed below, institutional learning is a potentially powerful tool to help reinvent arrangements to suit specific contexts. This is an important lesson for those seeking to reform large agricultural research and extension bureaucracies where the tendency is to search for 'one size fits all' solutions. (See Rasheed Sulaiman and Hall 2004 for detail discussion in relation to agriculture).

Reworking the stock of knowledge

Of the many definitions of innovation, Edquist (1997) stresses that while it can involve brand new knowledge, more often it involves new uses of old knowledge or new combinations of existing knowledge. This characteristic of reworking the stock of knowledge is illustrated by a number of the papers in this book. A good example is Shambu Prasad's story of how MCRC took the *Spirulina* technology and used, adapted, and diffused it in new ways. Algal technology had originally been conceived as a biofertilizer. Knowledge of *Spirulina* was reworked by MCRC to produce a food supplement technology. This idea has subsequently been reworked to meet diverse objectives such as rural employment, enterprise development, nutritional security, and disaster relief – all innovations on the *Spirulina* theme.

Learning, institutional learning, and capacity development

A key feature of all the successful cases discussed is that the organizations involved have approached them in an experimental fashion – none of the organizations approached innovation with a set plan, but instead had principles and guidelines that were tested and developed by trial and error. In other words, each organization accepted that failure was a learning opportunity that helped develop more effective strategies – it was part of the process by which organizations build new capacities. In the case of IDE(I), discussed by Hall et al. (Paper 1) its approach was developed over nearly a decade of experience in the small-scale irrigation sector, while the case discussed here is about a project to experimentally apply this approach in a new sector – post-harvest.

All of the cases allude to the fact that learning was an important aspect of their strategy and that their approaches are evolutionary and dynamic. What is much less clear, however, is the precise nature of the learning process. One gets the impression, perhaps unfairly, that learning is an intuitive ad-hoc process that takes place because the organization's culture encourages or legitimizes this process. None of the cases illustrate a purposeful mechanism by which learning takes place in a systematic fashion – although Biggs and Matsaert (Paper 7) suggest that actor-oriented tools could be used play this type of learning role.

One can draw a number of conclusions from this apparent paradox. Firstly, learning processes are chiefly intuitive and tacit and, given suitable organizational culture lessons from past and on-going experience, can help organizations to adapt and enhance performance. The second conclusion is that there is scope to enhance learning and make it a more systematic activity. Hall et al. (Paper 8) suggest that those seeking to promote innovation and improve its impact could usefully devote resources to building learning capacities in project staff, including scientists, as well as to ensuring that the organizational culture is conducive to the constructive discussion of both successful activities and those conventionally viewed as failures. (Watts et al. 2003 advocate such an approach for the CGIAR as a way of improving impact).

Another aspect of the learning process is the way it develops new ways of doing things – ie, institutional learning – and the way this can bring about changes in projects, organizations and systems. All the cases presented here have institutional lessons that others could apply in projects and organizations, and the institutional changes brought about would contribute to innovation capabilities. To continue with the example of IDE(I), if it was able to communicate the things it had learned about ways of developing, producing, and supplying post-harvest technology to others attempting similar tasks, one can imagine the way innovation capacities could change.

The operational significance of this is that all agricultural research organizations and research projects generate institutional knowledge. However, this is rarely documented, synthesized, or promoted, even though these are potential innovations in the same sense as new technologies. Not only should research organizations make more efforts to develop institutional lessons, but evaluation procedures should be sensitive in how they value these outcomes. Donors funding agricultural research could play an important role in providing incentives to research organizations to record and promote institutional innovations. Biggs and Matsaert (Paper 7) suggest that actor-oriented tools applied in an action research mode could help build up institutional knowledge during projects. Hall and Yoganand (Paper 4) summarize the sorts of institutional lessons that emerge from the recent projects and programs that they review.

A final related point here is that donors and research organizations should avoid the temptation to treat weak impact with efforts to improve technology transfer. Instead they should look at the capacity of local systems to generate, diffuse and use new technology, recognizing that capacity development in this total systems sense is the route to more effective impact from research investments. Institutional development and change is central to this type of capacity development. (See Hall 2002 for a discussion of the implication of innovation systems perspective for international research collaboration).

Research priority setting

Whether we like it or not, in an era of diminishing funds for research and with seemingly ever-expanding agendas, decisions have to be made about the way resources are allocated to different competing options. As alluded to early in this paper, and as is now increasingly discussed in the literature, there are serious questions about the usefulness of economic analysis tools to understand the value of different interventions and research investment (Hall et al. 2003; Horton and Mackay 2003; Watts et al. 2003). What is the alternative, and what can the papers in this book tell us about this topic? There are two complementary options that seem to present themselves. The first is the idea that groups of partners broadly define the nature of the problem that they feel is important to work on – for example, the commercialization of a crop grown by poor farmers. Then, as the work proceeds and the nature of the problem reveals itself, researchable issues present themselves. Shambu Prasad's discussion of the *Spirulina* innovation trajectory illustrates the way adaptive, developmental phases of the work threw up strategic research questions in just this way. Hall (2004) argues similarly that partnerships or task networks that deal with developmental problems can be a potentially important source of new research priorities. Of course, this still doesn't answer how the task or broad themes should be selected. Is it possible that perhaps these are self-selecting based on emerging coalitions of interest?

The other option that is suggested in this book is the idea of a technology foresight process. Hall et al. (Paper 5) argue that when a high degree of uncertainty exists about the future outcome of certain technological options such as those associated with biotechnology, conventional cost/risk/benefit analysis procedures can offer little assistance. Similarly, where there are multiple stakeholders with different agendas it is difficult to compute what the hierarchy of priorities should be. Foresight exercises try to get around these problems by canvassing the option of a panel consisting of a wide range of experts and stakeholders spanning the range of scientists to social commentators. The panellists are asked to predict future scenarios by identifying emerging technologies, opportunities and socio-economic priorities. Thus, it provides decision-makers with intelligence on long-term trends necessary for broad direction setting. The process of conducting foresight exercises also provides an opportunity to build consensus with stakeholders and creates partnering opportunities that help link up innovation systems. Hall et al. (Paper 5) argues that technology foresight could be an appropriate tool for research priority setting in the paradigm of partnerships in which research organizations are now finding themselves.

Poverty focus and social responsibility

In the introduction to this paper it was explained that one of the reasons for looking for alternative concepts such as the innovation systems framework was that it could assist agricultural research to enhance its impact. A key concern is improved relevance to poverty and increased poverty reduction. Many of the papers identify institutional change as a means of increasing poverty relevance, but few offer concrete examples of cases where this has taken place. The pomegranate innovation systems, discussed by Raina, is certainty a case where poverty reduction has taken place. It is less clear, however, which activities, other than choosing a suitable crop for the area where the poor lived, made this intervention particularly pro-poor.

Biggs and Matsaert suggest that the use of actor-orientated tools has the potential to promote socially responsible behavior in natural resources innovation systems. They seem to caution, however, that frameworks such as the innovation systems, while providing important insights, will not improve poverty focus unless actors in these systems decide to act in socially responsible ways and take the time and effort to use approaches such as actor-orientated tools. This seems to echo Chambers (1983) suggestion that poverty reduction efforts require new forms of professional behavior amongst development professionals. Recent efforts in the CGIAR to introduce a self-reflective Institutional Learning and Change Initiative (Watts et al. 2003) as a way of improving poverty impacts need to be aware of the need to focus attention first and foremost on the modes of professional behavior of those working in the CGIAR.

Conclusions

This paper provides an introduction to the use of innovation systems approaches in the planning and evaluation of agricultural science and technology interventions. It sets the scene for the remainder of the book and explores the way innovations in innovation could lead to the institutional changes needed to increase performance and impact. Synthesizing lessons from across the remainder of the papers in the book, it suggests that researchers and planners need to focus attention on: partnerships; multiple knowledge bases; innovation triggers; innovation champions; diversity and innovations in innovation; reworking the stock of knowledge; learning, institutional learning and capacity development; research priority setting; and poverty focus and social responsibility. The authors believe that systems perspectives on agricultural innovation truly offer the potential of helping realize the promise of science and technology in socio-economic development. Those in doubt are encouraged to read this collection of papers and draw their own conclusions.

Endnote

1. The authors apologize to anybody working on agricultural innovation systems whom they have failed to cite, and encourage them to make contact.

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Innovations in Innovation

1. Post-harvest innovations in innovation: a synthesis of recent cases

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Abstract

The paper synthesizes three cases of ***innovations in innovation*** *from the post-harvest sector in India. Using the innovation systems framework, five themes are used to compare these cases, namely: context, partnership, institutional rigidities, learning, and poverty focus. While we argue that this comparative analysis suggests a number of general principles, it also leads us to stress that there is no universal model or blueprint. Instead, what seems to be important are interventions that rely on and encourage the development of capabilities that allow adaptation to local circumstances, resources, and opportunities, and that rely on learning processes as a way of finding new ways to achieve goals. The conclusion raises two cautionary points. Firstly, much greater attention needs to be given to understanding the institutional and historical context of partnerships than was perhaps previously thought necessary in research planning and management. Part of this task concerns monitoring stakeholder interests during project implementation and particularly testing assumptions about the outcome of certain courses of action. Secondly, institutional change in the agricultural sciences is long overdue and is emerging as a serious impediment to the agricultural innovation system.*

Introduction

This paper synthesizes three cases of innovation in innovation in the post-harvest sector in India. These three cases were originally presented at a workshop that sought to demonstrate and analyze the diversity and often highly context-specific nature of the processes that lead to and promote innovation (see Hall et al. 2003d). The emphasis on **innovations in innovation** alludes to the constant search for and emergence of new ways of generating, promoting, and using new knowledge. These processes are now recognized as a principle element of social and economic development. With this recognition comes a renewed policy interest in the question of how innovation can be encouraged and promoted (Hall et al. 2001; 2003a; Douthwaite 2002; Watts et al. 2003). Yet despite the increasing policy interest in improving the effectiveness and impact of research, process narratives of research projects and other interventions are surprisingly rare. This paper addresses this lacuna with recent empirical material from cases of post-harvest innovation India.

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Understanding the nature of innovation processes has special relevance for the post-harvest sector. Research in this area cuts across many scientific disciplines spanning engineering, food science, pathology, marketing systems economics, and beyond. Neither does the sector fit into the neat categorization of research–extension–farmer. Instead, the post-harvest sector is characterized by its linkages and relationships between producers and consumers, and between rural and urban areas, with markets playing a large role in mediating these linkages. The sector includes technology clients and intermediary organizations from the whole range of organizational types – both public and private sectors. Similarly it is shaped by an equally diverse set of stakeholder agendas and interests that range from profit to social welfare. Furthermore, post-harvest technology applications often form part of complex techno-economic systems where many players are involved, each with different skills, responding to different incentives. As a result, post-harvest innovation is frequently embedded in a wide set of relationships and contexts (Hall et al. 2003b).

While post-harvest innovation is certainly characterized by the complexity of contexts and processes through which it emerges, this is arguably becoming evermore typical of agricultural research and development (R&D) in general in its contemporary setting. In this paper we argue that one of the implications of this is that much more of this process and contextual information needs to be revealed and understood in planning and evaluation procedures. Modern policy perspectives such as the innovation system concept are increasingly being recognized as important for the reason that it provides a holistic framework for understanding innovation processes in this way. This framework is used in the analysis of the cases explored in this paper.

The first case discusses the experience of a large horticultural sector development program and its efforts to establish technology development arrangements primarily with the local agricultural university. The case details the nature of constraints to effective partnership in the institutional environment of the university. It also discusses the way a learning-based management approach evolved alternative arrangements for both technology development and the wider sphere of activities related to supporting smallholder horticultural producers. The second case deals with a project exploring support to post-harvest systems in Himachal Pradesh, India. This case focuses on an approach that relied on establishing technology, production, and retail systems. The approach had been successful elsewhere, but this case discusses its novel application in the post-harvest sector. The third case provides an overview of the People's Science Initiative and provides details of innovation in the area of agro-processing. The approach described is relatively novel in that it explicitly sets out to develop the capacity of local technology systems. This involves building on indigenous knowledge and resources, and strengthening networks within the local economy. The approach also links into the formal science community when required, relying on a network of scientists that subscribe to the overall philosophy of the People's Science Movement.

The central message from the paper is that evaluation and planning of R&D initiatives that seek to promote innovation and bring about socio-economic development need to give much greater attention to institutional and historical contexts. A key task illustrated in the cases has been the active investigation of the networks of partners associated with innovation and the steps taken to ensure that the right types and patterns of linkage are in place. In the concluding section some comments are made on ways of implementing these findings and the implications for capacity development initiatives seeking to promote innovation. Before introducing the cases the next section discusses emerging issues about R&D in its contemporary setting and provides some conceptual orientation for the subsequent analysis.

R&D in its contemporary setting

There is now widespread concern that the conventional model of formal R&D as the central source of innovation needs to be replaced by something more suited to contemporary development agendas (Biggs 1990; Byerlee and Alex 2003; Hall et al. 2000; 2001). However, what is less clear is what these new arrangements might be. In part this need for change relates to a shifting development agenda, with poverty reduction and environmental sustainability as key organizing principles for strategies that also need to improve economic growth and international competitiveness in global markets. This shift is happening at a time when the agriculture and rural development sector is seeing the emergence of new capabilities, organizations, and organizational forms, and where partnerships are increasingly discussed as part of a new vision of agricultural and rural innovation. Similarly, advances in modern science are offering new opportunities while at the same time new patterns of accountability and governance are changing the role of scientists and their relationship with society (Mruthyunjaya and Ranjitha 1998; Echeverría 1998; Byerlee and Alex 2003).

Biggs and Matsaert (Paper 7, this volume) argue that in the contemporary setting of agricultural research and rural development, managers of R&D systems are often faced with making a range of decisions for which old frameworks of analysis are often inadequate. These old frameworks include economic rates of return, computer simulation models, and conventional monitoring and evaluation. One of the ways the agricultural research community is beginning to respond to the complex realities in which it finds itself is to plan its activities within the context of an **innovation system** (Byerlee and Alex 2003; Biggs and Matsaert (2004); Hall et al. 1998; 2000; 2001; 2002; 2003a; 2003c; Watts et al. 2003).

At its simplest an innovation system has two broad elements: firstly, the groups of organizations and individuals involved in the generation, diffusion, adaptation, and use of knowledge of socio-economic significance; and secondly, the institutional context that governs the way these interactions and processes take place – this includes the numerous norms and conventions that shape the way things are done, as well as more formal institutions such as intellectual property regimes and so forth. The usefulness of this concept is that it recognizes that the innovation process involves not only formal scientific research organizations, but also a range of other organizations and other non-research tasks. It recognizes the importance of linkages, making contacts, partnerships, alliances, and coalitions, and the way these assist information flows. It also recognizes that innovation is an essentially social process involving interactive learning and **learning by doing,** processes that can lead to new possibilities and approaches. Furthermore, because the process depends on relationships between different people and organizations, the nature of those relationships and its political economy is critically important. The conventions or institutions governing the way research and allied activities are conducted, and the role assigned to different organizations, is a defining context of the innovation process. As all scientists know, the nature of collaboration can make or break a research project.

Of course, in reality, agricultural research has always taken place as part of an innovation system. In the past, however, this wider context has been assumed away in the planning process. The convention has been for R&D managers to set research priorities and allocate resources within the framework of good science. Little or no attention has been given to the need to build relationships with partners working in complimentary fields, nor to seek linkages, relationships, and processes that would embed research in the wider innovation system and improve its relevance to developmental agendas. Much of this social side of innovation – the software – was assumed to be outside of the remit of R&D managers, whose job was to deal with scientific research – the hardware of innovation. As a result, the process of networking, forming alliances and partnerships, negotiating priorities, and selecting approaches to research and evaluation – which everybody knows are necessary activities – took place at an informal level with limited systematic support or planning. It is these sorts of activities and decisions with which R&D managers are now faced. The concept of an innovation system can act as a framework for analysis and planning in a more all-encompassing fashion and hence include consideration of ways of developing the software of innovation.

Principles of innovation system analysis

Linear and systems models of innovation

As has already been mentioned, the emergent view is that it simply no longer holds true that knowledge can be independently produced in specialized research organizations and that this knowledge can then be transferred to passive users. Innovation, as distinct from research and invention, is a much more complex process, often requiring technical, social, and institutional changes, and involving the interaction of actors across the conventional knowledge producer–user divide. Douthwaite (2002) believes that this holds true in cases of innovation ranging from rice drying in South Asia to wind turbines in Europe and North America. He shows how innovative success is a complex process of learning and adaptation.

Innovation and its context

An innovation systems perspective brings together thinking from a broad set of disciplinary perspectives that view development and change in systems terms (see Edquist 1997 for a review of this topic). At its heart lies the contention that change – or innovation – results from, and is shaped by, the system of actors and institutional contexts at particular locations and points in time. A related recognition is that knowledge production and use is a highly contextual affair.

The origin of innovation systems thinking can be traced to the idea of a 'national system of innovation' proposed by Freeman (1987) and Lundvall (1992). The concept, which build on empirical observations of best practice in different national and sectoral settings, states that innovations emerge from evolving systems of actors involved in research and the application of research findings. Lundvall identifies learning and the role of institutions as the critical components of these systems. He considers learning and knowledge production to be an interactive and thus socially embedded process that cannot be understood without reference to its institutional and cultural context, usually in a national setting.

This has many analytical implications: the need to consider a range of activities and organizations related to research, particularly technology users, and how these might function collectively; and the need to locate research planning in the context of the norms, culture, and political economy in which it takes place – ie, the wider institutional context. As already discussed the convention in R&D planning has been largely to ignore this context.

Similarly, it is no longer useful to think of institutional and organizational arrangements for research as fixed or optimal – clearly these must evolve to suit local circumstances. In the same way, the evaluation of innovation performance also becomes much more context-specific relating to the perspective of stakeholders and current imperatives, rather than either scientific peer review or economic justification alone.

The innovation system concept therefore provides a framework for: 1. exploring patterns of partnerships; 2. revealing and managing the historical and institutional context that governs these relationships and processes; 3. understanding research and innovation as an interactive social process of learning; and 4. thinking about capacity development in a systems sense. On this last point, Velho (2002) observes that national systems of innovation, made up of actors who are not particularly strong, but where links between them are well developed, may operate more effectively than another system in which the actors are strong but links between them are weak.

Innovation themes for analysis

Flowing from this discussion of the concept of innovation systems five themes present themselves for the analysis of our cases.

- **Context.** What were the key contextual factors that shaped each case, ie, both the historical context that shaped approaches and relationships and the opportunities, resources, and capacities that were specific to the case and influenced its form and direction?
- **Partnerships.** What were the critical partnerships involved, how were they established, and what led to the relative success or failure of these partnerships? What were the roles of partners and what essential/complementary skills/resources did they bring with them? How were roles negotiated? And what were the formal and informal rules that governed the partnerships?
- **Institutional rigidities and change.** What were the rigidities encountered in the organization or practices and norms of partners or wider structures (particularly public bureaucracies) and how did the nodal organizations cope with these rigidities or induce change?
- **Learning.** How do organizations learn and build up skills and knowledge? Are processes intuitive and ad hoc, or do they have specific learning mechanisms? How could these be strengthened? What other types of competencies do organizations build up that help to generate innovations?
- **Poverty.** What specific steps were used to ensure that a poverty/technology-user perspective influenced the outcome of partnership processes? Has this been verified either internally or independently?

Innovation and poverty relevance

This last theme on poverty relevance needs special attention since the policy agenda is not just seeking ways to improve innovation performance in a general sense, but doing so in pro-poor ways. A useful framework for making a judgment of this kind is to explore the **poverty relevance** of interventions, an approach used by, for example, the UK Department for International Development (DFID) to classify all its development projects. The approach involves sorting projects into one of three categories that describe the main way in which they address the poverty-reduction aim (see Underwood 2002 for an example of the application of this approach in the post-harvest sector). It is recognized that all categories are important and that choices will depend on specific circumstances and the strategy adopted to support poverty reduction. The three categories of poverty relevance are:

1. **Enabling.** Addresses an issue that underpins pro-poor economic growth or other policies for poverty reduction that leads to social, environmental, and economic benefits for poor people. Examples are:
   - Access/rights to resources/assets
   - Safeguarding environment
   - Reforms to regulatory, incentive, and institutional frameworks
   - Promotion of small-scale enterprises.
2. **Inclusive.** Addresses an issue that affects both poor and non-poor, but from which the poor will benefit equally (given economies of scale). Examples are:
   - Pest and disease control
   - Improved extension services.
3. **Focused.** Addresses an issue that directly affects the rights, interests, and needs of poor people primarily. Examples are:
   - Improvement for crops grown mainly by the poor – reduction of losses/vulnerability
   - Adding value to crops produced by the poor
   - Increased market access/diversification opportunities for the poor.

While this framework is relatively simple, it at least allows us to move beyond a rhetorical engagement with poverty in relation to the innovation process. In terms of the analysis of the cases presented here it helps us consider which innovations in innovation are relevant to the poor specifically, and which will only assist rural communities in a more general sense. This is an important distinction for innovation policy. For further discussion on policies for pro-poor innovation see Berdegue and Escobar (2002).

Cases of post-harvest innovation in innovation

Kerala Horticultural Development Programme (KHDP): a learning-based approach to technology development and promotion

KHDP was a project supported by the European Union (EU) and the Government of Kerala. It was established as an autonomous body of the State government in an attempt to provide a special institutional environment to develop replicable models of rural development. The program started field implementation in November 1993 with an objective to improve the overall situation of vegetable and fruit farmers of Kerala by increasing and stabilizing their income through reduced production costs, and by improving the marketing system. The KHDP interventions included R&D, provision of planting materials, extension service and demonstration plots, training, a credit package, marketing support and a processing unit. KHDP also organized self-help groups of farmers.

A critical partnership in the project was a contract research arrangement with the Kerala Agricultural University (KAU). While this started off fairly well it quickly became apparent to KHDP that the research undertaken by KAU was unlikely to have any relevance to farmers. There were a number of reasons for this, including the preference for on-station experiments, and an orientation towards academic research rather than solving applied problems. Where research may have had relevance, scientists were not allowed to release findings before they had been presented to the annual research committee meeting. As a result, much time was lost and in some ways the effectiveness of finds was blunted. Similarly, work plans could only be drawn up and approved annually, preventing reactive research to emerging needs. As the partnership proceeded, KHDP tried to encourage KAU to use participatory technology development (PTD) approaches in the hope that this would improve the relevance of research. This proved to be impossible in the rather conservative scientific environment of the university. Ultimately the contract research arrangement failed. In its place KHDP employed agricultural graduates as field officers who were then able to conduct PTD work with farmers. KHDP did however continued to use KAU for strategic research tasks, although this emerged as a relatively small component of technology backstopping. Its useful to note here the way that KHDP sought out partners, evaluated their effectiveness and reconfigured arrangements accordingly.

KPHP focused not only on technology backstopping to farmers, but also on improving their access to markets. The unique feature of the program was the way it integrated these activities through the following key features.

Self Help Groups and Master Farmers – KHDP used 'Self Help Groups' (SHGs) as its key way of promoting the development of farmers. An SHG is a voluntary unit of 15–20 neighboring farmers who cultivate and market fruit and vegetables. All project interventions converge at the SHG level. Every SHG selects three master farmers (MF), one each for production, marketing, and credit-related activities. The MFs are trained by KHDP in technical, managerial, and organizational skills. The MF (production) is responsible for providing technical information and training to farmers on production-related issues such as the correct application of seed, fertilizers, and other inputs, and on different ways to reduce costs of production. The MF (credit) helps group members to make a credit plan and links them with the banks. The MF (marketing) helps farmers to market their produce as a group. The MFs are replaced every 2 years. By 2003 there were 2153 SHGs and around 6400 master farmers. Another 5,500 ex-master farmers also act as a valuable resource group.

Group marketing. One of the important innovations made by KHDP has been group marketing where farmers now form their own market and invite traders to come and buy. Previously most of the fruit and vegetables were produced and marketed by small-scale producers without any grading or processing; the traders decided the prices unilaterally;

and there was a lot of exploitation through incorrect weighing and price-fixing. The current system developed out a number of failed attempts to establish workable marketing arrangements. The idea of farmer markets started in a very rudimentary way by introducing a 'bulking' point where farmers from nearby SHGs would bring their produce. Large volumes allowed farmers to negotiate better with traders. A group of 10–15 SHGs forms a 'field center' (FC). The MF (marketing) of SHGs are members of the FC committee and this body elects a President, a Vice-President, and a Treasurer to liaise with markets and traders. There are now 109 FCs in Kerala and each one of them on average markets 225 metric tons of horticultural products annually valued at approximately Rs. 0.35 million (Approx US$ 15,000).

Credit arrangements. Most of the fruit and vegetable cultivation in the State has been on leased land. As a result farmers are unable to mortgage land to raise working capital and hence they have no alternative other than to borrow from money-lenders at very high interest rates. The program developed a unique credit package that is acceptable to the banks. KHDP places a matching deposit with the bank as a resource support, which is not tied to the loans. The SHGs assess the credit worthiness and credit requirements of their members through a participatory credit planning session and then approach the bank on behalf of their members. Through this scheme five commercial banks are now sanctioning crop loans to KHDP farmers, including those on leased land without any registered tenancy agreement. KHDP is able to facilitate the flow of credit to farmers without depleting project funds. As the farmers are all members of SHGs there is peer pressure and a sense of moral responsibility for the borrowers to repay the loans. The average recovery rate at present is 80%. (This is considered impressive considering the average recovery rate of 60–70% for agricultural advances in India.)

Fruit and seed processing. To ensure farmers have a dependable source of income through processing produce, KHDP established a modern fruit-processing factory with farmers as shareholders. Farmers control 70% of the shares and the Government of Kerala controls the remaining 30%. The factory produces fruit juice concentrates, ready-to-serve drinks, and candied fruit; and presently these are traded in domestic and international markets. In the same way, to ensure availability of quality seeds, KHDP set up a seed-processing plant. Registered seed growers multiply the good quality foundation seeds supplied by KHDP and these are processed in the seed-processing plant before distribution to farmers.

Impact. Over the period of 9 years since its inception, KHDP has developed a replicable model for horticultural development, which is viewed as successful by a number of measures. The EU has accepted this program as a replicable model for the development of horticulture in under-developed countries of the world. The mid-term review mission by the EU in 2000 observed that the strategies and methodologies used for the implementation of the program have resulted in an increase in yields and cultivated areas, improved marketing and credit facilities, and reduced production costs: all of which contributed to an increase in farmers' income. An impact study reported a significant increase in area under fruit and vegetables in 86% of the SHGs and an increase in income in 75% of the SHGs (XLRI 1999). The same study also reported that the number of farmers availing credit increased from 21% in the pre-KHDP period to 41% by 1999 and increases in the efficiency of loan disbursal and size of loans. The activities of the Vegetable and Fruit Promotion Council, Keralam (VFPCK), the organization that succeeded KHDP, now reach around 40,000 horticultural producers in 9 out of the 14 districts in Kerala. The decision of the State government in 2002 to fund VFPCK for horticultural development in two more districts of the State is also an indication of the confidence of the State government in VFPCK and the strategies it employs to meet the objectives.

In summary the following points emerge from this case:

- **Partnership as the basic organizing principle.** This provided the organization with wider expertise and ability to provide a broader range of services (access to technology, credit, markets, value addition, and organizational development of farmers) than would normally be the case. The top and middle management of KHDP spent a considerable amount of time and energy on building trust and relationships with a wide range of partners: farmers, scientists, traders, banks, State government, management institutions, etc.

- **Organizational autonomy and the ability of the leadership to exercise it.** A new organization (KHDP) was created free from bureaucratic traditions and with complete autonomy. The KHDP leadership had the flexibility and authority to continuously improve procedures, thus enhancing managerial effectiveness.

- **Learning as the key management strategy.** A continuous process of self-reflection and learning enabled approaches and institutional arrangements that could effectively adapt to deal with changing contexts, demands, and opportunities.

- **Systematic procedures for monitoring and evaluation (internal and external) of staff and program interventions.** Apart from formal monitoring systems, the willingness of the KHDP management to quickly and effectively respond to emerging issues also contributed to the program's effectiveness.

(Further details of this case can be found in Sulaiman and Pillai 2003.)

Evolving technology through collaboration and partnership: the case of IDE(I)'s work with tomato packaging in Himachal Pradesh, India

This case study describes a novel intervention that a non-governmental organization (NGO), International Development Enterprises (India) has developed to establish pro-poor technology development production and supply systems. The approach developed over the last decade involves identifying market demand for technology, identifying suitable technology, and establishing networks to produce, supply, and sell it to the poor. It combines both entrepreneurial and technology development and requires locally specific technological and institutional innovation. This approach has been applied with great success in the context of small-scale irrigation/water resources technology. A recent expansion of activities concerned applying this approach to post-harvest technology in the context of small-scale producers of vegetables for the Indian domestic market.

The work was funded by an international donor and in the initial phase this had important consequences. Most important was the convention of the donor at that time that organizations from its own country should lead projects. IDE(I) had previously worked with an international NGO – subsequently referred to as IntNGO – based in the donor country, and although this partnership had not been without its problems, IntNGO was chosen to lead the project. The nature of this relationship meant that IDE(I) became the sub-contractor to carry out the work in India. As will become apparent from the following discussion of the case, the main task in the project concerned identifying local networks of partners and co-ordinating their efforts. As the project proceeded, the contribution of IntNGO became less relevant and since they controlled most of the project resources, this was a cause for much resentment. The partnership was ultimately dissolved by the donor and IDE(I) assumed the role of project leader. Other partnerships in this intervention were, however, much more successful and ultimately underpinned its success.

Turning to the project itself, the main objective was to apply the IDE(I) approach to technology delivery to the specific case of the post-harvest sector. IDE(I) began by making an assessment of critical post-harvest issues relevant to small-scale producers in the Indian hill State of Himachal Pradesh, an area in which it was already working. It found that for households with limited land resources, out-of-season tomato production is a critical livelihood strategy. Using family labor, tomato cultivation on 0.25 ha can generate about US$ 2000 in the short harvest season. These incomes are far higher than those accrued from any other type of farming in the area (off-farm employment opportunities are limited), and have raised farm families well above the poverty line. However, IDE(I) also found that recent changes in environmental policy banning tree felling, while clearly needed, threatened this livelihood option. The reasons for this was that tomatoes were packed in wooden boxes for transport to the lucrative New Delhi market. Without an alternative packing technology, tomatoes could only be sold in the local market and farmers would lose 70% of their income.

IDE(I) realised at an early stage of the intervention that, other than its expertise in identifying a technology niche using market analysis principles, it had no relevant post-harvest skills. As a consequence a decision was taken to implement the intervention by ‘working through others’, with IDE(I) viewing its role as one of managing relationships with its partners, establishing systems, and coordinating innovation.

Once IDE(I) had identified the problem – that environmental policy change was making the wooden packaging for tomatoes an obsolete technology – the key task then was to establish a network of partners around the development and supply of an alternative packaging technology – cardboard cartons. In fact this involved identifying and accessing four existing informal networks and establishing partnerships with them. The process of actually doing this was to some extent intuitive, although IDE(I) naturally tended to partner with organizations with shared interests and philosophies. The partnership networks were as follows:

- **Technology network.** This consisted of scientists from the Indian Institute of Management, Ahmedabad (IIMA), and a box manufacture with a design studio with whom IIMA had previously worked on packaging development. The scientists and their industry partners were willing to design and test tomato boxes. This involved conducting a major trial in 2001 when 1,000 cartons were transported from the field to the Delhi market. The adaptive development of the carton went through four generations before arriving at an appropriate design.

• **Local knowledge network.** A local grassroots NGO in the focus area that had already established a relationship with farmers in a network of different communities was identified. The communities formed the focus for the adaptive trials of the cartons. The network also included a partnership with the local agricultural university for information on local crop production systems. The communities subsequently took a lead in pre-financing the manufacture of cartons.

• **Market network.** This consisted of all those linking farmers to the Delhi market, including transporters, commission agents, wholesale traders, and the farmers themselves. This market network was important, as these were the people who would have to accept and use the cartons in their transactions. They had to be willing to promote their use.

• **Production and distribution network.** This consisted of local carton manufacturers in the focus area and box traders. Obviously it was important to partner with such organizations as they would form the backbone of the supply and distribution chain. To establish the first commercial production of cartons, farmers used a loan from a micro-finance institution to pre-finance a local carton manufacturer. Thirty thousand cartons were produced and sold to tomato producers in time for the 2002 season.

This intervention, which at the time of writing has been running for 3 years, has had a number of outcomes associated with the development and promotion of this post-harvest innovation. These include:

• **Poverty relevance outcomes.** A recent donor-sponsored poverty relevance review (Underwood 2002) of this intervention concluded that: 1. its impact would be inclusive of the poor, ie, both the poor and the non-poor would benefit from this intervention; 2. it addressed gender concerns in the sense that it recognized that women rather than men suffered the drudgery of existing package technology (making wooden boxes); and 3. that it addressed the enabling environment of the poor by reducing their vulnerability to policy changes – in this case environmental policy related to raw materials for packaging. The review also concluded that IDE(I)'s approach to targeting the poor, while successful in this case, could be considerably strengthened by a range of existing and well developed livelihood and stakeholder analysis approaches (Underwood 2002). It is too early to assess the direct poverty and environmental impact that will result from this project, but an assessment will be made in 2005.

• **Technological innovation outcomes.** A cardboard carton has been developed that can transport tomatoes from Himachal Pradesh to the Delhi market with acceptable levels of tomato quality deterioration.

• **Institutional innovations outcomes among partners.** All the partners involved in the project have been impacted in various ways. In Himachal Pradesh new relationships have been formed between organizations and individuals in the post-harvest system. This represents enormous social capital that did not exist before the project. Some of this manifests itself as the production and distribution system for the new carton and the technological development that underpinned it. This social capital may also be used in the future to generate other post-harvest system innovations. The scientists from IIMA, say that the project's impact on them is that it has opened their eyes to the need to work with partners from the rural development sector, and the enormous success that can be achieved by embedding their research in the work of others. This represents the dissemination of the institutional innovation – the IDE(I) approach.

Institutional innovation outcomes in IDE(I). This was the first time IDE(I) had worked in the post-harvest sector and it has learned many lessons from this experience. It has also built new relationships as a result of this work, including a relationship with the donor involved. The use of a self-evaluation exercise for all of the organization's activities that coincided with the intervention has helped it learn more effectively, thus further evolving the IDE(I) approach. An outcome of this learning is that IDE(I) is going to implement another project building on its experience with tomatoes in Himachal Pradesh, but this time exploring the post-harvest systems that link poor tribal communities in Orrisa with entrepreneurs and market opportunities. An important institutional innovation that that will be employed and that has resulted from IDE(I)'s relationship with the donor, will be the use of stakeholder and livelihood analysis as a way of ensuring that the interventions developed are more strongly poverty-focused. This will complement the commercial marketing principles that are at the core of the IDE(I) approach. (For further details see Phansalker 2003 and Clark et al. 2003.)

People's Technology Initiatives (PTI): embedding technology in community-based production systems

This case discusses the principles of an alternative paradigm of science and technology (S&T) and rural development promoted by PTI. The approach emerges out of the broader People's Science Movement in India, itself a backlash against what was viewed as the weak governance of science and its failure to meet the needs of the poor and to enhance their productive capacities. The elements of the PTI philosophy reflect these contextual origins with an approach that seeks to build technology systems around local knowledge, resources, and economies – rather than vice versa as is the case with conventional models of technology development.

The principal elements of the approach involve members of science and technology voluntary agencies undertaking systems diagnosis of rural techno-economic systems. This diagnosis seeks to identify locally relevant enterprises that can be developed collectively, and that explores the nature of the linkages that need to be made. The focus of intervention is then concerned with strengthening these systems and ensuring that there are local capacities and ownership to sustain these efforts. Underpinning this approach are a set of principles that seem to matter to PTI activists and which have clearly shaped this approach:

- A commitment to constructive protest for change – an activist philosophy
- A commitment to enabling access to scientific knowledge for all
- A commitment to reshaping technology systems so that they embedded in, and are shaped by the visions of the social systems to be established
- Guiding principles that recognize the need to break down the organizational and institutional (in the sense of rule sets and norms) boundaries of formal scientific research, seeking more socially relevant organizing principles
- Guiding principles that view needs assessment not in terms of technical constraints analysis, but rather in terms of the systems, resource, and skill embedded in and linked to rural communities: the potentials these present, and the way linkages with

other S&T nodes can be strengthened. This also helps focus on an entry point that can be used to strengthen local systems and the capacities they contain
- A view of the development process that recognizes that primary production through land-based activities is unlikely to be poverty-focused. This has led to greater emphasis on non-farm, secondary processing, and value addition through the development of (mainly) agro-based enterprises
- An ideological perspective that views the local or community economy as the unit of production. Operationally this means that a network or collective system of production has to be adopted. This is achieved through the establishment of workers' co-operatives
- A commitment to developing systems and nodal capacities that can allow the poor to interface with formal S&T and other individuals and agencies, and to do so independently of external intervention.

Currently, PTI focuses on the development of technology application models for the rural non-farm sector. These are characterized actions that focus on: 1. local value addition; 2. linking primary and secondary producers; 3. technological upgrading of existing occupations such as oil processing; 4. developing networking and clustering effects. In six Indian States users whose access to land is limited and who engage in mainly non-farm occupations are already using the principles of the PTI to technologically upgrade some of the rural non-farm sectors. People's Science Movement activists are helping these users to implement the technology models developed and thus help the development of local economies as a system. Technology models have been developed with the support of agencies including the Department of Science and Technology (DST), the Council for Promotion of Application of Rural Technologies (CAPART), and the Technology Mission on Oilseeds and Pulses (TMOP). Today a wide range of technology models are available for rural application by S&T voluntary agencies, including those for processing fruit and vegetables, economic and medicinal plants, biomass based energy systems, and leather, meat, and carcass products.

Readers unfamiliar with the approach may be surprised that already more than a dozen groups have been established with these principles in India. Each group has been able to involve about 200–300 households spread over about 30 rural and semi-rural settlements. Each initiative directly or indirectly benefits a target population of approximately 0.1–0.12 million rural people. Most of the initiatives have been implemented through the financial support of government programs for rural technologies. The approach has, however, received limited exposure in innovation literature, and is practically absent from general debates in India on agricultural technology and development, and in particular from those dealing with institutional reform in research and extension systems.

An important feature of the PTI case is that it has an explicit poverty focus to its work, seeking only to work with the poor. It achieves this focus in a number of ways. Perhaps the most important is that it believes that if the poor are to be reached by interventions these interventions should not be based on the ownership of land. In other words, by placing greater emphasis on non-farm, secondary processing, and value addition through the development of (mainly) agro-based enterprises, the approach seeks to focus on households without land. In many rural areas this landless category contains the poorest households.

PTI programs have been evaluated formally by their sponsors. These evaluations have tended to confirm that the approach is specifically addressing poverty reduction and targeting the poor. The PTI itself is not satisfied and feels it needs to strive harder to work for the poor and focus specifically on their needs. (For futher details of this case see Abrol 2003.)

Innovation system analysis

The three case studies presented here provide evidence of the diversity of approaches to innovation. Before discussing them it is useful to point out that they have all been successful in the conventional terms of technologies adopted, production, and incomes increased. More importantly, however, the projects have been successful in terms of the innovation capabilities that they have created. Innovations in the innovation process have strengthened the innovation systems involved. Put in another way, each intervention represents incremental improvements in the software of innovation in their own particular sphere of influence.

The following synthesizes the general principles that emerge from across the three cases. The five innovation themes of context, partnership, institutional rigidities, learning, and poverty focus are used to organize this synthesis (a summary of which is presented in Table 1).

Context

All three cases quite clearly demonstrate the way interventions, programs and projects are shaped by geographical, institutional, and historical contexts. The technology development strategy of KHDP was shaped by the fact that the institutional context of its main partner, the KAU, made it virtually impossible to conduct farmer-relevant research in collaboration with a formal research body. Learning from this, KHDP developed its own arrangements to conduct farmer-participatory technology development.

All of the cases illustrate the way in which novel approaches to innovation were developed based on the philosophy or culture of different organizations. For example, IDE(I) pursues a marketing-based approach that depends on establishing retail systems that deliver technology to the poor. Many of their staff have a marketing background and the approach had been developed successfully in the small-scale irrigation sector. This context was enormously influential in the way IDE(I) approached its post-harvest project – as with the small-scale irrigation sector, it approached post-harvest with the aim of improving input supply systems.

The PTI is shaped by an entirely different philosophical context. It is an approach that emerged from a leftist critique of development and relies on developing technology systems around co-operatively managed agro-processing enterprises. An important feature of PTI is the way that it recognizes that these systems have to be tailor-made to local circumstances, using a system design group to achieve this.

KHDP also has its own organizational context. It was originally going to be a program with the State government of Kerala. However, a senior bureaucrat had the foresight to advocate its establishment as an autonomous agency. This gave KHDP the freedom to do many things such as failing and learning that would simply not have been possible as part of a large public-sector bureaucracy.

Table 1. Summary of the key feature of the three cases of innovation in innovation.

	KHDP	IDE(I)	PTI
Context	• KHDP was purposely established outside the administrative structure of the State government. This allowed it to operate in a context where flexibility and experimentation were possible • The focus of KHDP on horticulture reflected specific livelihood constraints in the socio-economic and agro-climatic context of Kerala	• The approach developed from IDE(I)'s experience of establishing technology supply systems for irrigation equipment • The geographic focus of the project and selection of local NGO partners built on existing activities and relationships of IDE(I)	• The approach was shaped by dissatisfaction with conventional R&D and economic development models and the emergence of science and technology voluntary organizations as an alternative • Specific rural production context shapes technology system design for each intervention
Partnership	• The partnership with the agricultural university was thought to be the most important in terms of technology development. This proved to be unworkable • Partnerships with farmers' groups were important, not just for technology development, but also for a range of other activities	• A formal partnership, required to access funding, failed due to unequal roles in decision-making and accessing resources • Informal partnerships built on joint history and trust and shared objectives succeeded • Efforts were made to nurture these successful relationships as these partners formed the supply chain being developed • Partner identification was a key skill	• Involves partnerships with rural households, scientists and scientific organizations, government agencies and donors • The approach is built on the development of strong rural networks of partners • Partnership also important in promoting the PTI approach in mainstream research and rural development domains
Institutional rigidities	• Research conventions in the university system • Coped by developing its own arrangements for participatory technology development	• Some public-sector research organizations not willing to work with an NGO • Coped by bypassing unhelpful organizations	• Difficulties encountered with donors and their fixed ideas about how projects should be organized and monitored • Coped by seeking financial independence
Learning	• Intuitive as part of management philosophy	• Intuitive as part of organizational culture of sharing results and ideas	• Intuitive through a tradition of debate and self-analysis
Poverty relevance	• *Preventative* Targeted small-scale farmers with the rationale of preventing them falling into poverty • No systematic assessment	• *Inclusive and enabling* Targeted a commodity that was imported to the poor, but which was also important to the non-poor • Helped the poor and non-poor cope with environmental policy changes • No systematic assessment	• *Focused* Targeted landless households through non-farm rural employment, the rationale being that only the non-poor benefit from land-based activities • Assessment only through donor monitoring

All of these approaches have thus been quite different for the very good reason that they emerged from different contexts. The fact that they approached post-harvest innovation in different ways does not make any of them better or worse. Instead it highlights the fact that the approaches adopted were the right ones for the circumstances being addressed and that they built on existing strengths, organizational cultures, and lessons learned along the way. A general principle for designing innovation interventions therefore seems to be the need to recognize the importance of organizational histories and cultures, and building upon these (or finding ways of coping with them) rather than pretending that they do not exist or matter. This would also seem to support the general observation that externally developed blueprints rarely work.

Partnerships

All the case studies illustrate the importance of partnership of various types in the innovation process. All three cases used partnership for technology development including partners from scientific organizations as well as technology users, farmers, and rural households. KHDP and IDE(I) used partners to assist with technology and information dissemination. In the case of KHDP this involved farmer groups and master farmers to spread information on production and post-harvest technology as well as market information. IDE(I) used partnerships with both local NGOs and local entrepreneurs to establish its technology supply system.

PTI used partnership with rural communities both as a way of designing locally relevant technology systems and as a way of developing the capacity of these systems, ie, by identifying local artisans with specific skills and linking them into the system. Both the IDE(I) and the PTI allude to a partnership with sponsors of their program that is both important and needs to be managed. A final type of partnership that the PTI discusses is networks to spread advocacy for an new approach. For example, the network of science and technology voluntary organizations has been a powerful way of raising the profile of PTI in mainstream debates and interventions.

Both the KHDP and the IDE(I) cases included formal contractual relationships with partners. Both of these partnerships did not last the duration of the project. In the case of KHDP the institutional context of the partner, the State agricultural university, made it impossible for it to deliver its contribution to the partnership. The IDE(I) case was slightly different in that it was a partnership that was to some extent forced on them by conventions of the donor at that time. The weakness of this partnership was compounded by an earlier history between the two partners that was characterized by skewed power dynamics, a lack of trust between them, and a good deal of resentment. The contribution of IDE(I)'s partner, IntNGO, was less than expected and the partnership dissolved.

Conversely, both the IDE(I) and the PTI cases illustrate the way successful partnerships emerge from longstanding relations where trust has been established and where interests, philosophies, and organizational cultures overlap. Both organizations, having recognized the importance of partners, have developed skills and devoted efforts to identifying partners and strengthening relationship with them. A related observation is that KHDP, IDE(I), and PTI seem to play a nodal role in facilitating and coordinating the relationships required to promote innovation through the cluster of organizations with whom they partner.

A number points flow from this. As already discussed, partnerships and the relationships they involve often emerge from institutional and historical contexts and this can define their nature and effectiveness. This context needs to be revealed and managed if innovation systems are to be strengthened. A related point is that partnerships don't emerge overnight. Time and resources need be to spent on identifying new partners and exploring or mapping relationships and linkages that need to be strengthened and nurtured. It is important that those seeking to promote innovation recognize their role as systems coordinators and mangers, helping to make the right connections and relationships between the right partners.

Institutional rigidities

All three of the cases discuss the institutional rigidities encountered in dealing with public- sector research organizations. The PTI case explains the way its has coped with this by identifying scientists working in the formal research system who sympathize with the PTI and who might, for example, be members of science and technology voluntary organizations themselves. This approach has been described as 'science organizations without walls'. One could speculate that in the long term, if enough of these types of scientist are identified and involved in the PTI and allied approaches, it may start to alter the organizational culture of the formal research system. But there is clearly a long way to go.

The cases illustrate a more worrying phenomenon whereby the institutional context of public-research organizations is so rigid and unhelpful that they simply get by-passed and alternative arrangements are made. The KHDP case is probably the most dramatic illustration of this. Not only does it document the institutional obstacles to conducting farmer-relevant research, it also reveals that even though scientists working in the university realized the weaknesses in the set-up, there was no way that changes could be implemented, or even discussed. In other words the system had no capacity to learn and evolve. This is a major restriction to developing stronger links between scientific organizations and others involved in innovation systems.

What is all too clear from this is that institutional learning and change will be required in the Indian agricultural innovation systems and particularly in the institutional arrangements that govern the way science is conducted in public-research organizations (see Hall et al. 2003c for detailed discussion of this point). A useful starting point might be to legitimize the discussion of failures in research organizations, and develop skills of scientists in the areas of reflection and learning (Watts et al. 2003).

Learning

A key feature of all the cases discussed is that the organizations involved have approached them in an experimental fashion. That is to say, none of the organizations approached innovation with a set plan, but instead had principles and guidelines that were tested and developed by trial and error. In other words each organization accepted that failure was a learning opportunity that helped develop more effective strategies. In the case of IDE(I), its approach had developed over nearly a decade of experience in the small-scale irrigation sector. The case discussed is about a project to experimentally apply this approach in a new sector – post-harvest.

All of the cases allude to the fact that learning was an important aspect of their strategy and that their approaches are evolutionary and dynamic. What is much less clear, however, is the precise nature of the learning process. One gets the impression, perhaps unfairly, that learning is an intuitive ad-hoc process that takes place because the organization's culture encourages or legitimizes this process. None of the cases illustrate a purposeful mechanism by which learning takes place in a systematic fashion – KHDP did have a formal monitoring and evaluation mechanism, although one gets the impression that process lessons were learnt intuitively.

One can draw a number of conclusions from this apparent paradox. Firstly, learning processes are chiefly intuitive and tacit and that given a suitable organizational culture, lessons from past and on-going experience can help organizations adapt and enhance performance. The second conclusion is that there is scope to enhance learning and make it a more systematic activity. Those seeking to promote innovation could usefully devote resources to building learning capacities in project staff, including scientists, as well as to ensuring that the organizational culture is conducive to the constructive discussion of both successful activities and those conventionally viewed as failures.

Poverty relevance

Of all the three cases only the PTI indicated that it was explicitly designed to support the livelihoods of the poor. The KHDP case had a less-focused agenda, seeking to improve the livelihoods of small-scale horticultural producers, the rationale being that this would prevent them falling into poverty. This does not fall into the poverty-relevance categories discussed earlier, but perhaps it represents a new category – **preventative**. The IDE(I) approach did make specific efforts to target its intervention on households with limited land-holdings. It did this by using a needs assessment study to identify the crop that was most important to the livelihoods of small-scale producers. The intervention thus became inclusive of the poor, as non-poor households also produced this crop.

In the PTI case, the philosophy of the organization determined that the intervention would only focus on landless households, and that it would therefore concentrate on creating rural non-farm employment. The rationale was that all land-based interventions benefit the non-poor to a greater extent than they benefit the poor. The other aspect of this intervention is that PTI sought to increase the ability of the poor (as a collective group) to compete with organized entrepreneurs in the market. PTI highlights this as being important as it says this prevents the usual patterns of events whereby agro-process interventions cause competition between different groups of poor people.

All three cases made assumptions about what the poverty relevance/livelihood outcome would be at the beginning of their interventions, but, certainly in the KHDP and IDE(I) cases, these assumptions were not revisited periodically during the intervention. One might perhaps find this surprising given the emphasis now placed by sponsoring agencies on poverty relevance. One conclusion here is that innovations systems could be strengthened if more attention were given to monitoring assumptions along the way. This is not an issue of undertaken conventional impact assessment, but rather being aware that some processes and decisions during projects are going to affect outcomes on different stakeholder groups and that this needs to be monitored. Similarly critical assumptions need to be challenged as events unfold during a project.

The PTI case suggests that targeting non-farm rural employment maybe a better way of focusing specifically on the poor. This is certainly laudable as it breaks out of the often rhetorical discussion of the poor as farmers, and the accompanying conventions this imposes on agricultural research as a means to increasing productivity and safeguarding household food stocks. Developing rural agro-processing enterprises and the innovation systems to support them has therefore many attractions in terms of using science creatively to support the poor. The same caveat, however, remains. Namely that the assumptions about poverty relevance need to be monitored, and that this needs to be part of the capability of more effective innovation systems.

Emerging issues

Flowing from the discussion above are a number of points that warrant emphasis and need to be drawn to the attention of practitioners, research mangers, and policy-makers.

The first point is that emphasis seems to need to shift from supporting research that delivers a stream of technology products, and instead concentrates on developing the capacity of innovation systems. Research products are still important. But in rapidly evolving circumstances, supporting the continuous development of the innovation systems seems to be an equally important task. This suggests an innovation coordination manager role for nodal agencies. It also suggests that programs and other interventions need to be evaluated in different ways that also appreciate this capacity-development function.

The second point relates to the importance of allowing locally relevant approaches and arrangements to develop and evolve. While recognizing the administrative attractions of devising widely replicable intervention models, innovation systems and their development have to be context-specific. The challenge is to find ways of encouraging this diversity and locally specificity in the programs of large bureaucracies such as public research and extension systems.

The third point concerns the need for tools and strategies to understand institutional contexts and histories and to map and monitor relationship. All the cases pointed to the fact that it is these issues which provide the foundation of strong innovation systems and that unless these contexts are revealed and managed, failure is likely to occur. Tools are available, but are probably not yet sufficiently used, particularly by R&D managers, for example, stakeholder analysis (Grimble and Wellard 1997) and the actor-linkage matrices (Biggs and Matsaert 1999; Paper 7, this volume). The action research tradition is also useful in this regard.

The fourth point concerns the need for institutional learning and change in agricultural innovation systems and particularly in the institutional arrangements that govern the way science is conducted in public research organizations. (Detailed discussion of the concept of institutional learning and change can be seen in Watts et al. 2003.) The side-stepping or bypassing of public research organizations should be seen as a warning sign that unless somebody grasps the nettle of institutional change, the vast science and technology resources that a country such as India possesses will be become irrelevant.

Conclusions

The cases presented amply illustrate that in India, scientists and rural development practitioners are being enormously creative in the way they approach innovation. A diversity of approaches exists and it is hoped that this paper will bring some of these experiences to the attention of a wide audience. The cases highlight the fact that partnership and learning are at the heart of the innovation process. However, these experiences raise two cautionary points. Firstly, much greater attention needs to be given to understanding the institutional and historical context of partnerships than was perhaps previously thought necessary in research planning and management. Part of this task concerns monitoring stakeholder interests during project implementation and particularly testing assumptions about the poverty relevance of certain courses of action and the implications of decisions. Secondly, institutional change in the agricultural sciences is long overdue and is emerging as a serious impediment to agricultural innovation systems.

Endnote

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2. The innovation trajectory of *Spirulina* algal technology

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Abstract

Research in agricultural and post-harvest science in India has conventionally been seen as a preserve of State scientific establishments with private enterprise only playing an active role in recent times. Using the case of Spirulina *algal technology, this paper illustrates the 'hidden histories of science' in civil society initiatives, arguing that they need to be seen as part of the 'legitimate' narrative if science has to have a pro-poor human face. Civil society initiatives have an important role in scientific initiatives in developing countries and often follow an alternate paradigm of learning and innovation that holds many lessons for research project design, management, and practice. This case study describes the innovation trajectory of* Spirulina *and the central role of a civil society organization – the Murugappa Chettiar Research Centre (MCRC) in it. The discussion explores features of the research culture or scientific practice of MCRC that enabled successful innovation, reflecting in a way contemporary ideas about innovation as systemic phenomena. This contrasts sharply with prevailing research conventions in much of the Indian scientific establishment and thereby suggests important institutional lessons for research policy.*

Introduction

This paper explores a civil society initiative in agro-processing from the perspective of attempting to understand innovation processes and their institutional contexts. Civil society initiatives are unusual in that often they have not been driven by the formal science establishment and its outputs, but instead have been led by an alternative paradigm of learning and innovation. However, these initiatives have not been studied and their contribution to informing research project design, research management, and practice remain largely unexplored. This paper thus explores and highlights potentially underutilized sources of innovations from which research policy can draw inspiration and lessons.

The reported case study looks at the work of a non-governmental research organization, the Shri AMM Murugappa Chettiar Research Centre (MCRC), based at Chennai, India, and its work in developing *Spirulina* algal technology in India. The work, spanning a period of two decades, is an unusual case of the active involvement of a non-governmental organization (NGO) in all aspects of the innovation chain, ie, development of the scientific idea (invention), translating that idea into a commercial proposition (innovation), and extension of the technology both into the market and rural communities (diffusion). Through this case study, this paper also seeks to understand the institutional context of innovation in civil society initiatives in the agro-processing

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sector and its difference between State and market initiatives with respect to partnerships, a pro-poor focus in research, and the understanding of technology transfer.

The paper begins by briefly exploring the institutional setting of post-harvest innovation in India. This highlights the potential importance of civil society initiatives in this area, and also illustrates the fact that these tend to be overlooked. It is argued that, in part, the reason for this relates to the conventional sequential or linear view of innovation that continues to inform research policy, and locates civil society organizations conceptually at the end of the technology delivery pipeline. Contemporary innovation systems perspectives, it is suggested, may help to locate the activities of different organizations in a more holistic view of the innovation process and thus reveal the role and value of civil society organizations.

The second part of the paper presents a history of the *Spirulina* algal technology trajectory, detailing the different phases of activity and the evolution of actors, roles, and objectives associated with what was, in effect, an Indian *Spirulina* innovation system. It seeks to situate the work of MCRC within existing national research on algal technology, and highlights points of departure both in the nature of research and the way it has been practiced. It also explores the nature of partnerships in the various phases and the changing role of the main actors in the system.

The third part of the paper looks more closely at the research culture of MCRC in order to explore the way civil society conceptualizes research and development. Features of this research culture include the manner of problem definition, the continued emphasis on innovation, enabling of organizational learning, forming of partnerships, creation of multidisciplinary teams, and emphasizing multifunctional tasks. The technical and non-technical writings of research staff are critically examined for the analysis of the research culture.

The final section explores the implications of the case for agricultural science and comments on the way many of the findings substantiate the holistic perspectives embodied in the innovation system concept. The paper thereby seeks to demonstrate that the case is not just about *Spirulina* or MCRC, but also about a new framework for closer interaction between formal and not-so-formal science, ie, science by the State, and science by civil society.

Agro-processing innovations in different institutional settings

The post-harvest or agro-processing sector needs to be seen as part of the larger non-farm sector and decentralized rural industries. Moulik and Purushottam (1986) in one of the few studies on technology transfer in this sector have argued that the decentralized rural industrial sector in India is conceptually and operationally different from the agricultural sector and that therefore it is not enough to transplant successful experience of the technology transfer process in agriculture. Pointing to the complex dimensions of technology transfer in this sector, the Planning Commission of India in a review of village industries remarked that that most technical research centers in India were uni-disciplinary bodies and were ill-equipped to handle multidisciplinary problems of village industries (GoI 1981). The National Research and Development Corporation (NRDC) that provides a mechanism for commercializing laboratory ideas in industrial research and development (R&D) feels that the agro- or food-processing area is one of the most difficult in which to achieve successful commercialization. Some of the problems identified include: the requirement of multiple partners with diverse backgrounds, long gestation periods, non-availability of raw materials throughout the year, and many risk factors (NRDC 2003).

Hall et al. (2003) have recently argued that post-harvest R&D seems to sit uncomfortably in the conventional arrangements for agricultural research. Unlike crop improvement research that has clearly identified central scientific personnel (plant breeders, molecular biologists), well-defined products (new varieties), and a clear main client (farmer); post-harvest R&D has no neat categorization. It covers engineering, food science, pathology, and marketing economics, has a large number of players both public and private, and diverse stakeholder interests and agendas with different skills responding to different incentives. Post-harvest innovation (PHI) is thus frequently embedded in a wider set of relationships and contexts than is implied by the conventional research–extension–farmers' model of R&D. Managing PHI and doing so with a pro-poor policy goal is therefore challenging as it involves complexity of an order of magnitude greater than that associated with crop improvement-based innovations.

Dealing with this complexity has proved difficult and many of the constraints to post-harvest innovation have been identified as institutional in nature and relating to conventional approaches of R&D planning (Hall et al. 2001). The conventional (and widely criticized) model to which much of Indian R&D still conforms is premised on the desirability of linear relationships linking research and economic production. In this model, investments made in basic research are assumed to produce knowledge whose value increases through further 'downstream' incremental investments in adaptive research. The knowledge is finally given to a dedicated organization (extension) charged with passing it to a technology user who finally applies the new knowledge to economic production. In this model there is institutional separation, with activities associated with knowledge search and generation (research) organized separately from those involved with knowledge transfer and application. There is thus a division of labor whereby public scientific bodies – seen as the primary source of new knowledge – are organized in a hierarchical structure with a linear flow of resources and information from the top to the bottom. One of the problems that this mindset encourages is the view that civil society should be located at the last stage of the innovation chain (extension activities) and not as contributing to invention. After all, civil society organizations are not research organization and thus their activities should be restricted to disseminating the innovations of others. This case seeks to challenge this assumption.

There is now wide recognition that assumptions of the conventional or linear model of innovation do not reflect the complex reality of technology development and innovation in the agriculture sector. Instead this is now understood as a process that: involves linkages and feedback between the main actors (Clark et al. 2003); multiple sources of innovation (Biggs 1990); iterative processes of learning and reframing of approaches and research questions (Hall et al. 2003) that at times lead to new roles for actors (Hall 2004). Of particular relevance to the focus of this paper on innovation in civil society is the recognition that the actual practice of science depends to a large extent on the different settings in which it takes place. For this reason understanding the role of organizational cultures in research planning and performance evaluation has assumed importance (Pickering 1992; Feller 2002; Watts et al. 2003).

The concept of an innovation system by Freeman (1989) and others draws together many of these ideas. Innovations in this view emerge from the interactions of a number of players from both the research and non-research sectors; the production of knowledge and innovations is not linear, but iterative and contextual; it involves dead-ends and new directions, with experience from application throwing new research questions and opportunities. Institutional contexts are of fundamental importance in shaping innovation processes and outcomes; and these systems of actors and institutions are evolutionary in nature, relying on incremental learning to deal with emerging constraints and opportunities. The introductory comment of a review of these concepts by Edquist (1997) provides a useful overview of the main elements of recent thinking:

> 'Innovations are new creations of economic significance. They may be brand new, but are more often new combinations of existing elements. Innovations may be of various kinds, eg, technological as well as organizational. The process through which technical innovations emerge are extremely complex; they have to do with the emergence and diffusion of different knowledge elements, ie, with scientific and technological possibilities, as well the 'translation' of these into new products and production processes. This translation by no means follows a 'linear' path from basic research to applied research and further to the development and implementation of new processes and new products. Instead, it is characterized by complicated feedback mechanisms and interactive relations involving science, technology, learning, production, policy, and demand.' (Edquist 1977, p. 3).

An analysis of the capacity of post-harvest innovation in India reflects the linear understanding of innovation and the tension it creates concerning the appropriate role of scientific and civil society organizations. During the last two decades, there have been several compendia on rural technologies in India. These compilations were, in fact, responses to criticisms from within and outside the scientific establishment on the contribution and relevance of the formal science and technology establishment to the problems of rural India. Two key scientific institutions – the Council for Scientific and Industrial Research (CSIR) and the Department of Science and Technology (DST) – produced compilations highlighting their contribution to rural development. Simultaneously there were efforts from civil society to broaden the debates on expertise in science and technology by seeking to legitimize through these compilations the large numbers of scientific practices in rural areas outside formal science, and to address issues such as science and technology (S&T) and rural women. Table 1 lists these compendia and provides details of post-harvest technologies.

Of the compilations in Table 1, the 1993 database, though dated, has an interesting compilation of resource persons with their institutional affiliations and subject interest. This compilation has been classified into categories that indicate the concentration of various types of institutions in agro-processing, food processing, and post-harvest technologies. Table 2 below shows the distribution of resource persons from this compilation.

Broadly speaking, most of the resource persons who were part of the national agricultural research system (NARS) saw themselves more as specialists in post-harvest technologies, while resource persons from institutions in civil society saw themselves more in the areas of food and agro-processing.

Table 1. Compendia on rural technologies in India.

Year	Compilation	Publisher[1]	Postharvest technologies details
1980	Rural Development and Technology: A Status Report cum Bibliography	CSIR	
1982	Science and Technology for Women: A Compendium of Technologies	DST and CSV	Over 1000 voluntary organizations contacted for the compilation
1984	Technologies for Human Welfare and Community Services. Vol. 2. Technologies for Rural Development	CSIR	26 food technologies. All but 3 from CFTRI, Mysore
1986–92	CAPART Directory of Rural Technologies (7 volumes)	CAPART, TTTI and CRDAT	Vol. 1 'Farm and Postharvest Technologies' and Vol. 5 'Village Industries and Artisans'
1993	Directory of Resource Persons for S&T Based Societal Programmes	DST and CTD	904 entries including 236 on postharvest
1995	CSIR Rural Technologies: A Compendium	CSIR	109 of the 350 entries are on food and agro-processing
1996	Compendium of Replicable Technologies and Models	DST and CTD	31 technologies vetted only field-level experience only included
2001	Technology Models for Rural Application	DST and CTD	39 replicable technologies described

1. CSV = Centre of Science for Villages, Wardha
CTD = Centre for Technology and Development, New Delhi
CFTRI = Central Food Technology and Research Institute, Mysore
CAPART = Council for Advancement of Peoples Action for Rural Technologies
CRDAT = Centre for Rural Development and Appropriate Technology, New Delhi
DST = Department of Science and Technology
CSIR = Council for Scientific and Industrial Research
TTTI = Technical Teachers Training Institute, Bhopal.

This institutional analysis shows that the mandate of post-harvest technologies has gone well beyond the formal science establishment as represented by the Indian Council for Agricultural Research (ICAR) or CSIR systems. While the sources of post-harvest innovation in India are diverse, planning and thus formal R&D has been concentrated in a very limited number of establishments such as the Central Food Technology Research Institute (CFTRI) in the CSIR systems as well as the Central Institute for Post Harvest Engineering and Technology in the ICAR system. In recent years organizations such as the Council for Advancement of Peoples Action for Rural Technologies (CAPART) and the Science and Society section of the DST have emerged as important players. Further, the presence and expertise of NGOs representing civil society is by no means small. This is yet another reason why civil society initiatives need to be given serious consideration.

Table 2. Institutional distribution of resource persons in postharvest technologies.

Category	Agro-processing	Food processing	Post-harvest	Resource persons
Indian Council of Agricultural Research (ICAR) and agricultural universities	9	12	23	28
NGOs	10	16	13	25
Other universities and educational institutions	5	10	10	14
Other research institutes	3	6	6	10
CSIR laboratories	5	4	7	8
Private consultants	3	8	2	8

Source: Collated from CTD 1993. Many resource persons indicated more than one area of interest hence overlaps.

For the purposes of this paper the question is: what does the emergence of NGOs in the post-harvest sector imply for innovation processes and attendant polices?

Institutional context of civil society initiatives

There have been several initiatives from organizations outside the formal scientific establishment and the private sector in agro-processing. Although these initiatives have entailed significant institutional learning and potential insights for others, they have not been documented sufficiently and have escaped most narratives in the history of agro-processing in India. Efforts by civil society have often been presumed to be sporadic, small in scale, or trivial in scope and have bypassed academic analysis. Documentation of these efforts has, at best, been restricted to internal histories of these organizations and not as part of science or research policy debates. This case study of a civil society initiative in agro-processing argues that there are 'hidden histories of science' in agro-processing and that civil society initiatives need to be seen as part of the 'legitimate' narrative of institutional development if science is to have a pro-poor focus.

Since the early part of the 20th century, there have been critiques on the practice of public research in Indian agriculture. Some of these critiques have been translated into alternate scientific practice. The Allahabad Agricultural Institute started by Sam Higginbottom in 1910 was one of the earliest such experiments that had to its credit the first-ever degree course in agricultural engineering in India, one of the earliest schemes of extension projects, and a women's program in home science. Its emphasis on practical training set it apart from other agricultural schools in India that were then almost exclusively teaching centers meant to fill posts for the agricultural service with little or no direct contact with farmers (Hess 1967).

Though Higginbottom's work did not receive State attention, it caught the imagination of Indian nationalists such as Gandhi who had a long correspondence with him and wanted him to head the agriculture wing of the Congress. Years later, as part of a dissenting tradition of scientific intervention with a pro-poor focus, Gandhi constituted the All India Village Industries Association (AIVIA) in 1934. This can be seen as the first organized large-scale effort to intervene on behalf of the poor in the agro-processing sector.

Though AIVIA was a pioneer in civil society initiatives and rural innovations in agro-processing, it does not figure in standard readings on agro-processing in India. Articulating the need for a different science for the rural poor, a voice neglected by the formal scientific establishment, Gandhi remarked that "the intervention would need business talent, expert knowledge, and scientific training." Citing the example of nutrition he pointed out how his questionnaire to several well-known doctors and chemists on the chemical analysis and different food values of polished and unpolished rice, *jaggery* (unrefined sugar), and sugar, remained unanswered (Gandhi 1934). A notable part of the institutional structure that followed was the attempt to broad-base AIVIA by having a number of stakeholders. These stakeholders were to include laypersons who could be members with no qualifications other than the desire and interest to participate, together with agents who were to market the produce. Such a system necessarily ensured a better information flow between the various actors. In the writings of the outspoken Gandhian economist, JC Kumarappa, the secretary of AIVIA, one finds details of the kind of questions that should engage this new research and its scientists. These were linked to contemporary issues of food shortage and famine but were addressed within a much broader context that sought to include such non-productive and qualitative concerns as the requirement of a balanced diet for everyone as opposed to a mere increase in food supplies (Kumarappa 1971).

The conception of research that sought to look at integrated systems and not just at the productivity of their parts in AIVIA is noticeable. Thus, there was an emphasis on the whole plant as food for humans and fodder for cattle; in oil processing the research was conscious of the oil content of the cake as cattle feed and not just the productivity of the seed for oil. This emphasis on nutrition for the masses as an important consideration for research is noteworthy, and AIVIA collaborated with several scientific institutions of the time. Past attempts to look at science in civil society have overemphasized the critique of formal science. In the present institutional context the positive contribution of civil society is in the setting of research directions and parameters for detailed enquiry. Given their proximity to the field, the starting points of research in civil society often have critical field-level and user insights that cannot be achieved through any critical research and policy management exercise in formal science. This is sufficient reason for formal science to take research by civil society seriously and to engage in dialog with it.

There have been several innovations from civil society since AIVIA. The responses have been diverse, based on their respective institutional contexts. AIVIA has changed in character since the establishment of the Khadi and Village Industries Commission in 1957 that took over the mandate of AIVIA, making it a State-led and sponsored activity. This has led to serious erosion of AIVIA's original charter. However, there have been several organizations that have sprung up, especially in the late 1970s, to address a pro-poor mandate in the rural non-farm sector. One of these is the Centre of Science for Villages (CSV) at Wardha, that was set up in 1978.

The 1990s have seen major changes in the agro-processing sectors, with civil society initiatives seeking to establish new relations with the market through diverse products and institutional means. This is in the context of the large-scale failure of State-led efforts in enabling poor farmers to cope with the changing nature of local and global markets in the wake of liberalization. Some like the Nimbkar Agricultural Research Institute (NARI) in Phaltan, Maharashtra, have suggested diverse uses of such crops as sorghum. The Centre for Technology and Development (CTD) based in New Delhi with years of experience in rural industrialization is another such initiative. Conceived as a multidisciplinary group with engineering, natural, and social sciences backgrounds, this center has been involved in technology transfer for small-scale farmers in fruit, vegetable, and agro-processing in recent years. The experience of CTD shows an understanding of the contemporary market that is different from that of the State and corporate interests. A more recent institutional innovation, still in process, is the Rural Innovations Network (RIN) that has sought to approach the problem from a different perspective. It has been inspired by the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) initiative of the National Innovation Foundation, and the Honey Bee Network of farmer-led innovations. RIN sees itself as providing critical managerial inputs to facilitate the honing of entrepreneurial skills using business models of venture capital in the corporate sector, thereby ensuring both monetary and social returns to rural innovators, donors, investors, research institutions, voluntary organizations, entrepreneurs, and rural consumers.[2]

The institutional context of these diverse approaches to innovations in agro-processing from civil society is increasingly being realized. Scholars such as Vaidyanathan (2000) have argued the need to see the public space in agricultural research as much wider than government departments. Giving greater autonomy from governmental control to research organizations, and giving non-governmental public institutions the space and resources to play a larger, more effective role in research, have been seen as issues of direct relevance in restructuring the public research system. The case study of *Spirulina* algal technology at the MCRC below is but an explication of the tradition of constructive dissent and innovation of science in civil society.

Spirulina algal technology in India

As a food system innovation *Spirulina* has been seen as a 'wonder food'. It is a high quality food supplement containing vitamins B_1, B_{12}, B_{16}, C, and E in addition to protein, etc. It has tremendous potential for use in food, cosmetics, and health care. The only single, natural source providing the highest amount of protein ever known to man, *Spirulina* contains 71% protein, three times that of soybean, and five times that of meat. *Spirulina* protein quality is among the best. The annual protein yield per unit area is the highest among other protein-yielding crops. Like all other microbial cells, *Spirulina* contains all the natural vitamins, including the B-complex range, minerals, and growth factors such as gram-linoleic acid. It contains large amounts of beta-carotene, a precursor of vitamin A. Its concentration of nucleic acids is among the lowest recorded for microbial cells considered as food or feed. Other microorganisms, including those pathogenic to humans and other animals, are eliminated in the *Spirulina* production process due to its requirement of a very highly alkaline growth medium. *Spirulina*'s preference for tropical and sub-tropical climatic conditions offers a good use for land in arid areas.

Spirulina has wide-ranging applications as a food supplement (to combat stress by executives and by athletes for quick energy synthesis); health and medicine (non-insulin dependent diabetes; cholesterol control; vitamin A deficiency and malnutrition; as an adjunct to cancer patients undergoing chemotherapy; a lactating agent for mothers, etc.); as a feed in pisiculture, sericulture, and entomology; as a coloring agent in food and chemical assays, and in cosmetics.[3]

While the benefits of *Spirulina* as a wonder food have been shared within the international scientific community for quite some time now, the developments of this technology in India was not a local adaptation of an internationally developed technology. On the contrary, Indian research on *Spirulina* applications had many firsts to its credit. India was at one time the only country in the world conducting a joint effort by many government agencies covering all aspects of *Spirulina*, from simple cultivation basins to large-scale commercial farms. The Government of India (GoI) sponsored large-scale nutrition studies with animals and humans and investigated therapeutic uses. The world's largest feeding trial with *Spirulina*, involving 5,000 pre-school children who were fed a special formulation of *Spirulina* alga for one year, was conducted by MCRC. Medical reports confirmed that it was a useful supplementary vitamin A diet, putting to rest motivated attempts by corporate science that was keen to push synthetic vitamin A, and that raised doubts on the toxicity of *Spirulina*. India was one of the first countries to have a standard for the alga. India also has the first decentralized production facility for *Spirulina* in the world, which came about because of the earthquake-relief operation in Latur.

Spearheading much of the work in India was the MCRC a civil society organization led by CV Seshadri. Within the Indian research and development context, the work on *Spirulina* represents a rare case of an organization being involved in all stages of the development of an innovation – conception, commercialization, and extension to social sectors. In the following account the efforts made by MCRC are reviewed within the larger context of *Spirulina* algal research in India.

Indian work on *Spirulina* algal technology can broadly be grouped into seven phases or stages. Table 3 provides a timeline of *Spirulina* algal research in India together with some global developments.

MCRC and the innovation trajectory of *Spirulina* in India

The story of *Spirulina* and its transition from a research idea in the laboratory to an applied technology in the form of a commercially produced food supplement is typical of many stories of innovation. It is complicated. It is characterized by key players entering (and departing) the stage at different times, with champions emerging at critical points, only to fade and let others emerge. It involves basic research and applied and adaptive tasks, but not always in that sequence. And it is highly nuanced and not easily understood without an investigation of the players, institutional and other contexts, and process that relate to this particular innovation. It might be useful to think of this story as one about the evolving architecture of the *Spirulina* innovation systems. Over the last 30 years or so this has involved different grouping of partners, different relationships, and process. The main phases of this evolving architecture are discussed below. What is

Table 3. Timeline of *Spirulina* chronology in India and the world.

Year	Important event
1940[1]	*Giant evaporator used to dry Lake Texcoco at Mexico leaves algae (*Spirulina*) on external parts clogging extraction of soda brines*
1961	Singh's work on blue green algae for nitrogen fixation published by IARI
1967	*French director of Sosa Texcoco and other scientists decide to grow* Spirulina
1969	GS Venkatraman's book *Cultivation of algae* published by ICAR
1973	Indo-German algal project initiated at CFTRI. Focus on protein supplement *Scenedesmus obliquus* used, later found too expensive and elaborate
1974	India's first algal production unit established at Navsari, Gujarat
1976	All India Coordinated Programme on Algae (AICPA). Multi-institutional, as bio-fertilizer, protein source, fuel and component in recycling system. Institutions involved were CFTRI (food and feed), National Environmental Engineering Research Institute (NEERI) (sewage water algae), CSMCRI (food, feed, biogas), Auroville (food and feed), IARI (bio-fertilizer), NIN and IVRI (evaluating feed and food)
1976	*Sosa Texcoco first* Spirulina *producer in the world with daily production of 2 tonnes*
1977	Center for Algal Studies set up at MCRC later combined with Energy Division
1978	Spirulina *discovered as staple food in use in Chad and also by the ancient Aztecs. Dainippon Ink Corporation's (DIC's) first plant in Bangkok*
1979	Spirulina *exported to US for human health use. Earthrise markets* Spirulina *in tablets in natural food stores in USA*
1980	MCRC identifies and cultures local strain of *Spirulina fusiformis*
1981	*Earthrise Farms started in California for production by Proteus and DIC. Production begins in 1983*
1982	Ripley Fox starts work on integrated systems of *Spirulina* cultivation in Centre of Science for Villages (CSV), Karla. Mud pot cultures experiment initiated at MCRC
1984-91	MCRC work on *Spirulina* is commercialized and India's first production facility established
1991	Second AICP on algae initiated with four objectives including large-scale nutritional studies. MCRC receives National Research and Development Corporation (NRDC) Innovation award for *Spirulina* work
1992	Nutritional program completed. Bitot's spot deficiency decreases from 80 to 10%. Alternative to imported pure vitamin A demonstrated
1993	Ballarpur industries set up *Spirulina* production unit at Mysore. 200 t $year^{-1}$ plant
1995	MCRC asked by DBT to take up *Spirulina* as income generation in earthquake-affected Latur

1. Italics indicate developments outside India.

noteworthy about this story is how MCRC emerged as an important player at a critical time and, for reasons discussed later was able to drive the innovation process in ways that may not have been possible in an institutional setting of the formal scientific establishment.

Early work by IARI

Algal research in India dates back to 1953 when the Indian Agricultural Research Institute (IARI) began research on the use of algae for nitrogen fixation and later to treat sewage and industrial waste. Much work in this period was in the form of research on the taxonomy of algae and their use as bio-fertilizers. The organizations involved were CFTRI (in 1973 CFTRI entered into collaboration with Germany to produce a pilot plant), the National Botanical Research Institute (NBRI), Lucknow; the National Environmental Engineering Research Institute (NEERI), Nagpur; the Indian Veterinary Research Institute (IVRI), Izzatnagar; and Auroville, Pondicherry. An All India Co-ordinated Programme on Algae (AICPA) started in 1976 to cover various aspects of algal production for food, feed, and fertilizers (Becker 1993). The work on algal bio-fertilizers was ahead of its time, and did not fit into the push given to synthetic fertilizers as part of the Green Revolution in India. The first *Spirulina* farm in India was established at Navsari, Gujarat, in 1974. Although there were no major breakthroughs in *Spirulina* cultivation, this early work is important because it created a base for the later active involvement of MCRC. It also usefully illustrates the time lag involved in the commercialization of an idea.

MCRC's initial work

The MCRC set up in 1973 as a private R&D center of the Murugappa Group of companies was transformed by C V Seshadri who, as its director from 1976, made it into a leading autonomous R&D center with a range of activities showing strong social concerns. Seshadri brought to MCRC the skills of a researcher and academic with considerable industrial experience (he had just established India's largest yeast factory in Mysore). In 1977 the Algal Division was set up. An important conceptual leap at MCRC on algal research was the linking of energy and photosynthesis. The research outputs, entitled the Monograph Series on Engineering of Photosynthetic Systems (MSEPS) reflected a philosophy of integrated holism and involved an interdisciplinary team of scientists, engineers, and amateurs right from the start.

The point of departure from other research centers in India was MCRC's biomass emphasis and focus on algae as food instead of as fertilizer or effluent treatment. Algal cultures were preferred over conventional plants from an agricultural aspect as they gave high output per hectare, consumed little water per unit of useful biomass yield, allowed for whole cell or plant utilization, possessed high protection and vitamin output per hour, and were amenable to several engineering improvements because they could be cultured in liquid media.

The algal work at MCRC was given a boost when Jeeji Bai, an algologist at the Madras University, joined on an honorary basis. The scientists screened large numbers of algal cultures for a suitable selection and successfully isolated *Spirulina fusiformis* from a phytoplankton collection from a pond in Madurai. The isolate was then adapted by growing it in village conditions using unskilled labor.

This was followed by open-pond *Spirulina* cultivation with different nutrient media compositions using cheap raw materials (seawater of varying composition, crude sea salt, biogas effluent, and nutrient bag methods were tried). Unlike other parts of the world that focused on large-scale cultural systems requiring sophisticated and costly engineering design, the scientists felt that Indian conditions demanded small decentralized algal systems operated by non-technical hands. This approach was also a break from the general practice in Indian scientific establishments that paid little attention to adaptation to local conditions. Thus, while the CFTRI work with German collaboration was capital-intensive, MCRC work was cost-sensitive. Conscious efforts were made by the scientists to incorporate local materials and local conditions in the design.

Feeding trials were done on fish (at MCRC), dogs, and calves (at NRDI, Bangalore), and *Spirulina* was found to have an edge over other protein supplements. The uses of *Spirulina* in a few popular Indian dishes were also tried to determine its palatability. Experiments on algal milk farming using solar-boosted energy were tried out, and the feasibility of growing algae and fodder grass in a single area was explored.

The initial work at MCRC was thus one of vigorous experimentation over a wide range of activities. The simultaneity of basic and applied work and the design of experiments to suit Indian conditions and budgets set MCRC apart, not only from research carried out elsewhere, but also from 'normal' science in India. By the end of 1981 there was sufficient confidence to increase the scale of operations.

Large-scale cultivation and commercialization

Building on the laboratory investigations in the early stages, a pilot-plant feasibility study was initiated in the early 1980s. This indicated promise as a potential rural activity for food and feed production using waste materials ecologically and economically. In this phase the work was directed at mastering the cultivation of *Spirulina* from test tubes to flasks and small outdoor ponds. A separate group of nutritionists developed recipes for use with algal slurry and sun-dried flakes. The technology was sufficiently matured by 1984 for a pilot-scale facility to be commissioned.

Collaboration with the Murugappa Group companies and Industrial Credit and Investment Corporation of India (ICICI) saw the establishment of India's first completely indigenous *Spirulina* production facility. Technical innovations included the 'Prakara pond', the 'Raji' filter system, and a paddle-wheel agitation system that resulted in cost and materials economies. MCRC was also involved in test marketing the product and in formulating the Indian standard for processing of *Spirulina* alga, IS 12895: 1990. India was then perhaps the only country in the world where such a standard existed. The specifications covered minimum protein and vitamin levels in the dried product besides specifying its contents and tolerance levels.

A severe funding shortage affected the future of the project even as commercialization began. The timely involvement of NRDC allowed an inspired agreement to be devised to finance the project. This agreement, while protecting the interests of MCRC, also ensured continued interest by the Murugappa Group of companies. NRDC believed that the process was a breakthrough in indigenous technology development. This was recognized when Seshadri and BV Umesh of MCRC were awarded the NRDC President of India Award for Invention in 1991.

Simultaneous studies on village-level production

Simultaneous to the commercialization push of *Spirulina* there was a parallel effort aimed at the social objective of nutritional self-sufficiency for villagers. MCRC initiated experiments in downscaling the technology to suit village women. It is the rural client focus of civil society organizations that allowed for such a strategic shift in research direction. This again was a major departure in the work of MCRC from formal scientific establishments. Cultures using mud pots were tried out in late 1982. They were chosen because mud pots were easy to handle and good as transient cultures from laboratory to open-air conditions. Along with the technical innovation there was social innovation. Laboratory data were promising and it was felt that this would be a suitable simple technology to teach village women and training programs were initiated. The work was carried out on the hypothesis that *Spirulina* processing and marketing would make it an expensive proposition for the people who need it most, ie, village women and children. It was also felt that technologies that were developed exclusively for women had a better chance of social and cultural acceptance than technologies that were designed for men but later 'diluted' for women or for rural areas. The vision was to demonstrate that microbiological skills could be taken down to the personal level for nutritional self-sufficiency (Seshadri 1985; Jeeji Bai 1986; 1992).

Yet another experiment where MCRC did not work directly, but through others, was with the organization Nutrition on Wheels (NOW) based in Chennai. Here MCRC provided the *Spirulina* culture and NOW, in collaboration with Antenna Technologies, identified two villages near Chennai (Madras) for cultivation. Transtech, whose founder was associated with NOW, later marketed the *Spirulina* under the trade name Progen®. Village-level kits for 4–10 m^2 ponds were distributed amongst selected beneficiaries, and the women were able to augment their income by up to Rs 100 $month^{-1}$. The program had to be moved after a year due to unforeseen social problems and local conflicts in the villages (von der Weid 1993). This experiment is an interesting case in partnership, and in fact a precursor to MCRC's own extension outreach. Transtech importantly helped to develop the market for the product while creating an awareness of the usefulness of *Spirulina* amongst the general public.

MCRC-led All India Co-ordinated Project

In 1990 MCRC approached the GoI for large-scale field trials. The Department of Biotechnology (DBT) evinced interest and an All India Co-ordinated Project was initiated in 1991 with MCRC coordinating it. This was to have four components:

a. Large-scale nutritional supplementation (LSNS) with *Spirulina* alga
b. Preparation of feasibility reports on suitably sized plants
c. Maintenance of germplasm and quality improvement of strains
d. Preparation and testing of formulations for various applications.

The LSNS was preceded by experiments done at the National Institute of Nutrition (NIN), initiated by MCRC, which had demonstrated the toxicological safety of *Spirulina* and the bioavailability of beta-carotene (Annapurna et al. 1991).

With a view to exchanging notes among the larger community involved in *Spirulina* and reviewing the state of the art in India, MCRC hosted a national symposium titled '*Spirulina*: Ecology, Taxonomy, Technology and Applications (ETTA)' in 1991. This broad-based symposium resulted in the publication of a comprehensive treatise (Seshadri and Jeeji Bai 1992), which is cited extensively in contemporary *Spirulina* literature. The Indian effort was the only large-scale endeavor in the world dedicated to the therapeutic uses of the whole alga.

As part of LSNS, a well-monitored nutritional supplementation program using *Spirulina* was undertaken in a rural population of 5000 pre-school children in Pudukkottai district, Tamil Nadu, for one year. The unprecedented scale of operation of this program required major institutional innovations from MCRC that went beyond its professional mandate as a research organization. It involved collecting and analyzing nearly 9 million data points. Recognizing the need for beta-carotene administration in the form of a natural foodstuff, MCRC introduced *Spiru-om*, a mixture of *Spirulina* and *omum* or *Ajjwain* (*Trachyspermum ami*) mixed with icing sugar. This was administered to the children in the form of noodles and the results were monitored.

The results of the study showed statistically significant reduction in Bitot's spot and night blindness with several interesting anecdotal results as reported by *Anganwadi* [community childcare center workers and teachers in schools. The study demonstrated a cost–effective substitution of expensive imported vitamin A. It also provided conclusive proof of the benefits of *Spirulina*, setting to rest the motivated efforts by several multinational companies that sought to show *Spirulina* as toxic and their own vitamin substitutes as more effective. The cost was estimated at Rs 1.5 (US$ 0.03) per dose that could be reduced to Rs 1 (US$ 0.02) and even further if the product was made locally (Seshadri 1993a; Seshadri and Thomas 1993).

The LSNS experiment is an interesting example of partnership by an NGO that was ahead of its time and involved a wide range of actors from scientific bodies, research institutions, universities and medical colleges, to local health workers, extension workers, teachers, parents and children in the villages.

Extension activities – *Spirulina* as income generation 1993–97

With the potential of *Spirulina* having been demonstrated, scientific agencies such as the DST and DBT sought to extend its possibilities through such specific projects as biotechnologies for scheduled caste (SC) and scheduled tribe (ST) women. This was first tried out in villages in Pudukkottai district amongst nine women using medium-sized ponds. The concept was then extended as part of earthquake relief in Latur in Maharashtra under a project called *Spirulina* for Employment Generation and Rehabilitation of Victims of Earthquake (SERVE). Two hundred women were trained and a decentralized production facility, the first of its kind, was established.

Post-MCRC extension of village-scale technology 1997–2003

Work at MCRC on *Spirulina* has more or less stopped in recent years, although the organization maintains the culture, and is willing to train NGOs. The *Spirulina* work now has gone beyond MCRC in non-linear ways. NGOs inspired by the nutritional potential of *Spirulina* have taken to village-level production. The extension of *Spirulina* production in the 1990s is noticeable for the diversity of approaches in construction of tanks, processing, products, marketing, and distribution. It has entailed technical and institutional innovation beyond mere replication.

CSV in Wardha, Maharashtra, and Auroville in Pondicherry are two NGOs that have been involved with *Spirulina* activity for 20 years. Ripley Fox initiated CSV's work at Karla in 1982 through an integrated system involving sewage in the nutrient medium (Fox 1993). There has since been product diversification into skin creams (a combination of beeswax and *Spirulina*) and face packs for the local market, apart from the usual tablets. At Auroville the work has had a revival in the 1990s. Seven 30-m^2 ponds now in operation harvest 500 kg annually. The farm uses solar power for water pumping and over a thousand people consume *Spirulina* regularly. Auroville has also trained several people to set up their own farms.

The Antenna Trust based in Madurai with technical support from Antenna Technologies, Geneva, is a leading training center in *Spirulina* cultivation with a well-equipped laboratory and training manuals. An interesting case of innovations in the extension of a technology is the work done by the Reorganization of Rural Economy and Society (RORES), in Kolar, Karnataka. Enthused by the potential through an article in the journal *Health Action* (Anon 1997) that described the potential of the alga in combating malnutrition, RORES contacted MCRC for technology transfer. Stabilizing the production involved an iterative process of experimentation and visits to the Antenna Trust and a *Spirulina* factory apart from contact with MCRC. The technology has been modified substantially through several ingenious applications for an expanded capacity of 6 kg per day. Irregular rural electrical supply necessitated local innovation wherein the paddle agitator was solar-powered using an unused photovoltaic panel from a local NGO. The agitator was designed using high-grade stainless steel 316 blades chosen for its inert media and proven anti-corrosion properties. The 'high tech' blades and the motor were procured secondhand from a Bangalore scrap market and suitably redesigned.

The *Spirulina* activity fits in well with the NGO's agricultural extension activity. The laboratory for *Spirulina* does additional work on soil analysis. Greenhouses for the nursery were incorporated for solar drying of *Spirulina*. Markets are both rural and urban, the latter cross-subsidizing rural consumption. Farmers are encouraged to use *Spirulina* for cattle feed, and there has been a positive effect on cattle fertility. RORES feels confident about transferring the technology to innovative farmers but State support has not been forthcoming (RORES 2002). The RORES case highlights the iterative process of technology transfer where field conditions have given rise to interesting innovations in the process. This innovation by a local NGO has taken *Spirulina* production far beyond what MCRC had envisioned.

Spirulina cultivation has now spread to many production centers in India particularly in the south. In northern India, a university botanist – Pushpa Srivastava, a participant in the ETTA symposium – has innovated the use *of Spirulina* for income generation by underprivileged women belonging to the SCs and STs at Bassi near Jaipur, Rajasthan, and a larger experiment on the lines of Latur for Gujarat earthquake victims. It is thus evident that much activity is going on at the field level with diverse results and experiences in use and even in the health benefits of *Spirulina*. Most of these activities have been without State support and some are now sustaining themselves. The field-level experiences also indicate the possibility of greater scientific involvement especially with regard to exploring heath care uses of *Spirulina*. These grassroot workers would like to undertake studies to validate what are now largely anecdotal experiences with the notable exception of the study initiated by Antenna Trust with Madurai Medical College (Thinakarvel and Edwin 1999).

The future

If the story of *Spirulina* so far is anything to go by, the innovation trajectory may yet take new directions and present new possibilities. Thus, while many of the funding agencies have been looking at the *Spirulina* work as technically closed, with activities restricted to extension alone, field visits indicate that this is hardly the case. There have been several ideas at MCRC and elsewhere that have not been tried (eg, processing *Spirulina* in the form of easy-to-make processed foods like curds or cheese) and that such ideas are in need of scientific intervention. Similarly, no major effort has been made to repeat the nutritional study in another district or State on a similar scale. Even if not on that scale, it is clear that *Spirulina* consumption has been taking place in rural India for several years. No scientific input has gone into trying to assess its health impact or to make scientific sense of the wide range of anecdotal experiences in these areas. There is much work to be done.

Table 4 captures the evolution of the innovation architecture of *Spirulina* in India. Quite clearly, not only was MCRC critical in the *Spirulina* innovation trajectory, but there was also something unusual and valuable about the way MCRC viewed the task of innovation and its role in that process. In the following section this work is placed in context and the research culture that enabled the development of this technology by civil society is explored through an analysis of various writings of MCRC, both published and unpublished.

Innovation in context: research culture at MCRC

The *Spirulina* work was shaped by the unconventional research culture at MCRC. A central influence shaping the philosophy of MCRC was its Director during this period – Dr CV Seshadri. By many measures he was an extraordinary individual, a gifted visionary whose ideas (almost always) challenged conventional thinking and received wisdom on issues as fundamental as the laws of thermodynamics and the concept of time (Seshadri 1993b; Balaji 1996; Visvanathan 2002). Undoubtedly MCRC provided space for a fuller expression of Seshadri's ideas that would have probably otherwise not seen the light of the day in his earlier stint as an academic and researcher in formal scientific establishments. However it is also important to recognize that there was more to the research culture of the place than the genius of an individual scientist. The heuristics of such a culture of science are revealed in many of the technical notes of the organization and merit attention for their role in enabling innovation.

The unconventional ways in which problems were defined at MCRC is evident in the very first monograph of the MCRC group entitled *A total energy and total materials system using algal cultures* (Seshadri 1977). This monograph outlines the philosophy of work, while also positing a fresh approach to the role of a scientist or engineer in a developing world. It calls for the articulation and definition of an engineering problem based on a keen context sensitivity to the social issues of a developing country. This philosophy of 'holistic invention' was to form the key to the MCRC approach to problems of science and technology and rural development. The features of this research culture at MCRC are discussed below.

Table 4. Players, partnerships and process: the evolving architecture of the *Spirulina* innovation system.

	1953–72	1973–78	1978–84	1984–91	1991–93	1993–98	1995–2002
Activity focus	Taxonomy, maintaining cultures	All India Co-ordinated Programme on Algae; sewage water treatment, food, feed and biogas	Vigorous and diverse experimentation leading to cost-sensitive designs suited to Indian conditions	Innovation towards commercialisation, India's first plant set up	Coordinated program on *Spirulina* including a large-scale study among 5000 children	Demonstrated possibilities of income generation	Extending outreach of *Spirulina* to the poor, *Spirulina* in export and urban markets
Process / defining feature	*Setting the stage*	*Diversified knowledge generation*	*Rooting* Spirulina *in India*	*Commercialization of technology*	*Broadening the* Spirulina *base*	*Extension to new social groups*	*Diffusion by non-public agencies*
Main actor	IARI	IARI	MCRC	MCRC	MCRC	MCRC	None
Other actors		Other public research institutes, Indo-German Plant/MCRC	Murugappa group and few research institutes	Financial institutions industry, NGOs on nutrition	Scientific agencies, health departments, village-level institutions	Scientific agencies, local NGOs, earthquake victims	Private industry and NGOs
Innovation system features	Single actor basic research focus	Expansion through multi-institutional division of research. Separation of basic and applied (pilot plant). Emergence of new player outside formal science	Integration of basic and applied research, collaboration. Contextualization. Concurrent work on village scale	Partnerships with NGO, industry and research center towards large-scale technology and decentralization. Partners bring agendas and expand domain	Diverse partnerships between research and non-research actors allows for large-scale expansion	Social innovation for new groups – quake-affected, women	MCRC not active player, new entrants, lack of ownership of innovation system. No involvement from public research

The importance of visions

A guiding feature of research at MCRC was the way it was driven by visions of an extraordinarily ambitious kind. The technical ideas presented in the ‘total energy total materials’ monograph were novel in their use of energy analysis to determine the choice and definition of research problems at the Centre. Some of the technical ideas on carbon sequestration or recycling from power plants were ahead of their times. The idea to use both the energy of stock gases and the materials to fix the carbon in one of the most efficient photosynthetic systems, namely algal culture, was indeed novel and formed the basis of the *Spirulina* work at MCRC.[4] Even though the actual application of stock gases for algal photosynthesis did not materialize, the philosophy behind such an approach shaped the day-to-day practice of science and the research culture of the Centre.

In a rather bold and ambitious statement on the role of the engineer scientist in a developing country, Seshadri outlined his vision by proposing that creating integrated systems of sophisticated and appropriate technologies, marrying the vices of the former (modern technology with unlimited growth-oriented devices) with the virtues of the latter (traditional resource-conserving technologies) was the way for the future. He outlined two proposals based on such a reading. The first, an integrated technology to grow food, fodder, fertilizer, and fuel, and the second, to use the wastes of sophisticated industry for an agricultural application. He argued that the need was to have the best of both sets for an optimal mix, stating that “this kind of synthesis was necessary to better understand how affluent technologies can help sub-affluent people.”

Setting the agenda for the future work on algal research at MCRC and in India, Seshadri proposed three objectives of the work, the primary one being feasibility studies for a pilot plant of 1 t day^{-1} of food and fertilizer-grade algae using waste materials and energy from large power plants. Dissemination and use of the products of the facility, and integrating aspects of low-cost technology to minimize capital investments and employing as many skilled and unskilled workers as possible were the other objectives. There was a caveat to this broad agenda that realized the need for play in its actual implementation. Seshadri added that, “the division into objectives is arbitrary and not the basis of priorities. The attempt has been to think of integrated systems of technology to maximize common good.” The proposal, he believed, outlined one way by which pre-industrial man could use the wastes of industrial man to make a post-industrial product.

What the monograph indicates is that sources of creativity and invention for research ideas often do not conform to traditional readings of the history of science and technology that are based on a linear narrative of successive stages in the development of a particular technology or discipline. Non-linear and lateral narratives in other disciplines, including those from the social sciences and real-life situations, are often sources of creativity for scientists and cannot be ignored. The monograph provides us with a vision of the MCRC and also indicates the source of the ideas for future work on algae. Importantly it also highlights the experience in research that often not all ideas generated at an early stage translate into reality. Some are, in fact, ahead of their time.

Valuing failure

Another feature of research at MCRC relates to valuing failure. Conventional project evaluations with a strict success/failure framework do not value processes and 'failures' of ideas. On this point Seshadri had the following to say

> "One important aspect of developing systems of science and technology that is integral to our paradigms of development is the recognition that failure is an essential part of innovation; it is an important part of learning. In India today we are thought to perceive knowledge as a 'finished product'... It is a massive effort, to develop a 'knowledge system' for India, and we must recognize and learn from the failures in the process, wherever they occur" (Seshadri in PPST 1990).

Interviews with scientists who worked at MCRC and the manner of reporting used in technical and project reports at MCRC indicate an openness to share not-so-successful experiments. This was valued both as research culture and philosophy at the Centre. The MCRC had planned internal reports as a forum where such not-so-successful ideas would nevertheless find articulation (MCRC 1977). If not documented, these nascent ideas are lost to the research community, and it is probable that this could affect the tradition of innovation in the research center in the long run.

Staff at MCRC remarked in interviews that they were encouraged to make mistakes and learn from them. "The nature of the problems often was so unconventional that we had to make mistakes and learn from them." One of the scientists (an aeronautical engineer) remarked that when he first joined MCRC he was asked to make paper from silk cotton. The work involved various kinds of experiments that helped determine the technical constraints in the process. These crude experiments conducted by an amateur using tools such as pressure cookers later led to one of the more innovative projects at MCRC. All of this could not have happened without a research culture that promoted learning by 'thinking with hands' and making mistakes.

Interdisciplinary research at MCRC

The above instance of an aeronautical engineer working on problems not of direct disciplinary relevance was not an isolated instance. Multidisciplinary teams of scientists, technologists, and amateurs worked at MCRC, doing much of the early scientific work on *Spirulina*. The research center emphasized multifunctional tasks, and there were several instances in the *Spirulina* story where physicists were engaged in marketing and scientists in training, extension, etc. Resource constraints often created conditions for institutional innovations – staff having to do tasks simply because there was nobody else to do them. There were also programs at MCRC that enabled meetings across disciplines and encouraged the scientists to come out of their laboratories. In early times there were periodic campus-cleaning drives and activities that involved manual work that cut across disciplines and involved everyone in the organization. This research culture encouraged staff to drop their disciplinary labels.[5]

Problem definition and accent on innovation

The way problems were defined indicated an approach that set MCRC apart from conventional R&D centers. Balaji in the first Seshadri Memorial Lecture, 'Inventing the Future', elaborated on this:

> "That famous dictum – 'Technology is the solution', or 'technology is the answer' – was often questioned by Dr Seshadri, who asked, "Where is the problem, first?" Technology or invention must arise out of a problem, not as a result of market pressure or organizational restructuring alone ... they must address a very serious developmental issue. And, with this, he went around nurturing inventiveness and innovativeness in all kinds of people. School drop-outs, semi-literates, and PhDs all came with some kind of a new product or the other, some kind of new idea, under his guidance." (Balaji 1996).

Seshadri was once asked in an interview, "Are you not trying to reinvent the wheel?" He responded by stating that you need to re-invent the wheel to understand the process of innovation, creativity, and technology, and to write the operation manuals for current conditions. Importing a technology will not solve the problem. Much of the work at MCRC revolves around this accent on invention and the need to introduce a culture of invention, both at MCRC and within the communities with whom they worked. There were thus no blueprints for invention either, but approaches that they sought to follow in their work.

However, it needs to be emphasized that this accent on innovation was not innovation for innovation's sake, but was seen as critical to the whole innovation process of an idea being translated into reality. Table 5, taken from a 3-year review of MCRC, indicates an appreciation of the innovation chain and where each piece work or experiment was situated.

Learning across projects.

One of the features of the organization is the cross fertilization of ideas across projects. From the narrative of the *Spirulina* project it is noticeable that there were major shifts in research directions, especially in the manner of applications. A look at the projects of MCRC in the last 25 years indicates several activities happening simultaneously in different projects. This enabled learning in the *Spirulina* project and vice versa. Two of the earliest programs in a cluster of villages focused on providing nutritional and energy self-sufficiency. A significant outcome of these efforts was the conception of the notion of 'Integrated Energy Systems' that views waste(s) from one part of a system as input for another. This concept was used in the *Spirulina* project. Similarly, training women in using workshop tools or income-generation activities led MCRC to experiment with *Spirulina* production by rural women. Several small-scale experiments fed into the large-scale trials both in *Spirulina* and in other projects. Nutritional requirement studies in the early 1980s helped create the atmosphere and capacity required for LSNS in the 1990s. These LSNS helped the Latur project and so on.

At another level, developing algal cultures gave the group a chance to explore a whole range of renewable energy devices. Windmills were designed and built to agitate the cultures. The solar energy based devices were developed to dry algae after harvesting.

Table 5. Evaluating work in progress in MCRC.

Area of research	Idea stage	R&D	Proto-type	Field test	Technology transfer	Publica-tion
Identification and separation of algal strains	X	X				X
Spirulina culture in inorganic nutrient	X	X		X	X	X
Spirulina culture in modified biogas media	X	X		X	X	X
Biogas and sea salt	X	X		X	X	X
Biogas, sea salt, and bone meal	X	X		X	X	X
Biogas and sea water	X	X		X	X	X
Spirulina culture in sewage	X					
Development of harvesting equipment for *Spirulina* culture	X	X	X	X	X	X
Wind agitators	X	X	X	X	X	X
Feeding trials of cattle and fish	X	X		X	X	X
Human feeding trials	X	X				
Protein estimation in *Spirulina* incorporated in food	X	X				
Nitrogen estimation in *Spirulina* incorporated in food	X	X				

Source: MCRC. 1980.

Innovations in low-cost digesters were made to use carbon dioxide from biogas plants. From each of these innovations a further set of devices and technologies grew. The work on biogas and improving its quality in turn enabled identification of cellulose-degrading bacteria. This led to the development of a microbial pulping process for papermaking. The solar drier work led to development of water-distillation units that use sunlight as an energy source (Thomas 1996).

What is clear from this is that MCRC viewed all its activities (both research and development) as learning exercises. And because these different sets of activities 'talked' to each other this learning could be used to stimulate innovation. The lack of barriers between research and developmental activities together with a culture of viewing these as both important with valuable contributions to make, was an important feature of MCRC.

Sources of innovation

Seshadri believed that the Indian experience in making technologies so that technology comes to fruition through sale of product or process was marginal, and that often the professional bodies of science are unclear and lacking in judgment about when a technology was ready. He added that what was considered invention and/or creativity in India was import substitution at all levels including the idea, need, market, development, and sale. In this scenario, he argued, it was hardly surprising that creativity and innovation seldom take root. Indeed, he stated that:

> "Invention is a social act. The fact that the science and technology establishment has sequestered this for themselves is a sad feature of Indian life. Invention cannot be categorized, classified, displaced and disposed of, and can take place anywhere. Further, the recognition that it costs money and efforts to convert inventions into products is also absent. If science cost Rs1, technology may cost Rs10. Hence support must be available all the way" (Seshadri 1991).

The wider institutional context of MCRC and its philosophy

What was the context to which MCRC was responding? What was the larger context within which the MCRC work needs to be placed? Some of the critiques of development and research in Indian science to which MCRC felt there needed to be an alternate model are presented here. MCRC started primarily as a private research center, though its character soon changed to that of a non-governmental civil society initiative. In the early period Seshadri at MCRC reflected on science in India and commented that "a sad feature of the profession (of science) is the way private sector scientists are treated by government scientists with a lot of suspicion and hostility, almost as though they were non-Indians" (Seshadri 1984). This was one of the contexts to which MCRC was responding, ie, that of science being treated exclusively as an elite activity of the scientific establishment, with the rest of scientific activity having to fight for their legitimacy in their practice of science.

Science and innovation in alternative institutional settings

This paper began by suggesting that post-harvest innovation processes are characterized by a degree of complexity with which conventional R&D arrangements in the public sector have difficulty coping. In contrast, despite being overlooked in policy debates on this issue, it was argued, civil society organizations are active in this domain and, in fact, are practicing science and promoting innovation in ways that hold many lessons for research policy. The main empirical section of the paper has presented an innovation trajectory that has been played out to a large extent within the institutional context of a civil society organization. What is striking about this case is the way it so amply demonstrates the systemic nature of the innovation process and thus seems to support the growing calls for the use of innovation systems ideas in agriculture and post-harvest research planning and evaluation (Hall et al. 2001; 2003; Biggs and Messerschmidt 2004).

What then can this case tell us about: 1. the nature of post-harvest innovation processes and systems; 2. the nature of that institutional setting that promotes innovation; and 3. the policy measures and analytical perspectives that should be brought to bear, so that not only does public R&D perform more effectively, but also, civil society organizations are valued for the role they play in innovation systems?

Features of innovation processes and systems

Evolving groupings and diversity of players and roles. The *Spirulina* story demonstrates the way innovation involves a large number and diversity of players and over a considerable period of time. Furthermore, it demonstrates that the players change, that groupings or partnerships emerge and evolve, and that the roles of different players can also change. For example, what had started with the agricultural establishment in India being the major player initiating basic research in the 1950s shifted to the current situation where the scientific establishment had virtually no role. In between there has been one major player – MCRC – that has transformed the way *Spirulina* was seen in the country, a role that has now been taken on by other organizations. The inventory of actors in Table 4 shows that innovation is a process involving a large number of players – formal and informal, research and non-research actors. The roles of actors involved in innovation also seem to be diverse. Some are scientists, some are development practitioners, and some are entrepreneurs. Some are even visionaries. Moreover, these roles are not necessarily fixed. Note how at certain times MCRC needs to play a scientific research role and at others it needs to play the role of disseminating technology – the more stereotypical role of the NGO. Another example is the way RORES, an NGO involved in extension, became an important source of technical innovation when it became involved in developing village-based production systems. These cases illustrate that there is a non-linear progression from a research to a dissemination role (or vice versa), but instead, non-linear organizations play the role most appropriate to achieving objectives at a given point in time. A key feature of the innovation system associated with *Spirulina* has therefore not only been the diversity of the players involved, but also the way both the composition of players and their roles evolve over time.

Partnerships. The *Spirulina* story demonstrates some of the reasons partnerships are important to innovation and shows that important partnerships are often between research and non-research actors. The case of partnerships between village women that the NOW initiative and the LSNS studies illustrates is an example. Here the value of partnerships has been to:

a. Bring **new agendas** to the research process that go beyond the scientific focus and perspective of the researchers involved. In this case the client focus (rural women) of research was sharpened.
b. Bring **new skills, resources and networks.** The collaboration with NOW helped MCRC develop the market and greater public awareness of the benefits of *Spirulina*. Similarly the LSNS study enabled greater access to the medical community leading to several independent studies on the health benefits of *Spirulina*.
c. Raise the levels of **accountability** of MCRC and the *Spirulina* innovation system. MCRC could no longer rest on its glory of commercializing the product, but had to

become an important player and partner in a new system with different norms of accountability for nutrition in rural areas. While MCRC always believed in the concept, the partnerships actualized the possibilities.

An important point here is that the *Spirulina* innovation system has a capability that is more than the sum of its parts. It concerns levels of skills and resources, but also concerns the way the system behaves – ie, the agendas it pursues and the patterns of accountability to which it responds.

Reworking the stock of knowledge. The MCRC experience suggests that innovation is all about drawing from the existing stock of knowledge and using, adapting, and diffusing it in new ways. Algal technology had originally been conceived as a biofertilizer. Knowledge of *Spirulina* was reworked by MCRC to produce a food supplement technology. This idea has subsequently been further reworked to meet diverse objectives such as rural employment, enterprise development, nutritional security, and disaster relief – all innovations on the *Spirulina* theme. As Edquist (1997) points out, innovations involve creations, which may be brand new, but are more often new combinations of existing elements.

Responding to evolving opportunities. The *Spirulina* story indicates innovation is often a response to emerging opportunities and that successful organizations are those that can seize these opportunities when they arise. There has also been a gradual evolution of objectives and trajectories along the way – eg, food, fodder, energy, large-scale, small-scale. The use of *Spirulina* for the earthquake relief work was another such response. Successful innovation systems are those that respond quickly and flexibly to changing circumstances in response to both opportunities and constraints.

Interplay and iteration between research and technology application tasks. It is also clear from the way *Spirulina* developed in India that there was no linear relationship between basic and applied research, or between applied research and diffusion. There has been a lot of iteration between these stages that are conventionally compartmentalized as strategic and applied tasks. For example, the changed client focus (rural women as producers) necessitated several changes in scientific research; the large-scale application requirements for food instead of fodder necessitated basic nutritional research. As we have seen this has allowed a gradual evolution of objectives and directions along the way. At MCRC this was often brought about by cross learning between research and applied projects undertaken by the organization. This is, of course, non-linear. An important point here is that throughout the life of an innovation trajectory, research questions arise that need to be addressed by science. The idea, therefore, of innovation as a systems concept does not diminish the importance of science, but instead locates it in different relationships and points in the innovation trajectory.

Learning. Many of the points above allude to an underpinning process that seems to be driving forward the innovation trajectory. This process is learning and it confers the evolutionary dynamic that characterizes innovation systems. See, for example, the way lessons from applied tasks suggest new research tasks and technical possibilities. Similarly, look at the way the LSNS provides opportunities for MCRC staff to work in new domains – nutrition – and how this allows them to develop further activities in this area. And also notice the way learning comes from different contexts – for example, from the experience of NGOs establishing village-level production systems. Notice also that some of these lessons are technological and some are institutional, ie, how to do something, with whom to work, how to test results and validate findings. Sometimes it was necessary to fail in order to learn how to move forward; in fact, while many of the ideas and designs failed, considerable useful insights were learned. Learning is thus a fundamental property of the innovation system.

Features of institutional settings that promote innovation. Table 6 summaries the main differences between the research cultures of MCRC and public scientific establishments. Some of the key features of the institutional setting that promoted innovation will now be discussed.

Creating opportunities to learn. A number of features about MCRC meant that learning was facilitated. By reducing internal barriers and hierarchies, cooperation and communication was encouraged across the organization. This allowed MCRC to learn

Table 6. Contrasts between research cultures at MCRC and public scientific establishments.

Aspect	Public scientific establishments	MCRC
Vision	Often not articulated, instigated from above, not reflective of work culture	Outlined very early, articulated in writings, 'Integrated Systems' and 'Holistic Invention'
Definitions of problem	Only in technical terms	In social and technical terms, open to ideas from social science and real life
Failure	Product focus, processes not recognized, reporting of success alone	Reporting of mistakes encouraged and seen as part of process. Failure as adding to stock of knowledge
Interdisciplinary	Not encouraged, strict disciplinary boundaries between scientists and technologists and social scientists, tasks as domain of specialist	Encouraged, professionals made to drop labels and work across disciplines, tasks are multi-functional, place for the amateur
Learning	None across projects	High across projects, large spin-offs within the Centre
Research accent	Import substitution	Innovation
Relationship between technology and development	Linear, market seen as taking care, diffusion not part of mandate	Seen as involved and complex, cannot be left to market alone, appreciates time-lag involved, cost sensitivity
Stakeholders	Rarely involved, if at all, at diffusion stage	Active involvement at both idea design and diffusion stages
Partnerships	Few, not seen as important	Large, seen as critical to innovation, and to enable survival beyond MCRC

from its own experiences, especially across projects. The fact that it had both basic research projects and applied field-based projects made this cross-project learning particularly powerful. For example, lessons on projects not directly connected with *Spirulina* helped the *Spirulina* project by bringing in such new possibilities as the approach of integrated energy systems, the focus on nutrition, or the possibilities of women being the main producers and users of technology. This learning was helped by an organizational culture that saw research not just as some specialized activity but also as capacity building for the whole organization. That the organization saw the need for 'reinventing the wheel', if only to rewrite operation manuals, illustrates an approach that valued learning in different cultural contexts.

Encouraging interdisciplinarity and flexible professional mandates. MCRC shows the value of a flexible approach to professional mandates, especially in evolving innovation scenarios. The involvement of trained physicists in marketing, or the involvement of amateurs in research teams broadened the research. The close contact of MCRC with field-level realities on the one hand and scientific organization on the other were strengths that facilitated better problem definition. Related to this was an institutional setting that encouraged and valued partnerships as a way of extending the reach and source of inspiration of the organization into both research and application domains.

Constructive treatment of failure. For MCRC, failure has been an important source of learning and was valued as such. In other words, failure was used to add to the stock of knowledge from which innovation can emerge. As Watts et al. (2003) have indicated, institutional contexts and professional behavior that can take this constructive approach to failure and learning have much to recommend them.

Ways forward

The *Spirulina* story has a number of lessons for research policy, particularly for public research organizations that still conform to linear modes of operation which are seeking to play a more effective role in innovation. These concern: 1. general policy prescriptions and analytical perspectives, and 2. specific comments about the role of civil society science and technology policy and implementation.

General prescriptions

- Conceptualizations of non-technical and non-quantifiable aspects of research need to be encouraged. There are presently few means for scientists to pick research questions from the field or user. The 'field' has a critical role in defining problems and not just as a space for diffusion of technology. Civil society organizations bring to the research agenda this critical dimension.
- Research projects that involve partnership, grouping or coalitions of diverse stakeholders have greater possibilities of success.
- There is a need for a change in organizational culture that encourages broader-based pursuits across the basic to applied continuum and that values failures, allowing for learning across projects and disciplines.

- It is necessary to spend resources on reflecting on the past and on institutional lessons of projects that have a bearing on the culture of research within an organization. In other words, there are learning possibilities through case studies of institutional and innovation histories that need to be more fully explored.
- In general, research activities need to be conceived as part of the larger process of innovation. Concepts such as the innovation systems could usefully be employed to help map out the architecture of these systems, helping identify missing links, and institutional failures.
- Research policy needs to pay more attention to building the capacity of these systems. In this task institutional innovations will be critical.

The role of civil society

The notion of innovation as systemic phenomenon allows the consideration of the role of civil society to go beyond the dualities of formal versus non-formal science. There is nothing in the *Spirulina* innovation trajectory that represents single ownership of ideas or concepts. For far too long, civil society and State science in India have seen each other's activities as in opposition. With the increasing realization that there is a lot of technical content in extension (as indeed this case has demonstrated), formal science needs to extend the domain from whence it chooses problems and research ideas. Within the new framework of the innovation system creativity can be celebrated irrespective of its institutional contexts. More than any increased funding allocation, this requires a change in approach in the way State science looks at the field and the complexities of technology transfer. Formal science needs to recognize the 'hidden histories of science' in civil society initiatives and incorporate them as part of the 'legitimate' narrative if science has to have a pro-poor human face. The *Spirulina* case study in fact illustrates a critical and underutilized role of an alternative paradigm of learning and innovation.

Endnotes

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1. This report has benefited immensely from the several discussions with research staff (both past and present) of the Murugappa Chettiar Research Centre and the NGOs and researchers who shared their experiences on *Spirulina* cultivation. The views expressed however are those of the author alone.
2. For more details on the Nimbkar Institute see www.nariphaltan.virtualave.net and for the Rural Innovations Network see www.rinovations.org, also see www.sristi.org.
3. For various applications of *Spirulina,* see www.nrdcindia.com, www.spirulinasource.com, and Seshadri and Seshagiri 1986.
4. Seshadri (1977) points to the enormous energy in the form of waste heat of thermal plants and estimated that the waste heat of a 100 MW plant as sufficient to supply the energy requirements of 20,000 village households. This figure would swell to 10,000,000 village homes if all fertilizer and cement plants, blast furnaces, and oil refineries were included.
5. For a fuller discussion on the difficulties in implementing interdisciplinary research in universities, see Feller 2002.

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3. Technological and institutional innovations: a case study of pomegranate production and marketing

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Abstract

Over the last decade important innovations have taken place in pomegranate production and marketing in Maharashtra, India, and these developments have been associated with a wide network of actors. This paper presents a case study of this 'innovation network'. Starting with a short overview of accounts of innovation in relation to rural resource-poor communities, the paper explores some of the causal relationships that brought about innovations in pomegranate production and marketing. It looks at technological innovations in the production and marketing of the fruit, and associated institutional innovations – ie, the changes in the way these causal relationships evolve and work, together with changes in the roles of actors/organizations. The central lesson is that this cluster of actors and their mutual dependencies enable continuous innovation in pomegranate production and marketing. In conclusion, the paper translates some of these empirical insights into a possible framework for action by actors in public agricultural research and extension organizations.

Introduction

This paper explores the nature of the innovation processes associated with major changes that have taken place in the production and marketing of pomegranate (*Punica granatum*) in the semi-arid region of Maharashtra, India. A series of related innovations have literally transformed these areas and the livelihoods of poor households who depend on dryland agriculture. As a result of these changes rural migration during the dry season has virtually stopped – previously all able-bodied persons would migrate during this time in search of employment. The case is interesting, not just because of the dramatic effects it has had on the livelihoods of poor people, but because of the range and diversity of processes, relationships and interconnected events which have brought about these innovations.

The crop in question, pomegranate is a fruit tree that produces a table fruit, considered exotic in many parts of the world. It is used mostly as fresh fruit, though the food industry also produces a syrup called grenadine from pomegranate juice – especially in the Middle East and the West. Pomegranate has a long shelf life and is an ideal fruit for long-distance transport and prolonged storage. India is the largest pomegranate producer in the world, with about 50% of the world's production and about 5% of the international pomegranate trade. Almost 80% of Indian pomegranate production comes from the Deccan plateau, mainly from Maharashtra. Production has grown rapidly, especially over the past decade, and has now caught the attention of the

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policy makers. In May 2003, the Ministry of Commerce of the Government of India (GoI) sanctioned an Agri-Export Zone for pomegranates in Maharashtra. It is expected that the quality of Indian pomegranates will improve to meet international market standards. In a country where processed pomegranate is unknown, the Agri-Export Zone also promises to create processing facilities, encouraging farmers to produce relatively higher proportions of export-quality and processing-quality fruit. That these farmers were, until recently, poor cultivators or migrant labor with no cash reserves worth mentioning, and no marketing skills, perhaps makes the demand for high-quality production and export of processed products seem a bit far-fetched. But a wide network of actors (including these farmers) innovating with pomegranate production and marketing has, over the past decade, proved its mettle. This case study focuses on this ‘innovation network’. The objective is to document and analyze the innovations that have enabled the emergence and success of horticultural production and marketing in an arid region.

The paper begins with a short overview of accounts of innovation, especially among rural resource-poor communities. This is followed by a brief introduction to horticultural production and marketing in a resource-constrained village that has been studied in depth. An outline of how livelihood patterns have evolved and different types of learning have emerged in this dry and resource-poor village is presented. The next section explores some of the causal relationships that brought about innovations in pomegranate production and marketing. It considers both technological and institutional innovations – the changes in the way these causal relationships evolve and work, as well as changes in the roles of actors/organizations. The innovations systems perspective is employed as an underpinning framework for the analysis. The section that follows explains how this dynamism has been sustained through the collective effort of the (informal) network of actors. This innovation system has now made its own policy impact with the GoI declaring an Agri-Export Zone for pomegranate. The conclusion draws attention to the lessons from this innovation system. These lessons reveal several crucial systems features that operate in successful innovation networks. Notable are the importance of mutual dependencies among actors/networks and the value of non-hierarchical partnerships and learning. The paper concludes with some lessons and principles outlined for actors in public agricultural research and extension organizations, in relation to pro-poor innovations.

Accounts of innovation

As this story of innovation in pomegranate production and marketing unfolds, it can be seen that developments in this sector arose from a combination of purposeful technical and other interventions together with spontaneous innovations, changed circumstances, and some unpredictable developments. This reveals several nuances in the way innovation takes place. It challenges many of the accepted norms and assumptions of research and development (R&D) planning where the view is that research by scientists delivers technologies which extension transfers further down the line for farmers to adopt.

The diffusion of innovation in a linear fashion, from the science that generates it to the extension effort that disseminates it down to the farmer who uses it, is the institution or rule that defines the organization of public-sector research and extension. Even though this myth of the smooth linear flow of knowledge and technologies has been widely discredited in the literature (Biggs 1990; Roling 1988), this linear model still holds sway (Ruttan 1996) and the structural and functional bifurcation of research and extension as two distinct organizations continues. This demarcation of functional boundaries for research and extension enables compartmentalized accountabilities limited to, say, release of varieties or identification of pathogens in research, and number of farm visits or hours of training conducted for extension. It ensures that the world of agricultural science does not face or acknowledge the complex processes of technology generation and use, and can continue to legitimately ignore technological contexts (see Hall and Clark 1995).

R&D planners and administrators are starting to use the idea of an innovation system to acknowledge a more holistic and dynamic network of actors and functions for technological and economic development. As an organizing device the innovation systems framework is useful because it breaks out of the narrow planning and analytical focus on research alone. The innovation systems approach provides a framework for: 1. exploring patterns of partnerships; 2. revealing and managing the institutional context that governs these relationships and processes; 3. understanding research and innovation as a social process of learning; and 4. thinking about capacity development in a systems sense (Lundvall 1992; Hall et al. 2000). The pomegranate story in this paper reveals that there is much iteration between research and action in the field. Successful interventions are often those that have a significant potential for adaptation, in terms of design and content of the technology, to different location-specific demands as well as to rapidly changing circumstances and opportunities (Douthwaite 2002).

As the pomegranate innovation system is explored, we will see that innovations arise from a variety of different sources, including formal research settings and fields of operation, and that these innovations can be both technological and institutional. There is no predetermined sequence of discovery, diffusion, and adoption, and perhaps most importantly of all, the learning process of all those involved in interventions is a critical way of driving technical and economic change. This suggests that successful interventions and policy environments are those that avoid blueprints and instead concentrate on shepherding progress through the complexities of the innovation maze.

Conventional public sector R&D: the current pomegranate scenario

Before presenting the complexities of the pomegranate innovation story it is useful to briefly explore the public-sector R&D arrangements for pomegranate. This provides a benchmark against which the field-level pomegranate innovation system can be compared. Conventionally, in Maharashtra, horticultural (here pomegranate) production technologies are developed in the four State Agricultural Universities (SAUs). Like all other SAUs in India, they have a mandate to train extension officers in the State Department of Agriculture, through their subject matter specialists (SMSs). The extension officers then transfer this technology/knowledge on pomegranate production to the farmers in their respective designated areas, and preferably on designated days of the week or fortnight. The public-sector knowledge generation and transfer responsibility ends there. It is the farmers who seek out the private input suppliers, the public subsidies for specific inputs (drip equipment, plantation investment, fertilizers, pesticides, etc), the credit/loan agencies or families, the product markets, and any other knowledge or material input that can help their farms. This linear handing down of pomegranate production technologies and drip irrigation technologies still continues, beginning with the publication of the annual Package of Practices by the SAUs, the SMS training the extension officers, and the latter training/targeting farmers. The actors and their respective inputs in a conventional pomegranate R&D model are arranged in a strictly hierarchical fashion, with the farmer at the lowest rung designated as the beneficiary.

Table 1. Actors and roles in a linear R&D model.

Main actors	Respective roles
Government – State/Central	Policies/Subsidies/Programs
SAUs/ICAR/Other R&D units	Varieties and NRM technologies
Department of Horticulture	Extension/service targets
Input dealers/processors	Markets/contracts
Public service agencies	Credit/Transport/Insurance
Farmers	Beneficiaries

Implied in this design (Table 1) is the notion that technological and economic change involves a number of sequential steps whereby technology is developed by the scientific community and it is then validated and transferred to farmers and other users. It is also implied that there is a sequence and hierarchy in the interactions among different actors, and that there is no real-time learning or experimentation/adaptation required. The pomegranate story presented and analyzed in this paper reveals a complex maze of actors and roles. It has much to tell about the innovation system, its actors, their networks, linkages, roles, and learning processes. It reveals that the public-sector R&D actors are aware of and do discretely participate in these dynamic innovation systems. But they lack the capacity to reform existing institutions of R&D to enable their effective participation in these innovation systems. In the final section some capacity-building measures to this end are addressed.

Dryland horticulture innovations

The Solapur region of Maharashtra is known for its migrant labor. Almost half the population in the district, obviously from villages in the dry and less-fertile parts, traditionally migrates every year. This migration would invariably be towards the sugarcane fields of the richer neighboring districts, or the urban labor markets in Mumbai or Pune. The migration period would last from January–June/July or October–April depending on how much water the village had, and how much crop mainly sorghum (*Sorghum bicolor*) or maize (*Zea mays.*) – was available to be harvested and stored. According to villagers, since 1998/9 this lean-season migration for survival has been reduced to almost a third of what it was in 1995. Reduction in seasonal migration is the most potent proof of the improvement in rural livelihoods due to increased horticultural production.

Overall, the transformation in land and water use and horticultural production in these dry tracts has been made possible by the introduction of drip irrigation, a technology renowned for its irrigation/water-use efficiency. The technology has been widely known and applauded in the world of agricultural R&D since the 1970s. In Maharashtra, the SAUs, and the Agricultural and Horticultural Departments have recommended several dryland crops for adoption by farmers of the region. The government of Maharashtra initiated a broad policy to encourage the use of drip irrigation in the State. Since 1986/7, the State has been subsidizing the establishment of drip-irrigation systems in farmers' fields. The central GoI subsidy for drip irrigation came into effect in 1990/1, and together with State subsidies has promoted drip irrigation. An attractive instrument in the State policy was the provision of a 100% subsidy to farmers who established horticulture/fruit orchards as part of the Employment Guarantee Scheme (EGS). This subsidy met the entire capital investment required to establish an orchard.

Maharashtra now accounts for over 70% of the total drip-irrigated area in India, and its farmers cultivate over 20 crops using drip irrigation including: grapes (*Vitis vinifera*), banana (*Musa paradisica*), sugarcane (*Saccharum officinarum*), and orange (*Citrus sinensis*).[2] For a relatively creditworthy farmer – with sufficient land and assets, access to the irrigation subsidies, agricultural technologies, and good markets – the policy framework (subsidies), the drip-irrigation technology, and the fruit markets seem to have worked well. But a poor farmer, especially in the relatively degraded lands with little water for any cultivation, has no access to credit or subsidies. The government subsidies and drip-irrigation equipment in the 1980s and 1990s were concentrated in the rich fruit districts like Nashik, Nagpur, Jalgaon, etc. Little of the subsidized equipment and fruit cultivation reached the farmers in Solapur.

A village in Solapur: the case of Tippehalli

In an attempt to understand what made pomegranate cultivation possible for farmers in an area that had otherwise given up cultivation prospects in its own land as barren waste slopes, focus is placed on one village, Tippehalli, in Sangola block. Sangola now produces the best quality pomegranates in Maharashtra. This village, Tippehalli, helps illustrate the microcosm of the pomegranate innovation system – and how poor, migrant households in the village have negotiated their interests, skills, and roles to develop and sustain pomegranate production (Table 2).

The farmers, input dealers, and market/contract agents interviewed in Tippehalli village are united in their view of pomegranate as a crop that saved their village. The differences they expressed, however, relate to the causal relationships that brought this breakthrough and the emergence of technological and organizational changes. It is these changes – technological, organizational, and institutional – that are analyzed in detail here.

In Tippehalli, where the owner of about 16 ha of land is considered poor, a pomegranate plantation of 2.5 to 3 ha is considered large and rich. The wealth or asset consciousness of the people here is not land ownership, but directly a function of how the land is worked. The cultural norms of the village are evident in the following statement by a farmer: "My daughter must marry into a household with hardworking sons – preferably people who understand technology and know how to work the land, and not just a household with hundreds of hectares of land."

Only 25 of the households in the village are non-adopters of pomegranate cultivation. They are either families with very limited land (just enough to grow some sorghum or

Table 2. Tippehalli village then and now – an impact scenario.

Before 1997/8	Now – March/April 2003
Almost 350 households migrate – entire families	Only 40 families migrate – usually only the men
40 ha of pomegranate	Over 445 ha of pomegranate
Two agri-input dealers – in Junooni	Several agri-input dealers in the village – also advice on use
Sorghum, no or little cooking oil, few vegetables or meat	Wheat/rice, many vegetables, poultry,
Only two bicycles in the village	50 motorbikes, 7 trucks, 2 tractors, 6 jeeps, bicycles in almost all households
Illiteracy, poor schooling	Want residential schooling

Source: Interviews and group discussions, Tippehalli village, Sangola, April 2003.

maize); no land at all (landless laborers) and no source of water; land that slopes too steeply (where the drip layout is a problem); or who cannot afford even low-cost drip-irrigation equipment (wage labor being their only source of income); or who cannot take time off wage labor to invest in establishing their own orchards. One household reported morbidity of the women as a reason for non-adoption of pomegranate cultivation.

Farmers agree that pomegranate is ideal for this village because it demands very little water during the long dry summer. Because Tippehalli is a relatively high-altitude village in the block, it has limited access to water. An open well (about 10–15 m deep) yields about 30 min of water supply when pumped out for irrigation during the dry spell (approximately from January to July). Even though the water table is inaccessible because of the hard rock plateau under the thin topsoil, the dug wells are recharged overnight when about 15 cm of water flows into the well, largely from sub-surface flows. The farmers have devised a system of irrigating their small or medium-sized pomegranate plantations in a series of small patches over about 4–5 days. Of the 350-odd households in the village almost all own a well or have access to at least one dug well, with shared ownership and use among small groups of 4–5 households.

The first person to adopt pomegranate cultivation in the village made use of the State government's EGS 100% subsidy in 1987/8 to establish a small pomegranate orchard of a little less than a hectare. But the lack of further support to cultivate the fruit properly made him give up the plantation within 2 years. Part of the land went back to sorghum or was laid bare again. However, it was known about three decades ago that pomegranate could grow well on these poor gravelly soils,[3] so some households tried pomegranate cultivation again the following year. The early 1990s witnessed the emergence of several private and voluntary organizations. These provided such inputs and services as seeding material, technical advice, and market/export support. Some of these actors also visited Tippehalli. With the subsidies available under the EGS, about 10 households established pomegranate orchards. The local nursery (from where the cuttings came) offered much of the initial technical advice. Other sources of interaction were the local NGO and the input dealers at the local market center, Junooni. By 1996/7 there were already 40 families cultivating pomegranate. Of these, 10 had drip irrigation – government-approved and -subsidized equipment installed in their plots. Returns from these drip-irrigated plots of pomegranate were visible to all farmers. What was even more evident was the rate of expansion from one season to another, increasing the area under pomegranate. There were some minor and major problems like die-back disease of the pomegranate plants, lack of knowledge about appropriate cultivation practices, cost of the (subsidized) drip-irrigation system, mistrust of market agents, etc, that held the farmers' enthusiasm in check. But there were also solutions that were tried and that worked. Private input dealers in particular encouraged farmers to take the risk and establish pomegranate plantations.

The first investment to be made was in ensuring access to some water. By the mid-1990s almost all farmers in Tippehalli had gradually built their access to water, through institutional changes in the ownership and operation of wells. NGOs facilitated this, with financial support for some pomegranate cultivator households, and technical and organizational support for some groups of households. In the latter case, intervention by the NGO helped devise rules for cost and resource sharing. All these farmers had already made the move from exclusively rainfed agriculture to irrigated agriculture, using locally improvised/purchased/donor-aided lift-irrigation equipment (pumps) and furrow-irrigation methods. Their irrigated crop was mostly *desi* (local) cotton (*Gossypium* spp.) and, in some rare cases, vegetables.

In 1997, following an NGO demonstration by the Mahatma Phule Samaj Sewa Mandal (MPSSM) of low-cost drip irrigation and papaya (*Carica papaya*) cultivation, farmers in Tippehalli made a formal request to the NGO for drip irrigation and possible horticultural crops, especially pomegranate that could be grown in the region. What led to the adoption of pomegranate cultivation and installation of drip irrigation by nine farmers in 1997? The farmers of Tippehalli point out that there are two main features that characterize the pomegranate production and marketing system in the village. The first is the presence of NGOs in the area, including watershed development programs and all the actors associated with these watersheds. Secondly, the village and the entire district have been classified as a belt for dryland horticulture. The actors here argue that this 'dryland' status attracts some Government programmes or projects and that gives a fillip to the existing dynamic innovation system in the village.

Tippehalli village provides a microcosmic illustration of an innovation system. There are several actors ranging from the State (public sector R&D, programmes for horticultural production, employment guarantee, watershed development, subsidies, etc), NGOs (watershed projects, irrigation and input management, marketing), private sector (nurseries, input suppliers, drip irrigation) and farmers (as individuals and small groups of well-owners/groundwater allocators). There is evidence of technological and institutional changes, as in the actor linkages and institutional changes that enabled collective ownership and access to water. There is little evidence here of the linear research, extension, and adoption phases. Scientific research is not a central driving force or actor here. Innovations, both technological and institutional, seem to have come from different actors, not in any specified chronological order, and do not conform to the given hierarchy of knowledge. Most clearly visible is the ability and willingness of each actor to collaborate with other actors and learn from each other. The innovation system microcosm illustrated here is also evolving continuously.

Types of learning associated with pomegranate innovation

There is unanimous agreement that it was the availability of low-cost drip kits and the demonstration of good gains by the early adopters which led to the wider acceptance of pomegranate. Though this demonstration is a step in conventional linear transfer of technology models, it is evident that there were several types of learning processes that took place in this pomegranate innovation system. It is difficult to mark out each learning activity involved in this innovation system, chronologically or actor-wise. We shall instead attempt to identify the different types of learning, ie, by the nature or process of learning.

Accessing knowledge

Along with the affordable micro-irrigation technology (AMIT) came accessible training for farmers on drip technologies and pomegranate cultivation. Other training programs in vermicomposting, pest management, pruning and interculturing, water-harvesting techniques, etc, were also available. What marked these training programs was the amount paid [at least Rs 25 (US$1 = Rs 48, as of 2003 exchange rate) per training program] by the farmers to participate and learn. There were no free training programs. Compared to the conventional extension training and visit (T&V) methods, covering larger number of farmers (snowballing to hundreds from the 10 contact farmers every fortnight), the training and learning programs in the pomegranate innovations often witnessed fewer numbers (30–35 farmers in a 1-day training session). But this was a group of farmers that had paid to learn, so they made sure they got what they wanted from the training, and had access to the relevant actors to voice their problems. One of the first problems aired was the lack of organic manure and poor soil conditions in the village. The vermicompost training that followed had three farmers instantly buying vermicompost, and in a few months over 20 farmers in the village had followed suit.

Was it ethical that farmers paid to learn and acquire knowledge that was otherwise in the public domain? The farmers had no problems paying for this knowledge. No GoI officer, let alone any extension officer, had ever visited or imparted ‘public knowledge’ to them in the history of Tippehalli village. This is a remote village by modern standards, without even a public transport (bus) service. Extension effort organized in the public sector demands regular transport access, which this village lacks. Farmers also reckon that since almost the entire village, except the really old members, used to migrate for months together (often January to June), even State transport cannot be blamed for ignoring them. Until 1997, the only source of agricultural knowledge came from the input dealers who would visit Junooni, the nearest commercial point for about 20 villages in the area. The situation has improved now, with input dealers regularly visiting the village and offering direct credit and access to the best of pesticides and fertilizers.

Given the initial demonstration of a successful crop, the farmers in the village seem to have sought and accessed the knowledge they required to cultivate the crop. This pro-active learning process distinguishes the farmers in an innovation system from the passive adopter farmer in the linear model to whom extension officers transfer knowledge.

Interactive and network learning: production skills

Farmers in Tippehalli gained important crop production skills by participating in a wide network of actors. These skills include: size, depth, and methods of pit digging; choice of variety and planting methods; pruning (timing and judging the timing of pruning); drip irrigation; thinning; intercropping; fertilizer and pesticide application; grading and marketing. Most of these skills came to farmers through their own drip-irrigation dealers/ assemblers, input dealers, or field staff of NGOs or private organizations, neighboring farmers, and NGO training programs.

One of the problems voiced recently is the increasing costs of pesticide and fertilizer application. Will increasing pesticide applications affect our export market? How do we grow organic pomegranate? What would the costs be? How do we get organic certification and who will tell us how to grow organic pomegranate, with no pesticide or chemical residues? Is 'organic' more than just absence of residues? These questions are now voiced in a village that only a decade ago was migrating en masse to other villages for wage labor during 4–6 lean months each year.

Between the two commission agents or booking agents who handle the marketing of pomegranate in Tippehalli, there has been talk about farmers' (about 10 out of the 80 farmers with one agent) borrowings from agents exceeding the price fetched by their pomegranate produce. Since the agents are pomegranate farmers, they are aware of the increasing pest attacks (fruit borers, aphids and mites, semi-loopers), bacterial blights, and soil fatigue, plus increasing costs of fertilizers. In the past 4 years, fertilizer prices have increased from Rs 167 25-kg bag^{-1} to Rs 250 bag^{-1}. A cartload of FYM that used to cost Rs 100 just 2 years ago now costs Rs 500.

There is much discussion among various actors in Tipehalli about how the pomegranate system may be unsustainable in the long run, unless complemented with other crops that can cope with drought stress and poor soil conditions and give a reasonable yield. Again, the actors involved are all consulted, opinions sought and resources mobilized. The first of these alternative or complementary knowledge inputs are integrated pest management (IPM) practices, and other crops like castor (*Ricinus communis*), ber (*Zizyphus mauritiana*) or custard apple (*Annona reticulata*). Two situations that farmers would prefer to continue are the knowledge network and the farmers' access to fruit grading and marketing channels. Recently, in 2002–03, the introduction of an innovation in micro-irrigation (the Eazy Drip) has suddenly opened up the possibilities of seasonal crop production, greater production and market control for farmers.

Participating in this innovation system involving a network of actors, farmers and other actors, acknowledge that they gain constantly, both in finding solutions to existing problems and in asking the right questions about their production skills and future options. Here again, there are multiple sources of knowledge and variations of communication and adaptation patterns. The only common thread in this is the interactive mode of learning.

Iterative learning: grading and product quality

A salient feature of the way pomegranate production and marketing innovation have emerged is that they have built up slowly over time. Farmers had to acquire a great deal of knowledge to successfully produce and sell the fruit. This was largely a matter of

Table 3. Yield and grades of pomegranate produced on a 1-ha drip-irrigated plot in Tippehalli, Maharashtra.

Years from planting	Produce grade	Productivity ha^{-1} (in boxes)	Current prices[1] (Rs box^{-1}) and gross revenue (Rs ha^{-1})	Approximate cost of cultivation and marketing for a 1-ha plot (Rs)[2]	Net profits per drip-irrigated hectare of pomegranate (Rs)
3	Q1 Q2 Q3	145 75 50	200 125 100 (43,375)	35,000	8,375
4	Q1 Q2 Q3	250 75 50	200 125 100 (64,375)	38,000	26,375
7	Q1 Q2 Q3	850 400 200	200 125 100 (240,000)	125,000	115,000
8	Q1 Q2 Q3	975 500 200	200 125 100 (259,500)	125,000	134,500
15	Q1 Q2 Q3	850 390 200	200 125 100 (238,750)	125,000	113,750

1. Farmers express concern about the current prices – they feel that a glut in the market can depress prices, and advise that calculations of their benefits be made with the assumption that prices may not increase, while input costs certainly will.
2. In costs farmers also express the initial plantation and planting material costs, price of the pump, well expenditure, etc, although several of them received the State Government subsidy to establish their plantation under the EGS, so profits are likely to be much higher. Given that the AMIT kit is replaced after about 7–9 years, and that prices of pesticides and chemicals are increasing, farmers claim that costs do not decrease as the plantation ages. Since these figures were gleaned over discussions in 2 days with farmers and commission agents in the village, readers are cautioned about the accuracy of the data. But the yield and price figures do correspond closely with Naik's (2002) study of AMIT marketing. That again makes the reporting suspect if smart farmers are used to reporting a particular quantity and price.

learning by doing, trying things out and failing, and learning to do better. The experiences associated with developing grading and product quality mechanism are a case in point.

One of the first decisions, the choice of variety, followed the demonstration of success by the first farmers and from experiences in the market. In selecting varieties, the farmers in Tippehalli had two choices – the pink-seeded *Ganesh* or the red-seeded

Mridula and *Bhagwa*. Among the traits that were common to both were stress tolerance and high yields. But what *Mridula* gained in the market in price (due to its blood-red seeds) *Ganesh* gained in the market in the size of its fruit (pomegranate is graded by size) and a higher proportion of first-grade produce. An important choice made by the farmers after a couple of seasons of fruit sales was to choose *Ganesh* as their most-accepted variety, although there is a significant proportion (about 30%) of the area under *Mridula*.

Horticultural production and marketing in this remote village is highly professionalized, with each farmer being acutely conscious of the cultivation practices that can ensure maximum output of first-grade produce. The three grades of pomegranate are Q1 (12 pieces per box)), Q2 (24 pieces per box), and Q3 (36 pieces per box). Farmers claim that assured irrigation throughout the year, even if there is a minimal amount of water supplied per irrigation, ensures that there is maximum production of first-grade produce. Another observation by farmers that encourages the drip-irrigation technology to go hand-in-hand with pomegranate cultivation is that the overall productivity of a drip-irrigated plot is almost 1.5–2.0 times that of a furrow-irrigated plot. Farmers observe that grading pomegranate by size makes it a fair market – both the producers and the buyers know exactly what grade they are handling and therefore the correct price.

Given that pomegranate trees start yielding from the 3rd to the 4th year after planting, there is much to be gained from installing a drip kit. On average, the pomegranate plantations in the Solapur area provide stable yields till about 15–18 years after planting, and then gradually decline.[4] The share of the first-quality (Q1) produce remains more or less the same during the peak yielding years. Gradually as the plantation ages, yield quality declines. The produce grade and average productivity per hectare in Tippehalli are given in Table 3.

Tippehalli village boasts a turnover of Rs 115 million from its 445 ha of pomegranate in one year (2002), bringing a profit of about Rs 55 million to the village (an average of Rs 1.5 lakhs per household per year, given that the village has 370 households). At least 10 export agents dealing directly with fruit markets in the Persian Gulf make regular visits during the harvest season to select the best fruit (Q1) for export. They bring their own labor and packaging material and pay farmers directly in the field, based on the number of boxes filled. About 25% of Tippehalli's pomegranate is sold to these exporters.

For the next grade (Q2), and some first grade (Q1) that is left, the Tippehalli farmers prefer the primary market network to which they have access, ie, the wholesale markets in Delhi and Mumbai. The operation of booking the produce in advance with a wholesale agent in Delhi or Mumbai, transporting the produce, collecting the total amount and re-distributing it to individual farmers (depending on their produce quantity and quality) is done by their own local commission agents (whom they trust and from whom they often borrow). The process is fairly transparent and in the case of wholesale auctions, the commission agent has access to information about the highest bidding that took place for his lot of produce shipped to the wholesale market. The Delhi market is preferred because the produce is booked for an assured amount. The wholesale merchant sends the price booked as soon as the shipment reaches him in Delhi. The wholesale merchant in Delhi gets 8% of the total sales value. Both the farmers and the wholesale merchant trust the local commission agent. Farmers consider it beyond their access to verify the final rate at which their produce was sold in the wholesale market. Some Tippehalli farmers have tried taking produce to the Mumbai market, but this is a market that is very difficult to decipher, with huge entry barriers. The farmers have therefore decided that it is advisable for them to go through a trusted partner who has entry and access to a known wholesale market.

Several of the questions about costs of production and marketing have led this system to explore other options, ranging from further cost reduction to pomegranate processing options. In Tippehalli, there is a process of dynamic innovations, with different actors evolving from one technological and institutional change to another. What is now a pomegranate monocrop may change to (or incorporate) vegetables, drumsticks (*Moringa oleifera*), castor, cotton (*Gossypium heirsutum*), custard apple, or other crops. The actors interviewed are confident that the system will evolve to new crops, new vistas, new markets, and employment opportunities, so long as they ask the relevant questions, understand their mutual dependence, and work towards conserving the water resources of the area. This confidence in the evolutionary potential of their innovation system is derived from their capacity for iterative learning. In this innovation system a farmer makes a pruning error or underestimates the irrigation costs only once. These farmers cannot afford to repeat a mistake – and therefore every error is a major lesson and is documented and retold within families, in local markets, and amongst other actors. Iterative lessons are lessons well learned.

Starting from fertilizer use, irrigation practices, pest control options, intercropping, etc, at the field level and going on to locating the ideal market agent, negotiating and finalizing a fair price/deal for the produce, etc, the innovators in Tippehalli are engaged in a continuous process of experiments and iterations. Although significant learning is enabled through networks of mutual dependency, individual farmer capabilities, plot location/topography/edaphic features, and attitudes towards and decisions about commission agents/distant markets, etc, are almost entirely drawn from iterative learning processes.

Causal relationships and actors in pomegranate innovations

The different types of learning identified here – by directly seeking and accessing knowledge through interactions with networks of other actors, and by experimenting and iterations – take place simultaneously, with a constant give and take among the different types or processes of learning. These learning processes are not consciously documented or analyzed even by the more articulate actors like the NGOs or their trainers. Their documentation, however, does include new approaches to development, new actors, and new roles for each actor in the innovation system (Hall et al. 2001). Here we attempt to include these learning processes in our analysis of causal relationships and actors in order to draw out the underlying assumptions and the processes enabling learning and innovation.

Pomegranate innovations: the business development approach

International Development Enterprises (India) [IDE(I)],[5] is an important actor in the low-cost irrigation technologies and institutional arrangements that enabled the widespread adaptation and adoption of pomegranate production. IDE(I) worked in Maharashtra in the late 1990s and has been working in the State again since October 2001. The IDE(I)'s 'market creation' approach to development assumes that every actor involved in the pomegranate innovation system is an enterprise, with its own interests in the development issues concerned [IDE(I) 2003]. In the IDE(I) market creation approach, the farmer, resource-poor or otherwise, is a micro and small enterprise (MSE). As an entrepreneur, the farmer or farm family is not a passive beneficiary located at the tail end of the R&D chain, but an active participant in the market, and its innovation processes and related institutions. This approach essentially focuses on the incentives that each actor has to participate in the innovation process. In this market creation or business development services (BDS) approach the passive beneficiary small-scale farmer in the conventional (linear) R&D approach has an active and profit-based, business-oriented role in innovating and improving the system.

By locating horticultural production and irrigation technologies within this market creation approach, the BDS approach challenges the central assumptions of the linear technology generation, diffusion and adoption model (Table 4).

Table 4. Assumptions of linear R&D models challenged by the business development approach (BDS).[1]

Assumptions	BDS – gaps identified
Technological solutions	No effort at adaptive improvements
Science leads to relevant solutions	R&D does not understand social constraints
Establish R&D organizations	Isolated organizations with no local linkages
Diffusion of technology	Disbursement mode is inadequate
Subsidies – orchards/drip systems	Access limited to rich farmers
Input and output market access	Beyond the risk profile of small-scale or marginal farmers
Public services available	To a few with credit worthiness – biases operate
Target small-scale farmer beneficiaries	Families forced to migrate – survival at stake

1. Based on personal interviews in Aurangabad, Jalna and Solapur, April 2003.

The BDS approach enabled IDE(I) and its partners to see and assess several institutional arrangements and technological changes that would lead to small-scale and marginal farmers purchasing drip irrigation sets. Encouraged by the farmers reporting that the only purely technological difference between the State-subsidized Indian Standards Institution (ISI) marked[6] sets and the AMIT kit was in the point of emission, the innovations continued to focus on cost reduction of the drip-irrigation technology and better institutional arrangements. The cost for a subsidized drip irrigation unit would be Rs 44,000 to Rs 49,500 ha^{-1} depending on the horticultural crop sown. Given a 50% subsidy, the cost would come down to around Rs 23,000 ha^{-1}. If the SCs and STs get more than 50% subsidy then costs would be lower. They were assured that this subsidized drip-irrigation equipment would last for about 20 years.

Drip-irrigation innovations when seen in the BDS approach revealed several other materials, methods, and institutional arrangements which the active MSE – the small-scale or marginal farmer – would demand, and several of these were taken up by the IDE(I) and its partners in the field. A major innovation was in the use of cheaper plastic material for the laterals and the use of microtubes for emission along the lateral irrigation pipes, which reduced costs to Rs 14,800 ha^{-1} without any subsidy. Introduced and constantly modified as part of a flexible and highly adaptable set of technologies and institutional arrangements, the benefits of the AMIT kit listed by farmers outnumber and surpass the conventional R&D impact indicators often limited to yield or income increase, and cost reduction. These benefits mentioned by farmers included:

- Lower costs – initial investment only Rs 14,800 ha^{-1}
- More plants/trees ha^{-1} and for a given water source, given that almost all plants would survive the dry spell because of drip irrigation
- About 3 to 4 hours of pumping day^{-1} is enough to irrigate about 0.5 ha of horticultural crop (compared to 7 hours for flood irrigation using the furrow method)
- About 50% less water required
- Much lower labor requirement for irrigation and for weeding (almost 75% of the labor cost is saved because weed growth is limited and no furrow maintenance is required)
- Access and control by women in the family – no major supervision is required in the AMIT kits other than checking that the microtubes are discharging well and within the required root zone for the crop
- Access to assemblers and fitters and other organizational support (from input dealers and commodity market agents) within the AMIT network
- Access to pomegranate production technologies and timely advice on several pomegranate growth stage operations within the AMIT network
- Relatively lower input costs – at least in the initial years, the costs of farmyard manure (FYM) and other inputs was lower (but the past 3 years have seen an increase in pesticide and chemical requirements)
- Much better quality of pomegranates produced from AMIT kit-irrigated plots thereby fetching higher prices.

The relatively lower life span of the AMIT kit was not a major constraint because the standard (ISI marked) drip systems were expensive, taking them way beyond what small-scale and marginal farmers could afford.[7] What clearly was beyond the access of the small-scale farmers were the contacts (and bribes) and credit-worthiness demands of the subsidized drip units. In other words, the institutional context of the subsidized State-supported drip units: there was little access to input and produce markets for these small-scale farmers (basically the poor who had to migrate every year to make a living during the lean season). They were beyond the regular contacts, sales, and negotiations that some of the (best) private input dealers would make in remote rural areas in the region. The BDS approach had to explore the inter-dependencies among the rural actors – the rural landless laborers, the small-scale and marginal farmer, the large-scale farmer, the input dealer/drip-kit assembler or dealer, the nursery, the fruit market actors (the commission agent), the local NGO or self-help group (SHG), the Government Department of Horticulture/Agriculture, the State policy regime (subsidized drip systems), and the export market – to ensure that the poor/marginal farmers also had access to the AMIT kit and pomegranate cultivation technologies.

Clearly, IDE(I) is an important actor in the irrigation and institutional innovations in this pomegranate innovation system. But IDE(I) itself argues that its role in pomegranate innovations and the effectiveness of its BDS approach are nested in larger systems like the watershed programs, appropriate institutional arrangements in the market and among farmers, new private sector enterprises, and State- or NGO-supported local initiatives. Success for IDE(I) is determined by the extent to which their effort at promotion/sales of affordable drip-irrigation equipment has led to or converges with efforts of other actors in the innovation system. Important lessons for the system are in the innovation potential to be had from collaborating with other actors in the system, and in identifying and enabling appropriate institutional arrangements and technologies for each actor/user context.

New actors, new roles

One of the significant developments following the State-sponsored and subsidized innovations in pomegranate cultivation and irrigation technologies, and the watershed development and agri/horti market programs, was the emergence of several new actors and new partnerships among old actors. Starting from the late 1980s, and throughout the 1990s, several horticultural scientists, agronomists, water technologists, and soil scientists were sought by NGOs and watershed development programs with agroforestry or silviculture and horticulture components. Seven major NGOs working in the Solapur region have agricultural/horticultural science professionals on their advisory boards, conducting their training programmes, exploring new crop/resource problems, and working out new partnerships with other organizations/farmers in the region.

Technical expertise also reaches the dry and resource-poor parts of Solapur through private enterprises – the ones that have established markets in neighboring districts. These are mainly firms that deal with seeds/seedlings, plant production and protection inputs/equipment, and marketing or processing services. These firms are keen to make a quick profit, but are imbued with a sense of experiment and confidence in the agricultural technology market. There are lessons on innovation opportunities, in the successful case of the onion produce used to cure the dieback disease in pomegranate orchards (see Box 1).

Besides innovations in plant protection and organic farming practices, pomegranate plantations rely on a special set of actors – the nursery growers. The farmers' trust in the quality and variety of seedlings they take depends on the quality of the seed firm. The nursery is a point where the farmer places much trust. The nursery grower thereby is held in great esteem. Besides information about the way cuttings are to be planted, the nursery grower often advises farmers about choice of variety, can come to inspect (and approve) the pits and soil conditions in the pits, and can suggest reliable sources of fertilizer and pesticide.

The farmers are wary of private input dealers, but willingly respect the private research and technology-support laboratories. Again, it is the nursery grower who is a lead to most of these laboratories. Note that most of the nursery growers and the private technology support laboratories have a background in the agricultural sciences or chemistry. They may even belong to the same family or village – and offer linked services. For instance, the services offered by a typical laboratory include, fertilizer management technology – including a computer-simulated reading of the nutrition

Box 1. Plant pathology from a private agro-technology firm

The pomegranate plantations are always threatened by the dreaded dieback disease caused by an endophytic fungus the *Pleuroplaconema* spp. The fungal pathogen attacks the tree and causes a fungal wilt. The wilt then gradually kills the plant. In 1999 it was reported that over 60,000 ha of pomegranate in Nasik, Solapur, Pandharpur, Bijapur (in Karnataka), and Pune was dying from dieback. An accepted cure for the disease is treatment with organic fungicides like neem. The case, reported widely in May 2000, was that of an opportunity exploited by a private firm to save pomegranates from dieback and also use a massive glut in onion production to good effect. When the Maharashtra State Co-operative Federation (MSCF) announced in March–April 2000 that it had a glut of onions procured from farmers, an agro-technology firm in Nagpur started thinking about converting this onion harvest to organic manure, adding neem cake/extracts to make it useful in pomegranate plantations. The pathologist in the firm helped to convert the 350 thousand tons of onions they had procured from the MSCF into organic manure. Managing to sell this manure, procured at Rs 100 t^{-1} (US$2 t^{-1}), for Rs 3500–4000 t^{-1} (US100t^{-1}$) was a real success. Farmers in the dieback-affected areas provided a ready market: since they were willing to buy the neem-enriched organic manure that could effectively cure the disease.

requirement for each crop during different months/seasons, assessment of real-time plant hunger by evaluating plant tissue, soil and water analysis, agronomically sound and environmentally responsible nutrient management etc. The private research laboratories are often the targets for questions about options for processing pomegranate.

An important area in which the nursery grower advises and the local NGO provides training is in the pruning of pomegranate plants. The plants are cut back when they are about 2 feet high, allowing 4–5 shoots to develop from below this point. This is a crucial operation, especially during the first 3 years of the orchard. Since the third year is when a reasonable harvest is expected to begin, this year marks the success of the pruning effort. Pruning is an art – an ability to judge the time and extent of pruning each year. In all the training programs on pomegranate cultivation, it is the women who take an active interest in the timing of pruning, a crucial decision, since immature/early flowering can spoil the entire harvest. It is important to get the plants to fruit at the right time, and to pick the harvest before the rains. The latter is an observation made by the farmers and the commission agents in these villages – the argument being that once it rains around harvest time, fruits lose their taste and sometimes crack open when packed. In imparting and gaining these skills, the actors – the private input dealers, farmers, the commission agents, the nursery growers, and the local zonal agricultural research stations (ZARS) – are all keen to maintain the quality of the harvest and use resources (water especially) in a sustainable manner.

In 2001/2, the institutional and technological arrangements in irrigation innovations were actively evolving, with the AMIT kit assembler becoming the dealer as well. The additional skill demanded of the dealer – in some cases an earlier assembler – was the knowledge of the farmer's terrain. A cheap micro-irrigation system promoted in the region since 2002 October, is the Eazy Drip – simple plastic tubes (colored black to keep out algal growth) that can be used by puncturing or inserting a simple microtube into the plastic tube laterals. The Eazy Drip dealer was also an extension agent of sorts – he or his assistant would help the farmer install the drip and would act as a change agent, learning and changing the land or crop or the farmer's skills. The dealer or his assistant is always paid by the farmer for the services. Services for natural resources management (NRM) technology (assumed to be not obvious and therefore always delivered by the public-sector R&D) is now a private input for which small-scale farmers are willing to pay in this resource-poor region.

Another innovation in this pomegranate cluster is the introduction of new actors and roles into the drip irrigation–crop production system. An understanding of the recharge pattern (hydrology) in each ecosystem, land slopes/terracing or bunding requirements, choice of vegetable or horticultural crop, promotion campaigns to encourage small plots, involvement and encouragement of women decision-makers in the households, institutional innovations like persuading a local tailor, a chemist, and a doctor to be dealers/retailers for Eazy Drip, and other role adaptations from one context to the other, were all part of this innovation system. Besides the Eazy Drip being cheap – there are about 100-m of drip laterals kg^{-1}, and the cost of 1 kg Eazy Drip is only Rs 100–110 – the profit margins in the drip irrigation innovation network are around 5–7% for manufacturers, input dealers, distributors, and dealers (with perhaps a maximum 10%), and the farmers make about 15–30% profit (because pomegranate demands some crucial 'recurring expenses') depending on water availability, pruning, and pesticide/fertilizer costs. In addition to the interactive learning process that involves each actor, this innovation system reveals the ability of each actor to take on new roles and responsibilities that are beyond their conventional roles. It is the inherent acceptance of the learning processes within the system that enables each actor to understand and negotiate with the other actors in addition to taking on new roles.

This internalization of the learning process is not a feature of conventional R&D. A significant lesson comes from an attempt by an IDE(I) field officer to get the Eazy Drip technology ratified by the SAU in the region (see Box 2).

Contrary to the three well defined actors (researchers, extensionists, and passive farmers) with specific mandates to generate, transfer, and adopt technologies, the actors in this innovation system are many and do not conform to particular mandates. This is because they are constantly learning from the changing contexts and mandates of other actors in the system. Besides new private-sector actors, there are innovation expectations and roles taken up by such other actors as women in the household, commission agents, nursery growers, and input suppliers as well as the conventional researchers and extensionists. They also reveal a remarkable flexibility to change roles in different contexts or actor linkages. Do the public sector R&D organizations involved in pomegranate production and marketing have this flexibility in collaborations with other actors? Box 2 is a pointer to the relative isolation of the public research and extension organizations and their methods of research, extension, and/or validation of results, in the midst of this dynamic horticultural innovation system. The researchers are aware that technology assessment demands new methods and institutional frameworks, and most crucially, viable relationships and communication among actors at the field level.

Box 2. Evaluation of Eazy Drip

The confidence of the IDE(I) network in their Eazy Drip innovations was evidently drawn from the results in the field. Sale of Eazy Drip kits were booming towards the end of 2002. The Eazy Drip clearly gave farmers much-needed control over their cropping patterns, crop layouts, etc, besides being significantly cheaper than any other known precision irrigation technology.

Yet, the IDE(I) with all its belief in the evolution of the innovation system it had helped build, desired ratification from an established conventional knowledge actor, the SAU. The Area Manager of the Solapur region went to Mahatma Phule Krishi Vidya Peeth (MPKV), the SAU in Maharashtra designated to work in the region, and met the staff at the Department of Irrigation and Drainage. The specific request from the IDE(I) staff member was that the SAU experts test the Eazy Drip and prove its efficiency and cost-saving features so that the IDE(I) network would have the certification from the SAU. The professor considered the request and enquired whether farmers were buying Eazy Drip and whether they were adapting it to their own specific farm requirement. The Area Manager answered affirming both. "Then why do you need the SAU certification or validation? We can show you over 200 irrigation technologies that have been tested and recommended by us and other SAUs that no farmer has ever used. How do you think certification helps? Do you know if our economists will understand and include the small-scale farmers' innovations and control over resources in their evaluation of this Eazy Drip? How will evaluation methods incorporate the trust and the norms of mutual dependence you have built with your field partners?"

This was a crucial lesson for the IDE(I) staff that enhanced their own skills within their innovation system. The IDE(I) partners already trusted each other, and were willing to collaborate non-hierarchically to improve/adapt the technology, or find institutional changes that can make the technology accessible and adaptable for small-scale farmers. In an innovation system that recognized the mutual dependence and reciprocal dependence of each actor/component on the other, there was no need to check/certify the technology. In an innovation system where the actors communicate with each other without organizational boundaries there was no need for so-called 'experts' to formally approve the technology/product.

Emergent insights into innovation

The pomegranate innovation system reveals an active network of actors, each seeking and gaining opportunities within the innovation system, for employment, markets (inputs, produce, training, other services), production, resource conservation, and development.

The pomegranate story illustrates that innovation is a complex process and that each actor in the innovation network is constantly learning about other components and relationships in the system – from changing contexts and demands of other actors. The elements of this innovation system come together with some planned and some unpredictable outcomes that are more important than the linear sequential processes to which the rules/norms/procedures of conventional R&D, such as the SAUs/research stations, subscribe. What can this case tells us about the generic features of the pomegranate innovation that might have wider relevance to pro-poor innovation?

Wholeness. A key systems feature evident in several instances in this case study is that of wholeness – ie, the way developments related to several important aspects of rural livelihoods. There is also a belief, operationalized in this innovation system, of *gestalt* – seeing that there is more to be gained than the sum of individual benefits. The BDS approach of IDE(I), the design and cost profile of the entry product (the bucket kit)[8] and the selection of a doctor and a tailor as actors in the pomegranate–irrigation–production–technology system are all instances where the wholeness and *gestalt* phenomenon are evident. The roles of each actor in the innovation system are seen as part of the larger social role, context, and relationships of each actor.

Mutual and reciprocal dependence. The mutual and reciprocal dependence of actors and components are evident: for example, in the farmer–input dealer interactions. It is evident that farmers are aware of increasing input costs and are looking for alternatives. The input dealers aware of this change are forewarned and have themselves come up with suggestions for future innovations in processing and alternative farming practices – for instance, organic produce, new markets, and other crops or intercrops in pomegranate orchards. Both from the private-sector laboratories and through the export agencies that visit these villages, the farmers have heard of organic produce and the possibility of its fetching higher prices in the international and domestic market. There is increasing process awareness; the farmers are conscious of their reciprocal dependence vis a vis other actors, and of cost and quality, markets, and cultivation practices. The small-scale farmer in this cluster of actors does not 'depend' on the State or the extension officer from the Department of Horticulture. The State Department of Agriculture and some other actors like the large sugar factories are now wooing the small-scale and marginal farmers with access to drip irrigation: in the case of the former to encourage farmers to take more subsidized inputs; in the case of the latter to help ensure steady supplies for their factories. The reciprocal dependence operating in this case reveals that each actor (including the State) is a beneficiary and is dependent on the relationship among other actors for gaining access to benefits (foreign exchange, international trade, poverty reduction, etc) accrued through innovation.

Actors engage with complexity. In the pomegranate innovation system, the actors seem to have developed a capacity to understand and address complexities in the bio-physical realities of the field, complexities in the actors generating and utilizing knowledge, and the location of each of them in complex science–society interactions. This innovation system is facing several challenges even now – and will always continue to do so so (see for example the emergent pest problems and solutions discussed in Box 1). The entire case study reveals the dynamic evolution of the pomegranate innovation system. There are several instances here of how both institutional and technological innovations paved the way forward. In contrast to the reluctance of conventional agricultural research to face complex realities (see Biggs and Clay 1983; Hall and Clark 1995), in this case all the actors – including researchers (private, public and voluntary sector) – were willingly working in partnerships and adapting or evolving to address the complexities in their own and other organizations/contexts.

Flexibility and learning. All the actors involved in this successful and evolving pomegranate production and marketing system have an incentive to be there, and to promote innovation processes and relationships. The innovation process involves all the actors in a continuous learning process. The actors conduct their own learning processes – be it about technologies or suitable institutional arrangements. They are constantly learning about the field situation and are involved in the experiments, adaptations, and innovations that each actor (farmers/input dealers/contractors/nursery growers) is making. It is evident that search and learning, or research, is a process that takes place constantly among all the actors.

Focusing on specific social groups. The gender dimension emerges as a totally unexpected but challenging outcome of this innovation system. Water rights, especially for women, are negotiated through their access to the means (labor and resources) to operate (and maintain) the water resource and technology. In conventional crop production and irrigation-technology generation, these are obviously beyond the concerns of the science and technology actors. If at all, issues of women's access to water or water rights are located in the Irrigation Engineering or Administration departments of the State. And these organizations are equally indifferent to gender concerns in water rights, control, allocation, and access (Zwarteveen 1997). At best the irrigation channel will include a special *ghat* (stairway or passage descending into the river or canal) for women! The biased gender relationships that lead to unequal access to and availability of water for women are often reduced to the number of irrigations per crop or other such technological variables in women-headed households. Even more blind is the view that women's water needs are confined to the household drinking water, cooking, and washing needs. This case study reveals how the BDS approach in its non-hierarchical fashion places an entry product for these resource-disadvantaged women, not for better household provisioning, but for direct market access and control over water (natural resources) and its market production. Changes in household decision-making due to less migration, or to only men undertaking seasonal migration, has brought gender empowerment dimensions to this arid horticulture innovation system. This is perhaps the most significant unexpected outcome from the developments associated with the pomegranate innovation process.

Lessons for public sector innovation actors

There is a visible distance between the formal public R&D organizations and this dynamic innovation system. Notable is the relative isolation of public sector R&D (despite its relevance to pomegranate innovations). Based on the evidence of this case study, this isolation of public-sector R&D is a result of its inability to engage with other actors in the innovation system and its reluctance to learn from the evolving technological contexts. We believe that this is one of the reasons for the impact of public R&D on agricultural development, poverty reduction, and social/environmental improvements. How and where can public-sector R&D intervene meaningfully in this innovation system, or in other similar contexts that demand pro-poor innovations?

Understanding systems and processes in which public R&D is located. This case reveals a cluster of innovators (though there is considerable diversity in their interests and motivations) who have recognized their mutual dependence. They have evolved together. No actor hands technologies or institutional arrangements down the line to the farmers. Even NGOs (like MPSSM) and private organizations like the IDE(I) or nursery growers, experiment openly and learn interactively with the farmers on appropriate institutional arrangements (say, investing in wells and water-sharing equations, contractor deals, roles of nursery growers/input dealers) and technologies (pruning times, drip layouts, choice of intercrops in orchards, etc). There is no actor designated to 'transfer' a 'ready made' technology. Learning is equally important to all actors, and is the key to their ability to adapt and seek new institutional arrangements and technologies. What is at hand are several questions, a range of technological and institutional options, and several actors. The actors are aware of their role(s) as distinct components within the system and their linkages with other actors in the system. For public-sector R&D (research, extension, and development administration) an open introspection of their systems relationships, using techniques like context mapping or focused group discussions is an essential first step that could be initiated immediately.

Institutional change for learning. The actors in this case study are all willing to learn together in a non-hierarchical fashion. They have different types or processes of learning. Some go about directly accessing knowledge where they are ready to pay for the expenses incurred in organizing a training session. Even in these training sessions, every participant – the expert, the NGO, and the farmer – learns through their interactions with others, much like the interactive learning that the network provides. A nursery grower or input dealer who helps establish an orchard with a micro-irrigation system is as much a beneficiary and learner as the farmer. Public-sector research and extension organizations must shun the rigid hierarchies and seek equal partnerships in the field. To begin with, this would entail consistent support from research managers and extension supervisors as well as the relevant stakeholders/other organizations. The agenda is to instill in scientists and extensionists the fact that generating or transferring a technology is only one part of the job – the real aim is to promote sustainable gains in farm income and rural development. These organizations for research and extension need new institutional arrangements, such as new criteria for formulation of research projects, conduct of research, development of meaningful partnerships, etc.

For public-sector agricultural research and extension, the central message from this study is that of learning. The management or leadership in these organizations must develop and encourage in scientists and extensionists the capacity for internal learning within the organization and collective learning in collaboration with other actors. The management also has the responsibility to inculcate acceptable and absolutely necessary transformations in the role and functions of each of these actors in different contexts. Research managers and policy makers must seek and build in new norms/ rules for partnerships, internal evaluation, and operational flexibility when improvements in rural livelihoods demand changes. This innovation network points to certain principles that can guide active learning in these organizations:

a. Acknowledgement and incentives for meaningful improvements in both technological and institutional arrangements
b. Pro-active involvement with other actors, and encouragement of partnerships appropriate to each location and resource situation
c. Capacity for critical reflection and learning, with ample corrective measures and scope/flexibility to exploit and adapt to new opportunities and constraints.

Capacity building to aid understanding of complex technological contexts. In the pomegranate innovation system in the fragile agro-ecological context with a poor natural resource base, maximization of yield for the conventional beneficiary of agricultural research – the farmer – does not seem to be the operating norm (see Jodha 1991). Several other concerns like cost reduction and sharing, quality judgements and assurances, trust in the contractual arrangements, sustainability of the minimal water resources, and improvements in soil quality – defined as health of the soil and not merely as productivity of the soil – are all addressed by technological and institutional innovations. Each technological or institutional innovation was made in response to some specific requirement. These were made by NGOs and farm households, private nursery owners and inputs dealers, farmers and drip-irrigation dealers, etc, adapting the technology to each context where learning and adoption takes place (see Douthwaite 2002). The actors attempt to make meaningful improvements rather than present a list of recommendations to the other actors in the system (Bawden et al. 1984). For instance, the routinely published 'package of practices' for pomegranate cultivation becomes redundant, because its recommendations are bereft of local understanding and appropriate institutional arrangements. They do not bring actors and their adaptable roles and learning processes. 'Agriculture, when seen as an interaction between social and natural systems' demands that routine recommendations be replaced by innovations and strategies for meaningful improvements in each context' (Bawden et al. 1984).

The need for systems understanding, meaningful improvements, and appropriate partnerships can appear intimidating to routine professional research and extension actors. Policy-makers or management must deliberately build the capacity for such institutional changes within agricultural research, extension, and development administration. Capacity-development workshops in different technological and institutional contexts are necessary for routine professionals to make the transition from linear R&D perceptions to understanding and working in dynamic non-linear innovation systems.

Better informed innovation policy. In terms of direct participation in and scaling up, these lessons learned reveal the importance of State commitment to resource-poor regions/groups. This public investment is the knowledge and administrative foundation upon which pomegranate innovations have evolved. This is a crucial input to innovation and development, whether it is located in the public or private sector. It is unlikely that the private firms offering nursery inputs, and direct technological inputs and services would have evolved in the absence of a public sector policy commitment and knowledge base. Yet a centralized perception of this policy and knowledge obscures the public sector actors from active non-hierarchical participation and learning. Moreover, any co-operation of SAU faculty with the private sector or an NGO and its partners is looked down upon within the public sector, largely because the SAU carries with it a 'public goods' motto. The private sector promotes a market creation approach that delineates the importance of incentives/profits for each actor. Public-sector science and extension, being institutionalized in the welfare goods theme, fights shy of these incentives whenever confronted with them in other systems. This case study has shown that private profits and/or other social/academic incentives, for the agri-inputs industry, farmers, processors, and all knowledge actors are possible and necessary for innovations to take place. Innovations involving private rooted capital do take place in the poorest environments and small and marginal farmers do participate and determine the nature of these innovations. It is not advisable to sacrifice innovations in the altar of public welfare as understood by isolated academic actors and public policy makers. This case also demonstrates that innovations are not the exclusive property or prerogative of either private or public sector R&D organizations. Each of these has its own place and different roles in the innovation system. Paramount here is the capacity of these actors to perceive these roles and their ability to affect role transformations to innovate and cater to development goals in different contexts.

Endnotes

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1. This case study acknowledges major information inputs and help received from all actors interviewed in Solapur, Aurangabad, Jalna, and Delhi, and comments from colleagues. The author is solely responsible for any omission, value judgement or interpretation.
2. The crops, bananas (11.67%), grapes (27.28%), orange (11.54%) and sugarcane (16.69%), account for over 67% of the total area under subsidized/State-sponsored drip irrigation in Maharashtra (Narayanamoorthy 1997).
3. This was one of the research findings, which identified suitable crops for dryland agriculture, that came out of the local agricultural college – it later became the Mahatma Phule Krishi Vidya Peeth (MPKV). Pomegranate grows well on poor soil conditions in the cold frosty lands of southern Russia, in the Americas and in Mediterranean countries.
4. Farmers have been asking for research results that tell them whether drip irrigation ensures plants yield for longer periods. Little is known about the effects of reduced drought stress on the yielding period/life of the plant.
5. Much of the information in this section comes from interviews with IDE(I) personnel in New Delhi and in Maharashtra, and IDE(I) (2003), and Naik (2002).
6. The ISI mark is issued to all products approved by the Bureau of Indian Standards (BIS), as per the BIS Act of 1986.
7. D Raghunandan of the Centre for Technology and Development (CTD), New Delhi, recommends that it is worthwhile enquiring how standards are set and what the criteria for standards are. Is longevity of equipment a criterion for setting standards and granting an ISI mark? The AMIT sales record in Maharashtra demonstrates that farmers prefer cheaper plastic that lasts fewer years but serves the purpose just as effectively as a government-subsidised drip system.
8. The bucket kit is a 15–30 liter bucket with a nozzle attachment at the bottom, which can be hung from a tree or pillar with the main water pipe running from the nozzle to the small plot (generally vegetables), where the pipe can feed a few drip laterals and the micro-tubes attached to them. This is promoted as the most affordable entry to irrigation equipment and horticultural markets for small-scale and marginal farmers, especially women in poor households.

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4. New institutional arrangements in agricultural research and development in Africa: concepts and case studies

AJ Hall[1] and B Yoganand[2]

Abstract

There is a growing realization that performance of agricultural research in Africa is restricted by organizational and institutional factors. The agenda for institutional change includes the need to devise research and development (R&D) arrangements that are client-responsive; that are consensual in priority setting, planning and implementation; that are well integrated into market and entrepreneurial sector activity; that include sustained financial and political support; and above all, are driven by the goal of poverty-focused, sustainable development. Recent policy perspectives in innovation systems draw attention to the need to stimulate broad-based participation in R&D systems and the desirability of locally lead, organic processes of institutional change and continuous evolution. Three case studies are provided that illustrate the contextual nature of institutional learning and change. Conclusions focus on the need to concentrate on capacity development in an innovation systems sense.

Introduction

Current debates on the future landscape of agricultural research and development (R&D) in Africa place great emphasis on: the role of the private sector, partnerships, and poverty impacts. Underneath these headline-grabbing themes are a series of complex institutional and organizational issues that need to be resolved by both public national agricultural research and extension organizations (NAREs) and the international agricultural research centers (IARCs) of the Consultative Group on International Agricultural Research (CGIAR). The context of these issues relates to the now widespread recognition that the performance of conventional NAREs arrangements in much of Africa needs urgent attention (Rukuni et al. 1998) and that it is organizational and institutional problems that need to be addressed rather than technical capacity per se (Byerlee 1998; Byerlee and Alex 1998).

At the heart of this agenda for institutional change lies the need to devise R&D arrangements that are: client-responsive; consensual in priority setting, planning and implementation; well integrated into market and entrepreneurial sector activity; that include sustained financial and political support; and above all, are driven by the goal of poverty-focused, sustainable development.

Unfortunately, while these concepts and lofty ideals have been widely discussed, sparse conceptual or empirical insights are available (especially for Africa-specific material) to inform the policy-making process or predict what recent developments may mean for research arrangements and procedures. This paper is an attempt to draw together recent thinking and experience and, in particular, to provide a platform from

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which to explore the implications for research arrangements in the semi-arid tropics of Africa and the strategies of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners in the region.

Changing institutional arrangements for agricultural R&D means that hard decisions have to be made about both focus and strategy and where to allocate increasingly scare resources. Like its NAREs and IARC partners, ICRISAT needs to consider the relative desirability of pursuing broader partnership and development agendas as a route to improving impact. Inevitably this includes questions about whether resources should be diverted from traditional public-sector partners to a wider set of development actors, including the private sector.

One of the problems with much of the debate on these issues is that while the conventional (and simplistic) linear model of public-sector, science-driven agricultural innovation is widely rejected (and has been for some time), consensus on a framework to replace it has yet to emerge from the mainstream debate. This is not to say that the broad contours of institutional change are not widely discussed. They certainly are (see, for example, Byerlee and Alex 1998; Rukuni et al. 1998). Rather the problem is that there is as yet no broad acceptance of an alternative model of innovation that is sufficiently holistic in its treatment of institutional and organizational issues to provide a useful framework for the planning and evaluation of evolving R&D arrangements.

This paper argues that a starting point for a more holistic analysis needs to be a shift in focus to **innovation** rather than the narrower concept of research and technology development. This provides a much more inclusive organizing principle and one that requires the investigation of the wider institutional and behavioral factors (especially learning and evolutionary processes) that underpins economic change. It is in this context that notions such as the **innovations systems framework** can be so potentially valuable in the debate of institutional change and development.

To provide some verisimilitude to these conceptual positions, three recent African case studies are presented that illustrate institutional development in agricultural R&D. These case studies are interesting for a number of reasons. First and foremost, they document tangible examples of interventions in which private-sector involvement, partnership and impact focus have been attempted, and with a promising degree of success. Secondly, they illustrate the way the involvement of the private sector may be very different in African countries from other regional contexts. In Africa much of the role of the private sector is likely to be in input and output markets, rather than as a major research player, although naturally there will be exceptions. Thirdly, the cases illustrate the way poverty focus, and more generally impact, is now being given much more attention and the way new patterns of accountability are strengthening this focus in programs. It nevertheless remains a challenge to devise institutional arrangements that give a voice to the poor in the face of entrenched patterns of social dynamics. Fourthly, the case studies point to the fact that to understand, and even to describe these interventions, the interactions and processes in a very wide institutional and organizational arena have to be explored. This needs to be appreciated by planning and evaluation processes.

In the discussion of these case studies the key institutional changes are summarized as a way of analyzing what the implications of the new arrangements might be. The innovation systems framework is then used to draw out some of the remaining challenges in the evolution of new arrangements for poverty-focused rural innovation.

The following section provides a very brief introduction to the historical development of NAREs in Africa. Then the conceptual debate concerning models of agricultural innovation is explored before the case studies are presented. This is followed by a general discussion.

Historical development of the NAREs in Africa[4]

The evolution of the NAREs in Africa has taken place in three distinct phases. The initial phase took place during the pre-independence era, focusing on R&D support (both public and private) for major commercial commodities – cotton, sugar, tea, coffee, and so forth. In the second phase, following independence, these research organizations were often consolidated under one publicly funded umbrella organization. This period also saw attention start to focus on wider agricultural technology needs, particularly the problem of increasing food production.

Such developments were usually accompanied by the establishment of a public agricultural extension organization to facilitate the dissemination of new production technology to farmers to help 'modernize' agriculture. The general pattern that emerged was one of widespread public investment in agricultural research and extension systems (often with external donor assistance for capacity development). While there was regional variation in the precise timing of this growth phase, the 1970s witnessed an annual growth rate of 6% in public investments in agricultural research (Alston et al. 1998). This rapid growth phase was often accompanied in many cases by the proliferation of research institutes and a rapid expansion in staff numbers.

The third phase, that began during the 1980s, saw investments in research start to decline in Africa. With large staff numbers and declining research funding, many NAREs found themselves spending ever-larger proportions of research budgets on salaries, with little left for research. This slow-down in research continued during the 1990s.

The declining level of public funding available for agricultural research has focused attention on the need to reform NAREs – and indeed the CGIAR centers also felt this pressure. However, the need for change was not brought about by shortage of funds per se, but by a complex of political, economic and institutional factors that started to take shape during the 1980s. Triggering this has been an almost universal tendency to re-examine the appropriate role of the State, taking place at a time when, despite evidence of high rates of return to public investment in agricultural research, it was clear that NAREs were struggling to fulfill an increasingly complex role (Byerlee 1998). Three related issues have been important.

New policy agendas. Many national agricultural research organizations were established following an institutional model designed to apply science to problems of agricultural productivity and the need to produce more food. Over time, not only did this initial goal reveal itself as much more complex than initially anticipated, but also policy agendas began to move from food production alone, to include natural resource management and environmental protection.[5] During the 1990s the donor community began to shift attention towards a much more explicit poverty focus. While the CGIAR centers have felt the brunt of this change, NAREs have also had to respond to the poverty agenda in cases where they have been dependent on donor funding (Byerlee 1998). Underpinning this shift has been a wider set of agendas concerning the role of the poor in the development process, and more general patterns of governance of agricultural research. Advocacy for participatory agricultural research has been one manifestation of this.[6]

New players. While public-sector agricultural research has become increasingly embattled, agricultural research and related capacity in technology promotion and application have emerged in other quarters. Most notable has been the growth in the private sector. Internationally, this has emerged from a combination of developments associated with: biotechnology, strengthening intellectual property regimes, and increasingly liberal trade and economic policy regimes. In many African countries the most obvious expansion has been in the seed industry, but it is also evident in animal health, crop protection, horticulture, and commodity trading. Research and allied expertise, however, are also emerging among non-governmental organizations (NGOs) in rural development sectors, and in farmers' and producers' associations (Marter and Gordon 1996). Similarly it is increasingly being recognized that universities and other public research organizations have expertise that is relevant to agricultural research and that private research foundations also have a potentially important role. These developments present the opportunity to network public-sector efforts into a wider set of players that have complementary strengths in both research and technology promotion. It also highlights the need to redefine the most appropriate role for the public sector.

Institutional inertia. The response of NAREs to the new policy agendas and the opportunities presented by the emergence of new research capacity has taken place against a background of apparent conservatism – although there are exceptions. Even within the public sector it has been difficult to restructure institutional arrangements. So for example, while it is now widely recognized that conventional institutional distinctions between research and extension are unhelpful, moves towards the creation of more holistic and integrated national agricultural research and extension organizations are yet to emerge in many countries. World Bank support of training and visit (T&V)-based extension systems tended to reinforce this conservatism and a top-down technology development and transfer approach (Kidd 2001). Re-mapping relationships with private and other non-governmental agencies represents a significant alteration to accepted working practices and norms and has been very slow and recent in many countries. For example, Hall and Nahdy (1999) discuss this institutional conservatism in the context of the introduction of participatory methods in Uganda.

Commentators such as Rukuni et al. (1998) trace the problems of African NAREs back to the transition from colonial to national governance and management, and the associated (unmet) need for different patterns of patronage and partnership. Eicher (1989) suggested that some of the blame lies with the donors, who prematurely inflated the size of NAREs and took the pressure off managers to mobilize domestic political and financial support to sustain the system after foreign aid was withdrawn.

However, as discussed above, the lacuna was not just financial. Unfortunately, the NAREs were not able to adapt to meet evolving development imperatives and as a consequence their performance declined in terms of the technologies produced and adopted by farmers. To make the same point differently, institutional development in the NAREs did not keep pace with the institutional and political development that was driving national development plans. And of course, where institutional developments become disconnected from society, patterns of governance and accountability become increasingly tenuous.

It is widely acknowledged that the core of this problem is institutional in nature (Gijsbers 2001). Donors have pursued this theme encouraging a reform process that includes privatization of some research and extension activities, a stronger role for NGOs, competitive research funds, private funding and execution of research, and stronger collaboration between the public and private sectors. Byerlee and Alex (1998) define the following seven features (all institutional) of good practice in NAREs:

1. Separation of research funding from research execution
2. Pluralistic structure (a system conceived as a combination of public and private actors)
3. Focus on public good and diversification of funding
4. Complementary nature of public and private sectors, with a sharing of resources and skills
5. Autonomy for participating public research organizations
6. Stakeholder participation in defining the research agenda
7. New models of technology transfer that include broader stakeholder participation.

However, as Tripp (1993) has cautioned following a detailed analysis of maize research in West Africa, the enthusiasm for replacing public agencies with those from the private and NGO sectors needs to be tempered by the fact that these organizations, while often complementary to the public sector, can rarely replace it. The ability of the private sector to 'fill the gap' is also questioned by Pray and Umali-Deininger (1998). Tripp (1993) insists that a much more important policy task is to define a new and more effective role for public- sector research and extension in this evolving environment. The corollary being that the new role of the public sector and its relationship with other development actors will be: country-specific, dynamic (Eicher 1989; Thirtle and Echeverría 1994), and not amenable to policy processes that rely on generalized blueprints.

This location-specificity will be particularly apparent in relation to the level of private-sector development. This is likely to be (at present) lower in Africa than in Asia or Latin America, and with large country-to-country variability. Rukuni et al. (1998) describe the way indigenously driven institutional developments have been so important in reforming agricultural research in the southern Africa region. Here the dual agrarian societies of commercial and smallholder systems provides a very specific (although evolving) institutional and political context in which the role of the public sector needs to be defined.

The process of evolving new institutional arrangements for agricultural R&D in Africa is clearly an on-going task. Based on the above, critical institutional issues that still need to be fully resolved would appear to include the following:

- Involving a wider set of actors from the research and non-research sectors in the research process
- Defining a new role for the public sector, and evolving new types of relationship with partners relevant to the agricultural sector, including partners as sources of funding
- Establishing priority setting and technology development and testing approaches that broaden the participation of stakeholders, particularly poor technology users but also the enterprise sector

- Establishing mechanisms to improve the accountability of publicly funded research and to explore and demonstrate impact, specifically on the poor but also on more general economic development
- Responding to and contributing towards a more broad-based vision of rural development that goes beyond increasing agricultural productivity and includes developing wider livelihood opportunities including those in the rural non-farm sector and the development of wider market opportunities
- Defining the most appropriate organizational focus for capacity building, given the broader patterns of participation being sought and the expanded objectives that are being addressed.

Models of agricultural innovation

The challenge that faces the policy process is that the imperatives for change and the types of institutional development required, suggest a fundamentally different R&D system to that embodied in the conventional institutional arrangements of the NAREs. In the later, the main elements of the research system were scientists working in public-sector organizations. Roles and relationships were fixed, reflecting the acceptance of an institutional model that envisages a straightforward progression from fundamental research to applied and adaptive research, to technology transfer and diffusion. Replacing this is a vision of a dynamic, evolving system that includes a variety of research and non-research organizations from the public and private sectors, and one that recognizes its existence in a dynamic political economy.

It is this combination of institutional issues and the dynamic element of this new vision, along with the associated process of learning and evolution that conventional theories of agricultural innovation find most problematic. For example, in the 'induced innovation' model (Hayami and Ruttan 1981) factor prices and user demand are predicted to **induce** scientists to develop appropriate technology – a **demand-pull** theory. This has not proved to be the case. The chief reason being that such a model ignored the political and institutional context in which resource-allocation decisions are made in R&D. The widely cited 'diffusion of innovations' model of Rogers (1962) is blind to similar institutional issues that not only determine the types of technology developed, but also determine decision over how it is promoted and to whom – a **technology-push** theory.

The essentially neo-classical economics underpinnings of these models tend to exclude institutional issues from the analysis. One branch of economics that recognizes the importance of institutions, albeit in the formal rules sense, is the new institutional economics (NIE) school. Writings from the transaction cost tradition of NIE tend to suggest that this type of analysis can lead to the necessary institutional developments that will go hand-in-hand with technical developments generated by R&D systems (Kydd 2002). Presumably this refers to the incentive structures necessary to allow the induced innovation model to operate effectively, although it is less clear how this will deal with power structures. However, since NIE sees organizations as a governance structure to reduce transaction costs and is more concerned with allocating existing resources than with creating new ones, learning plays a minor role (Gijsbers 2001). (As will be discussed later, learning and systems evolution are central to contemporary theories of innovation).

What then is a more-inclusive framework in which to think about agricultural innovation? Biggs' (1990) proposition of multiple sources of innovation model is one that is widely cited in the literature. He observes that agricultural innovations (both technical and institutional) come from multiple sources: research staff, development agencies, farmers, NGOs, private companies, and entrepreneurs and artisans. Biggs' key contention is that each set of actors has its own set of agendas and that these may often be divergent and contested. This implies a model of agricultural innovation where interactions between actors are multiple, iterative and evolving, and where the groupings of actors that exist at a given point in time reflect the relative strengths of current political and institutional interest groups. The practical implications of this are all too well known to scientists and mangers at the sharp end of agricultural research and rural development.

Such systems ideas can be seen elsewhere. For example, Lynam and Blackie (1994) talk of the need for a chain of technologies, institutions and policies that function as an effective system rather than as disarticulated parts. The concept of an agricultural knowledge and information system (Roling 1990) also adopted this systems perspective. Similarly, Echeverría (1998) pursues this common theme, discussing a system characterized by evolving institutional arrangements where the financing and execution of agricultural research takes place through a matrix of public- and private-sector involvement.

More recently the notion of an **innovation system** has started to be discussed as a way of thinking about institutional arrangements in agricultural R&D (Hall et al. 2001; Ekboir and Parellada 2001; Clark 2002).[7] There are a number of interesting features of this framework:

1. It focuses on innovation (rather than research) as its organizing principle. The concept of innovation is used in its broad sense of the activities and processes associated with the generation, production distribution, adaptation, and use of new technical and institutional, organizational, or managerial knowledge
2. By conceptualizing research as part of the wider process of innovation it helps identify the scope of the actors (including the public, private, research, enterprise, and technology-users sectors) involved and the wider set of relationships in which research is therefore embedded
3. Because it recognizes the importance of both technology producers and technology users, and recognizes that their roles are both context-specific and dynamic, it breaks out of the polarized debates of **technology-push** versus **demand-pull** theories. Instead it recognizes that both processes are potentially important at different stages in the innovation process
4. It recognizes that the institutional context of the organizations involved, and particularly the wider environment that governs the nature of relationships, promotes dominant interests and shapes outcome of the system as a whole. This aspect is enormously important for introducing a poverty focus. The framework provides a lens to examine and reveal which agendas are being promoted, highlighting the arena in which the voice of the poor can (and usually needs to) be promoted
5. It recognizes this as a social system. In other words, it does not just focus on the degree of connectivity between the different elements, but on the learning and adaptive process that make this a dynamic evolutionary system

6. It is only a framework for analysis and planning. It can draw on a large body of existing tools from economics, anthropology, evaluation, management, and organizational sciences, and is not bound to any one disciplinary convention.

From a planning and intervention perspective the innovation system framework places particular emphasis on the importance of learning processes as a way of evolving new arrangements that are specific to local contexts. This draws from a very large body of empirical studies on innovation performance that suggest learning and the ability to build up new competencies and configurations, often through interaction with others, are central features of successful arrangements.[7] Thus it contrasts with the conventional approach of seeking 'optimal' blueprints, and instead recognizes the importance of supporting adaptive systems and the value of the growth of diversity in approaches and practices.

One implication of this perspective is that capacity building becomes a much more important objective of research. The reason being that research interventions conceptualized as part of an innovation system need to explore and interact with their operational context and thus become concerned with establishing relationships and processes that will underpin future technology and innovation outcomes. The advocates of the approach suggest that its use for the evaluation and planning of agricultural technology development and promotion activities is a useful way to build locally adapted, collective operational capacities where such institutional concerns such as a poverty focus can be monitored and sustained (Biggs and Smith 1998; Biggs and Matsaert 1999; Hall 2003). It is precisely these perspectives that would seem to be required to support the development of the new institutional arrangements that agricultural R&D in Africa needs.

The following section illustrates how this might look in practice.

Case studies

The SADC/ICRISAT Sorghum and Millet Improvement Program (SMIP) in southern Africa: a case of the evolution of a technology program through learning and partnership development[9]

SMIP is a 20-year-old initiative supported by the United States Agency for International Development (USAID) and implemented by ICRISAT at its Matopos research station in Zimbabwe on behalf of the Southern Africa Development Community (SADC). Started in 1983, it has been implemented in four 5-year phases, the fourth running from 1998–2003. The first two phases concentrated on developing research infrastructure and human resources in the NAREs in the SADC region. This involved: establishment of breeding programs, developing research infrastructure, and the sponsorship of PhD and vocational training for scientists. This was done with a view to building capacity to produce a stream of technologies, mainly improved varieties. During these first two phases considerable technology development work took place, with 15 varieties being released.

The third phase (1993–98) while continuing capacity building and technology-development activities, started to shift focus towards technology transfer. This change related to developments in research methodology, particularly in farming systems and participatory approaches, and the way these developments started to impinge on the thinking and agenda of SMIP. An equally important influence was the wider political economy of international agricultural research at that time. In particular, there was a growing disillusionment among donors with agricultural research and an increased scrutiny of the impacts of research efforts.

During Phase III, SMIP began to engage in partnerships with actors other than NAREs. This was a response to the need for more direct contact with farm communities and the perceived value of working with NGOs as a way to achieve this. Analysis of constraints to adoption of technology had highlighted weaknesses in variety release and dissemination systems. It became increasingly apparent that to achieve wider improvements in seed systems (as well as in other spheres), SMIP and NAREs scientists would have to link much more strongly with a range of other partners including the private sector, NGOs, and community-based organizations (CBOs).

SMIP Phase IV was seen by USAID, the donor, as a way of capitalizing on early investments in capacity building, research, and technology development. This technology transfer theme meant that SMIP would need to continue to broaden its focus beyond strictly scientific activities and the generation of new technology, adopting a stronger developmental orientation. Pursuing these goals through a broader range of partnerships became an explicit objective.

The developmental focus and the partnership approach where re-enforced by the USAID-style project structure and its monitoring procedure. This entailed the identification of a number of intermediate results (IR). Not only were these prioritized by a group of regional stakeholders, but the quantitative indicators for the achievement of these IRs were defined, with annual targets set to monitor performance. The SMIP scientists leading the program component under each IR became directly accountable for achieving these targets which included: the area sown to new varieties, tons of sorghum and pearl millet entering commercial markets in key locations; quantity of seed of new varieties produced. This pattern of accountability was a significant new feature of SMIP IV. The SMIP scientists quickly realized, based on their past experience, that if they were to achieve these targets a pro-active approach to partnership would be essential.

Perhaps what is most interesting about SMIP IV is the challenges for normative practice in international agricultural research organizations such as ICRISAT as well as its partners, namely:

- Pursuing developmental (rather than scientific) agendas provides a common point of interest and helps draw in a diversity of partners. This increases the participation of technology users and their representatives in problem identification and definition. This improves ownership, relevance and uptake of technology and hence impact of research
- Better impact and research priority setting resulting from broad-based partnerships justifies diverting resources from scientific to developmental activities and diverting resources from traditional public-sector research partners to a wider set of developmental partners

An institutional analysis undertaken after 2 years of Phase IV (Hall 2003)[10] found that the SMIP scientists had entered into a broad range of partnership with NGOs, CBOs and the commercial sector, as well as with their conventional NAREs partners. This had been done by drawing together clusters of partners around specific themes or tasks. Hall referred to these as **task networks** and suggested that this represented a significant departure from conventional institutional arrangements for R&D. Table 1 summarizes and contrasts the key institutional differences between SMIP task networks and conventional arrangements. Some of the notable points include:

- SMIP scientists played multiple and different roles in task networks – sometimes as facilitator; sometimes as a source of information; sometimes as researchers; and sometimes as recipients of information
- The mixture of partners in a task network were specific to a task theme (due to resources, interests, and agendas), as well as to a particular location and institutional context, ie, who was available and how their interaction was governed)
- The adoption of objectives articulated in developmental terms rather than scientific points was critical in allowing the clustering of a broad-based set of partners around particular tasks. It broadened the scope for shared interest
- There was evidence of the task networks providing a mechanism for priority setting for further research, but this was limited and had not been exploited
- By adopting this task-network approach and thereby broadening patterns of participation, there was strong evidence from SMIP's monitoring system suggesting that significant impact was being achieved
- SMIP's task networks appeared to represent new innovation system capacity. While these are not designed to be permanent grouping, they help foster informal networks across research and development sectors that can be exploited in other configurations in the future.
- The policy significance of the way these institutional development can promote innovation and impact warrants synthesis so that it can be shared with scientist and research managers both at ICRISAT and within the southern Africa region.

The notable point of this case is the intuitive way SMIP scientists learned some crucial institutional lessons, particular in Phase III where they innovated with partnership approaches. Subsequently they were able to use these lessons about diversifying their partnership base to respond to a major institutional change in terms of accountability. This led to a series of institutional and organizational innovations creating different R&D arrangements to meet specific task contexts at different southern Africa locations. While there are many caveats to the nature of this intervention, it does highlight the potential value of adopting a developmental rather than scientific agenda and of adapting roles of public research organizations to suit the types of relationship into which they enter into with new partners.

The National Agricultural Advisory Service (NAADS) in Uganda: a case of indigenous institutional innovation in an evolving policy and political context[11]

The public agricultural research and extension system in Uganda, like many countries in Africa has faced numerous challenges and changes. Civil disturbances during the 1970s and 1980s saw a rapid decline in what had once been an effective and well-resourced research and extension system. As peace returned to the country in the late 1980s and early 1990s there was a need to rebuild both the physical research infrastructure and to re-establish a well trained and adequately paid public agricultural research and extension system. Such a research system was reorganized in the early 1990s by the creation of the National Agricultural Research Organisation (NARO), Uganda.

The agricultural extension service remained a separate administrative entity. An Agricultural Extension Programme was introduced in 1992, taking a unified (crop and livestock) approach based around the T&V system. However this T&V-based system was widely criticized (World Bank 1996).

Despite the reorganization of both the research and the extension systems, their broad institutional features systems remained unaltered. A classical hierarchy of relationships existed between the research organization who were responsible for technology development and testing, and the extension service who were responsible for technology transfer. This hierarchy also related to the relationship between extension service and farmer, where patterns of accountability and relevance were weak. Subsequent developments in extension such as the village-level participatory approach and the devolution of extension responsibility to the district level did little to alter this broad institutional design.

A further feature of the system was that even though there was considerable NGO activity in the rural development and agricultural development sector, this was weakly linked in any formal way to the public research and extension system. However by the late 1990s pluralism was increasingly a reality, with NGOs contracting public agents to deliver services (Kidd 2001).

During the period 1997–2001 a key institutional change took place that was to have fundamental implications for both research and extension services. This change began with the development of the Poverty Eradication Action Plan in 1997 and the subsequent adoption of this as the Poverty Reduction Strategy Paper for Uganda.[12] A core initiative to emerge from this was the Policy for the Modernization of Agriculture: Eradicating Poverty in Uganda (PMA). This sector-wide approach provided a broad vision of ways of improving livelihoods in a sustainable manner. Interestingly, in acknowledgment of the wide range of factors responsible for the modernization of agriculture that lie outside the scope of the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF), the responsibility for elaborating the plan was given to the Ministry of Finance. Kidd (2001) highlights the seven pillars of the PMA as follows:

1. Deepening decentralization for efficient service delivery
2. Reducing public sector activities and promoting the role of the private sector
3. Supporting the dissemination and adoption of productivity-enhancing technologies
4. Guaranteeing food security through the market and improved incomes
5. Enhancing and strengthening stakeholder consultation and participation in the planning and implementation of programs
6. Designing and implementing gender-focused and gender-responsive programs
7. Ensuring the co-ordination of the multi-sectoral interventions to remove any constraints to agricultural modernization (MAAIF 2000).'

Quite clear in the vision of the PMA is a very strong focus on extension – and notably less emphasis on research. It was in the context of these institutional changes, and growing frustration with poor access and lack of accountability in agricultural extension services, that the NAADS emerged. In 2001, under the PMA a NAADS taskforce was established with broad participation from NGOs and other public agencies. It was also supported by and linked closely to the Joint Donor Agricultural Sector Support

Table 1. Key features of the research management and technology promotion approach, conventional agricultural research arrangements and of the SMIP task networks.

Institutional features	Conventional agricultural research arrangements	SMIP task networks
Guiding agenda	Scientific	Developmental
Relationships involved	Narrow, hierarchical	Diverse, consultative
Partners	Scientists in other public agencies	Scientist, entrepreneurs, and development workers from the public and private sectors
Selection of partners	Predetermined by institutional roles defined by the arrangement of the research system	Coalitions of interest. Determined by the nature of task, national institutional context and skills, and resources available
Role of partners	Fixed. Predetermined by institutional roles defined by the arrangement of the research system	Flexible. Determined by the nature of task, national institutional context and skills, and resources available
Research priority setting	Fixed. By scientists	Consensual. By regional stakeholders and by needs of task network
Work plans and activities	Fixed at beginning of project	Flexible, iterative
Mandate for research/task approach adopted	Fixed by institutional norms of the research system	Negotiated through coalitions of interest
Knowledge produced	Technical/scientific	Technical/scientific and institutional
Indicators of performance	In scientific terms to other scientists	In development terms to donors. In terms of fulfilling role in task network to other partners
Responsibility for achieving impact	Other agencies dedicated to extension and technology promotion	SMIP scientists and their partners in task networks
Capacity building	Trained scientists and research infrastructure	Collective capacity of task networks, social capital, partnership skills

Note: This table polarizes the different been these two approaches for illustrative purposes, but we acknowledge that the conventional model (embodied by NAREs) has evolved over time.

Programme. The design phase relied on a wide-ranging consultation process, including stakeholders involved in research and technology transfer tasks together with political stakeholders whose advocacy was required in the support and promotion of a new approach in a major public-sector sphere of activity.

At the end of 2001 the NAADS bill was passed by Parliament and the phased introduction of the program began in six districts. The vision of NAADS is that in the next 25 years public financing of the advisory service will be gradually reduced to 50%. The financial support for the program is to come from the revenues of central government, districts, and sub-counties, from donors, and from farmers themselves. The flow of funds from a central common basket through districts and then sub-counties is integrated into normal planning and budgeting systems. The release of funds is based on the plans of registered farmer groups aggregated through farmers' fora and submitted to the NAADS Secretariat. Sub-counties then make contracts with private service agents.

The NAADS program has the following five key elements:[13]

1. Advisory and information services to farmers
2. Technology development and linkages with markets
3. Quality assurance – regulation and technical auditing of service providers
4. Private-sector institutional development (development of the private sector so that it can play the expanded role that is envisioned for it)
5. Program management and monitoring.

At the core of the NAADS initiative is the commitment to give technology users (farmers) control over financial resources with which to contract-in advisory services and (ultimately) to generate private funds for private delivery of these services. A further feature is the establishment of an **innovation fund** which the farmer groups can use to buy technology development or research services. Part of the novelty of the approach is that the farmers are able to buy advisory and research services from any organization that they choose. This could be the public extension system (which is still in place), public research organizations, NGOs, or private organizations. In the latter regard one interesting feature has been the emergence of local private advisory enterprises to service the needs of farmers, and indeed this is being promoted by NAADS. Although the emergence of such services will undoubted mature and evolve considerably, the development of new organizational types in response to a market for knowledge services is an important development.

Of equal interest is the tendency for research organizations from NARO (perennially short of operational resources) to seek funds from these farmers' groups. This is a significant institutional change with respect to the emergence of a more demand-driven model of R&D. Perhaps more significantly this suggests a more fundamental institutional change in the respective roles of research and extension in the design of the technology system. Under these new arrangement the priorities and approaches of NAADS, and their facilitation of farmers' voices in the research and technology promotion process, is starting (albeit in a limited way) to become a driver for the research organization. This overthrows the conventional research–extension hierarchy.

NAADS is clearly an ambitious initiative with significant implications for the institutional arrangements of R&D. These implications are summarized in Table 2. NAADS is at an early stage and it will be expanded as the wider processes of government decentralization reaches more districts. There are also some eligibility criteria that are NAADS-specific, including a willingness to retrench extension agents, the provision of counterpart contributions, and the 'institutionalization' of mechanisms for producer empowerment. It is arguably this last point that is the most critical challenge and at the same time one of the most important new institutional arrangement that NAADS and the wider centralization process embodies.

Kidd (2001) is cautious about the ability of NAADS to provide access to services for poor producers (often women), who are usually those with the least social capital. He is also cautious of the danger of males and elites 'capturing' farmers' organizations and other decentralized structures; and the conflicts of interest that may arise in the contracting process. The paradox is that by insisting producers register as groups, having social capital is a pre-condition for accessing services targeted at those who have least social capital. NAADS accepts that these issues will need close attention. Similarly the initiative is distinguished by its adoption of a flexible learning approach. It needs to pay particular attention to monitoring and steering the shifting power relationships that the

Table 2. Key institutional differences between conventional agricultural extension and NAADS.

Institutional features	Conventional extension	NAADS
Funding	Public only	Combination of public and private from farmers
Delivery	Public (sometimes through de facto privatization)	Multiple service providers from public and private agencies
Scope	Technology transfer	Advisory, including technology and market information
Organizing principle	Technology transfer	Livelihood support through modernization and commercialization of agriculture. (Facilitating operation of rural innovation system)
Program planning and implementation	Centralized, by public agency	Decentralized with participation of farmers and local government at sub-country level
Accountability	To central bureaucracy	To farmers through decentralized governance structures
Role in research	Promoting findings	Supporting client initiated priority setting and resource allocation through 'innovation funds'
Sources and modes of institutional innovation	External. Donor-driven through introduction of static blueprints	Indigenous. Designed though consultation. With provision for learning and the development of situation specificity
Role of donors	Funding and policy intervention	Funding and policy support through sector-wide approaches

program envisages among the various players related to agricultural extension (Kidd 2001). What does seem clear, however, is that the ability of the NAADS initiative to contribute towards the livelihoods of the poor in Uganda is inextricably linked to the emergence (and success) of wider efforts to develop a decentralized governance mechanism for the public sector and development of services that are truly accountable to poor stakeholders. This is an enormous task.

A number of points arise from this case study:

1. The importance of the historical context, and of contemporary institutional developments such as the PMA and decentralization, that have helped shape and generate support for this initiative (in competition with the contending, conventional extension approach)
2. The implications of adopting a more livelihood-relevant organizing principle for agricultural extension. This broadened the scope of extension to technology and market advisory services and linked the goals much more strongly with contemporary development needs of the producers.
3. The implications this has for the conventional research extension hierarchy and the emergence of a potential role for NAADS in rural innovation systems
4. The establishment of new organizational focus for priority setting and resource allocation (farmers groups) and service provision within new decentralized governance and accountability arrangements. A notable aspect of this has been the emergence of associated, rurally based, entrepreneurial activity and opportunities in the provision of advisory services
5. The relationship between NAADS, the wider institutional and political process concerned with decentralization, and the (attempted) creation of new patterns of governance in the development process.

A critical concern is the fact that the success of NAADS depends to a large degree on the success of the institutional change taking place in the wider political process in the country. A related point concerns the role of a range of stakeholders, including political ones in support and advocacy for a new and potential controversial type of public intervention. Note also that while the donors have played a large role in this intervention, this has been much more concerned with nurturing an indigenous institutional innovation within a wider vision of poverty-focused development. This contrasts strongly with the introduction of other extension paradigms such as T&V, where the approach had been to introduce an institutional blueprint. NAADS seeks to further evolve its approach through learning and innovation.

Banana tissue culture in Kenya: a case of multi-agency collaboration in biotechnology development and promotion[14]

Cooking and dessert bananas (*Musa paradisica*) are key staple food and cash crops in much of East Africa. While cooking types have traditionally played the central role in rural economies, domestic and export trade of dessert varieties presents an important opportunity for small-scale producers. However, the emergence of a number of plant pathogens, spread by the vegetative propagation of the crop, has increasingly threatened production. This case study describes an intervention that brought together public-sector scientific organizations and a number of private-sector companies. It concerns a project that exploited tissue culture technology to generate, multiply, and distribute disease-resistant planting material.

The intervention was led by the International Service for the Acquisition of Agri-biotechnology Applications (ISAAA). As an advocacy and facilitation organization the role of ISAAA was to: conceptualize the nature of the intervention required, attract financial support from the donor community, and identify and form partnerships with the range of public and private organizations relevant to tissue culture R&D and the production and distribution of banana plantlets. The Kenya Agricultural Research Institute (KARI) was chosen as a partner to host the project because of its research and extension infrastructure throughout Kenya, and because of its scientific capability in cultivar evaluation and agronomic studies of introduced varieties.

ISAAA also needed to identify a source of disease-free planting material for tissue culture multiplication. A South African company – DuRoi Laboratories – was chosen to supply banana plantlets as this expertise was not available in Kenya. A local Kenyan company, Genetic Technologies Limited, with expertise in tissue culture in other crops was identified to handle the materials supplied by DuRoi. Technical backstopping in, for example, virus diagnostics, was provided by the John Innes Centre, UK, and the Institute of Tropical and Sub-Tropical Crops, a South African public research organization. Again, ISAAA identified these partners.

ISAAA was able to attract financial support from The Rockefeller Foundation and the Canadian International Development Research Centre (IDRC). The African Technology Policy Studies Network paid for research to examine technology diffusion. This was carried out by the Centre for Development Research, University of Bonn, Germany.

As a result of this approach plantlets of a range of banana cultivars were transferred from South Africa, multiplied in Kenya, and tested in different agro-ecological zones and in different farm production scenarios where their characteristics were assessed for agronomic features, quality traits, and production costs and returns. The participation of farmers was sought in these evaluations. Improved material was found to produce bunches weighing 40 kg, while local variety bunches weighed 15–30 kg.

However, it was found that certain introduced varieties were not popular and emphasis shifted to producing disease-free plantlets of the local varieties. Since expertise to propagate local germplasm was not available in Kenya, assistance was sought from the Ugandan National Banana Programme (UNBP). The UNBP had received considerable funding from The Rockefeller Foundation and was presumably therefore well known to this key donor stakeholder in the Kenyan project.

The project was also able to respond to gender-differentiated variety preferences, since men and women cultivate varieties that cater to different market segments. This factor became an important determinant in the selection of local varieties for the development of disease-free material.

As the project progressed and marketing problems were revealed, banana growers associations were formed to improve the bargaining position of farmers. To meet the rapidly rising demand for tissue-cultured planting material, KARI and ISAAA identified church groups and key farmers to establish nurseries and distribution points.

Ex-post impact analysis suggested that average per hectare incomes could rise by 156% for small-, 145% for medium-, and 106% for large-scale farmers. The fact that there is strong effective demand for plantlets, with farmers willing to pay as much US$ 3 for each one, underlines the perceived value of this new technology. The project was not without its problems. It was found that a major bottleneck to technology adoption was the availability of credit to purchase banana plantlets. To resolve this, the project linked to local micro-finance institutions. These arrangements are still evolving appropriate approaches that include the development of community-based credit and savings groups.

Other important outcomes from the project were viewed as the development of a national capacity in banana tissue culture, plantlet production, and distribution. There are now five tissue culture laboratories in Kenya. While this capacity was contained jointly in the experiences of Kenyan public and private organizations, it also recognizes that this initiative has strengthened the linkages with the international research community. Similarly, the need for plantlet distribution has presented an important entrepreneurial opportunity to NGOs and CBOs.

A number of interesting points arise from this case:

1. The important role played by such organizations as ISAAA in conceptualizing and facilitating a network of partners around a key development task. Note that while the intervention is technologically based, its goals relate to setting up a technology development and supply system and to achieving and sustaining impact on the farmer. This has acted as an important organizing principle for the partnerships and strategy established. The other role of ISAAA is in identifying funds.
2. There is a great diversity of tasks that need to be achieved to introduce this new technology. As a consequence, a wide range of organizations is required including: scientific, entrepreneurial, technology users, CBOs, voluntary, market actors, and national and international public agencies. Similarly there is a diversity of roles that these organizations need to play. These go beyond the conventional institutional roles of strategic, adaptive research and technology-transfer tasks (although these still are important). Furthermore, organizations like KARI that initially have a critical role in evaluating new varieties have changed their role as the intervention has matured into a distribution task. Table 3 summarizes the range of organization involved and gives details of the roles these different organizations played.
3. A key characteristic of the intervention is its strongly iterative nature and the success emanating from adopting new strategies and partners.
4. The importance of an effective and impact-focused monitoring system that was used in the design and implementation phases.
5. The capacity-building effects of developing systems of this type and particularly those arising from the combined capacity of new networks of partners.
6. The potential of such interventions to create entrepreneurial opportunities, particularly in rural areas where new livelihood options can be limited.

New institutional arrangements for agricultural R&D in Africa? Implications and ways forward

In order to analyze the implications of the institutional developments illustrated in the case studies, it is useful to return to the two perspectives that were introduced earlier in the paper. Firstly, the six institutional changes mentioned earlier as being needed in R&D arrangements; and secondly, the analytical foci introduced in the discussion on innovation systems. Taken together these suggest that six broad themes of analysis are useful in evaluating the developments observed in these case studies:

Table 3. Summary of the organizations involved in the banana tissues culture initiative, their roles, and responsibilities.

Organization	Role and responsibilities
ISAAA	Program oversight, fund-raising, partnership development and advocacy
The Rockefeller Foundation and IDRC	Financial support, later on networking into complementary initiatives that they had also funded
KARI	Initially, evaluation of introduced varieties. Later the selection of local varieties for development and subsequently technical backstopping and plantlet production in the promotion phase, including training and extension. Also had a role in selling banana plantlets
DuRoi Laboratories, South Africa	Supply of banana plantlets of new varieties and associated technology
Genetic Technologies Limited, Kenya	Tissue-culture expertise to multiply imported disease-free plantlets from South Africa
African Technology Policy Studies network	Funding research on technology transfer mechanism and adoption, performance, and impact
Centre for Development Research	Ex-ante impact assessment studies including market assessment, and later ex-post impact assessment including adoption studies
Men and women farmers	Evaluation of imported material and selection of preferred local varieties
Banana Growers Association	Collective negotiation in output markets and to assist access to credit
Micro-finance institutions	Credit for replanting with improved material
Micro-entrepreneurs	Distribution of banana plantlets and related inputs at village level
Private Kenyan companies	Production and sale of banana plantlets. Linkage to export markets for bananas
UNBP	Expertise in generating improved disease-free material from local varieties
John Innes Centre, UK	Virus diagnostics expertise
Institute for Tropical and Sub-Tropical Crops, South Africa	Designing field management practices and developing commercialization strategy jointly with others

Source: Adapted from Wambugu and Kiome (2001).

1. Systems features
2. Roles of different actors
3. Governance of R&D
4. Wider institutional and policy context and its implications
5. Capacity building
6. Poverty focus and impact

Table 4 presents a summary and comparison of the three case studies using these 6 broad themes.

The three broad lessons that can be drawn from these cases help in the discussion of the institutional architecture of agricultural R&D.

1. New institutional arrangements for agricultural are starting to emerge in Africa – in the sense of both partnership and governance. They may be experimental and isolated, but nevertheless it is an indication that institutional developments are starting to take place and that there is an empirical basis for discussion of these issues.
2. While these cases address the six key areas of institutional change to varying degrees, their overall institutional arrangements are exhibiting many of the features that one would expect based on an innovation systems conceptualization. This gives us some confidence in the earlier assertion that the innovation systems framework can offer a conceptual basis for exploring institutional change and development.
3. Perhaps most important, all three cases, with the exception of NAADS that is at an early stage of development, suggest that these types of institutional arrangement are leading to enhanced developmental impacts.

There are a number of more-specific issues that arise from the case studies relating to the way R&D institutional arrangements are responding to changing development policy imperatives and the underlying innovation systems that are giving shape to this:

Systems features. The key feature of the cases discussed is that they exhibit systems features associated with innovation and change. This concerns the elements involved; the links or relationships between those elements; and the underpinning processes. All three case studies illustrate the value of forming partnerships with a range of both conventional and new partners. Furthermore, the types of relationship involved are also new, being much more consultative and less hierarchical. Arguably the most important lesson from the systems observed is the way these institutional arrangements have arisen and evolved. This has required both intuitive and explicit learning processes to be in place, leading to a significant degree of institutional innovation (see further discussion on evolving roles). Thus institutional and technical innovations are interdependent and hence a feature of successful systems is the ability to allow this co-evolution to take place.

Evolving roles. The case studies have some useful things to say about the new role of the public sector. In fact, there is no new generic role that can be defined. Instead, the public sector is likely to have multiple roles as facilitator, implementer, research and technology developer, source of funding, and contractor for privately funded research and technology services. The more important point is that these roles are highly contextual, relating to both institutional and task contexts.

This feature of contextual roles also applies to the NGO, CBO, and, in particular the private sector. The case studies clearly suggest that there will be involvement of more actors and certainly of the private sector. But this should not be thought about in terms

Table 4. A comparison of old and new institutional arrangements.

Features	SMIP	NAADS	ISAAA banana biotechnology
1. System features			
1.1 Actors and new patterns of partnership involved	Diverse combinations of actors from public, enterprise, NGO, and and CBO sectors	Diverse combinations of actors from public, enterprise, NGO, and CBO sectors	Diverse combinations of actors from public, enterprise, NGO, and CBO sectors
1.2 New patterns of partnership and relationship	Flatter more consultative partnership relationships to exploit complementary resources	Partnerships encouraging broader participation of farmers in planning and accountability of service-delivery agencies	Partnerships fostering the complementarity of public and private enterprise sectors
1.3 Sources of institutional innovation and learning	Experimentation with partnership in earlier phases of the program External advocacy by donor for broader partnerships Intuitive process in program driven by need to deliver impact	Indigenous institutional innovation through wide-ranging consultations Explicit recognition of learning and flexibility in program design	External advocacy for public–private sector partnership in biotechnology Considerable iterative institutional innovation during implementation and scaling up
2. Roles of different actors			
2.1 Private enterprise	Commodity output markets	Supplying advisory services	Production expertise in tissue culture Delivery systems, input markets
2.2 NGOs	Implementing initiatives Market studies, enterprise development Facilitating linkages between farmers and other agencies	Supplying advisory services	Delivery systems, facilitating rural micro-enterprise development
2.3 CBOs	Community-based seed production	Priority-setting and planning of advisory service programs	Collective bargaining and access to output markets and micro-finance
2.4 NAREs	Partner providing research services, technology and technical backstopping Creating regulatory framework for seed sector Linkage with international scientific community	Facilitating the development of decentralized, accountable and relevant advisory service	Providing access to research and extension infrastructure Providing expertise in technology evaluation Linkages with international scientific community Role evolved as program matured
3. Governance of R&D			
3.1 Role of donors	Direct source of funds Advocacy of private-sector led development model	Financial and policy facilitation through sector-wide approach	Financial support Informal network of other complementary projects and expertise
3.2 Role of inter-national agencies	Program management and oversight Linkage to source of funds Technology supply Research services Linkage facilitation	External evaluation	Program management and oversight Linkage to sources of funds International advocacy

Tabe 4. *(continued)*

3.3 Scope for participation in priority setting, resource allocation, technology development, and testingnetworks	Consultative with many partners, including farmers and technology users Some evidence of research priorities emerging from task	Program farmer-led Potential to generate research priorities	Farmer participation in technology evaluation Program responded to variety-selection criteria of men and women farmers
3.4 Accountability and associated mechanisms	SMIP scientist directly accountable to donor for developmental impact Rigorous monitoring system in place	Accountability decentralized to farmer groups and sub-county government through competitive service provision Overall program-monitoring system in place	Donor funded ex-ante and ex-post impact assessment studies
3.5 Scope of vision and goals	Developmental Food and livelihood security through better access to markets technology and a greater role for the private sector	Developmental Food and livelihood security through better access to markets technology and a greater role for the private sector	Developmental, through frontier science Improved access to technology and markets through private-sector involvement
4. Wider institutional and policy context			
4.1 Relationship with developments in wider institutional and political environment	Embedded in the debates in Southern African Center for Cooperation in Agricultural and Natural Resources Research and Training (SACCAR) concerning the need to introduce private and other players in research	Embedded in wider political and institutional changes associated with decentralization and new patterns of pro-poor governance	Embedded in advocacy for exploiting biotechnology in smallholder agriculture
5. Capacity building			
5.1 Scope	Transitory capacity in task network Longer-term capacity in partnering skills Development of formal network	Specific focus on private sector, capacity development with the long-term vision of a more pluralistic, integrated poverty-focused rural innovation system	Emergence of broad- based capacity in activities associated with the exploitation of tissue culture
6. Poverty focus and impact			
6.1 Impact	Monitoring targets achieved, but no specific quantification of poverty impacts. To be addressed ex-post	Too early to assess	Adoption and impact studies indicate initial income impact of more than 100% improvement
6.2 Mechanisms to specifically address access and governance of the poor	Develop stronger partnerships with organizations with developmental focus and operational access to the poor Voice and power structure not explored	Awareness of the need to monitor evolving power relationships and capture of decentralized structures explicit in program design	Attention given to the perceptions of both men and women farmers in technology evaluation and testing Impact assessment examined differential impact on different farm size

of a necessarily greater research role for the private sector. The case studies suggest that their involvement in input and output markets is going to be much more crucial. The NAADS case perhaps takes this conclusion one step further and suggests that if more broad-based innovation systems are to emerge, formal skill-enhancement capacity development intervention aimed at the private sector will be necessary. In this context, quality regulation therefore becomes another role for the public sector.

A corollary has to be that learning is going to be key in developing location-specific arrangements and roles, and that locally devised institutional innovations are going to be essential. This has important implications for both donors and international agencies. It suggests that a reliance on blueprints is misplaced. For donors, initial experience with the sector-wide approach seems to conform with this perspective. However, special projects probably have an important role in allowing local organizations the chance to experiment with new ways of working that may lead to institutional arrangements that can subsequently diffuse within a country. For international agencies – even the scientific ones – the cases discussed suggest that resources must be diverted to initiatives that stimulate institutional innovations through experimentation, facilitation, greater analysis of existing interventions, and well informed advocacy (for new approaches and institutional developments) and facilitation of the learning and change process. Another way of saying this is that the technology development prowess of the IARCs needs to be accompanied by institutional knowledge about the research process. Attention therefore needs to be given to finding ways of generating and promoting these institutional innovations as part and parcel of all agricultural science and technology interventions. This is often referred to as institutional learning (Hall et al. 2003; Watts et al. 2003).

Governance. All three case studies exhibit a consultative process for planning and implementation with wider participation of a range of stakeholders. This seems to be a general feature arising out of working in a broad-based partnership mode. The way this has been translated into new patterns of governance and accountability is less clear. SMIP has a very strong accountability regime, but this accountability is to the donor, not necessarily to the technology users and partners – although presumably these partnerships rely on implicit accountability in some form. NAADS has made organizational and institutional changes as an explicit attempt to improve the voice of poor farmers in program implementation. In relation to the emergence of new research priorities, the case studies present a less clear picture. However, the action-orientated framework of both SMIP and ISAAA interventions demonstrates the importance of flexible iterative research approaches where the search for new options and ways forward is central to this way of working.

Wider institutional context. The NAADS case stands out in the way it is embedded in and emerges from the wider institutional and political developments associated with the development paradigm being pursued in Uganda. Neither of the other interventions has such close integration with local development processes. However, even in the other initiatives the organizing principles that inform their vision and scope are much more closely related to contemporary development agendas than conventional science-led programs would be.

Capacity building. Formal R&D capacity building has not been a feature of any of the case studies. Instead, what is highlighted is the importance of creating stronger linkages between different organizations, sometimes through formal mechanisms and sometimes through informal networking. An important aspect of this capacity building is the development of partnering skills. This suggests that a crucial role for both national and international research and extension organizations is to help facilitate the development of such skills, as this will strengthen connectivity within innovation systems – a feature that seems important to their performance. There are also institutional aspects of this capacity building. That is to say that there are approaches and conventions associated with the cases that have helped innovation systems work more effectively or work in more pro-poor ways. To make the same point differently the capacity of the innovation system relates to: the skills and resources of the different elements or organizations in the system; the patterns of linkage between these different elements; and the institutional arrangements that govern how these patterns of interaction operate. Clearly this implies that capacity building needs to be viewed by donors and others as a much broader set of activities than training, and that these activities overlap, with interventions that might otherwise have been viewed as research or developmental activities.

Poverty focus. The poverty focus of NAADS is particularly interesting since, perhaps of all the cases, this one has acknowledged some of the difficult power dynamics embedded in R&D and technology promotion and the ways in which this is likely to affect the overall direction of the program. It is just this sort of institutional context that the innovation systems framework encourages the analyst to reveal and explore. A perspective of this type is going to be required if a stronger poverty focus is to be achieved in interventions.

Conclusions

The following points need to be considered when NAREs contemplate their future.

Priorities and approaches change. Research and technology-promotion activities are embedded in a changing world. Programs need to be able to adapt and evolve. Strategic changes need to be recognized and debated.

Learning is important. Making institutional learning processes explicit would seem to be a way of developing better programs and working practices. Resources should be diverted to this activity as a complement to technology development.

Developmental objectives help broaden participation. Adopting a developmental agenda shifts the overall organizing principle and in doing so draws in new partners and creates new roles. In part, this concerns giving R&D programs a shared perspective with a wider spectrum of organizations. By working with development-orientated partners the evidence suggests stronger participation from technology users. Overall this underlines the value of blurring the distinction between research and development. New patterns of accountability accompany a developmental framework, and can also be a way of strengthening partnership development.

Working with new partners, particularly the private sector, involves a learning process. Working with the private sector may initially be difficult, requiring adaptation to the procedures and skills of all partners. Institutional learning improves program evolution and design and helps organizations learn how to partner better. Institutional innovations of this type need to be recognized as being equally important, and probably co-products of technological innovations.

Partnerships need to be structured around problems and local contexts. Grouping partnerships and relationships around a problem or task is important. The value of this relates to drawing together a system of partners with a shared or intersecting interest, or agenda, with competencies relevant to the solution of problems identified and with the physical and financial resources required. The partners, relationships, and roles involved are therefore determined by local task, organizational, and institutional contexts. This underlines the importance of allowing a diversity of approach and letting partners evolve in specific contexts, rather than mandating blueprints. It also emphasizes the critical role of institutional innovation.

Partnership can be used as a mechanism for identifying researchable issues. While the evidence from the cases only showed limited examples of this, it does suggest that partnership groups offer a potentially valuable arena for identifying researchable issues and negotiating priorities.

The importance of flexibility and iterative work plans and procedures. Some of the success of interventions is that they are able to be slightly opportunistic, both in terms of developing relationships with new partners and being able to address emerging research constraints and opportunities. This suggests the value of flexible and iterative planning and implementation procedures. Since programs organized in this way are much more development/output orientated, the process by which this is achieved becomes an iterative management issue rather than a component of the initial planning process.

Greater emphasis on systems capacity building. A broad planning implication from the case studies presented is that if these types of systems processes and relationships are encouraged, the impact of research and technology promotion programs can be improved. This suggests that systems capacity needs to be built by: strengthening linkages, broadening participation, allowing local networks to evolve, and making learning and institutional innovation an explicit output of research and technology programs. This systems perspective on capacity building needs to compliment conventional investments in scientist training and research infrastructure.

Endnotes

1. An earlier version of this paper was presented at international conference on 'Targeting agricultural research for development in the semi-arid tropics of sub-Saharan Africa', 1–3 July 2002, Nairobi, Kenya. The paper was prepared with the financial assistance of ICRISAT and USAID.
2. The term institutional is used in the governance sense referring to rules, norms and power structures associated with research and development (R&D). It is also used as an embedded concept referring to the behavior of individuals and physical organizations (the manifestation their own rules and norms with regard to priority setting, accountability, level of stakeholder participation and so forth).
3. Throughout this paper the term NAREs is to refer to public agricultural research and extension organizations or agencies. This is done to distinguish it from the broader and often misused term national agricultural research system (NARS). As a concept NARS refers to a diverse, well integrated research and

extension system with many public and private actors, but in practice is frequently used mean public research and extensions organizations.

4. This is a vast topic that can not be comprehensively covered in so short a paper like this. Useful overviews can be found in Byerlee and Alex 1998; Byerlee 1998; and Rukuni et al. 1998, from which this section is drawn from. Also see Hall et al. 2000 for discussion of the evolving policy agenda and its implication for NAREs.
5. See for example, Byerlee (1992) for discussion of the need for institutional change in agricultural R&D to address the emergence of salinity problems from the Green Revolution vintage of technology packages.
6. The use of participatory methods in development and in agricultural research refers to a cluster of approaches whereby emphasis is given to the perceptions of the 'beneficiaries' of development initiatives and their participation is sought in the development and implementation of solutions. It has been criticized by some for its lack of acknowledgement of the wider institutional context in which research (and rural development more generally) inevitably takes place and the power structures that this context implies (Biggs and Smith 1998; Hall and Nahdy 1999).
7. This builds on the idea of a 'national system of innovation' (Freeman 1987; Lundvall 1992) developed to examine the differential performance of national economies and the factors underpinning innovation performance.
8. The literature on learning, competency building and innovation performance is very large indeed. Edquist (1997) provides a useful review of concepts in the context of innovation systems. See also Foss (1998) for debate on competency building. For discussion and illustration of institutional learning see Hall et al. 2002.
9. This section draws on the senior author's visit and discussion with SMIP scientist and partners in Tanzania, Botswana, and Zimbabwe in May–June 2001, further details can be seen in Hall 2003.
10. It should be noted that this review took place after only 2 years of Phase IV and was an explicit attempt to explore some of the institutional implications of recent program developments.
11. This section draws on discussions with the NAADS Director, a member of the NAADS Taskforce, and MAAIF (2000) and Kidd (2001).
12. Prepared under the debt-relief terms of the Highly Indebted Poor Countries Initiative.
13. Full details can be found in MAAIF (2000).
14. This section is based on Wambugu and Kiome (2001).

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Reflections on Partnerships, Institutions and Learning

5. The evolving culture of science in the Consultative Group on International Agricultural Research: concepts for building a new architecture of innovation in agri-biotechnology

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Abstract

This paper argues that the Consultative Group on International Agricultural Research (CGIAR) needs to respond to the wider implications of biotechnology in the way it conducts its research. This involves important institutional developments and capacity building in areas such as relationships with the private sector, intellectual property management skills and business-orientated perspectives, previously underdeveloped in most CGIAR centers. At the same time it should visibly engage in and promote a debate that helps quell public unease concerning the use of new technologies in the production of food crops while maintaining its mandate of poverty reduction and development. Using the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as an illustration, the paper explores recent innovation systems thinking and associated planning tools as possible means of helping the culture of international agricultural science evolve in useful ways.

Introduction

Innovations and impacts from research in the life sciences, and from biotechnology in particular, are increasingly dependent on new groupings, alliances, and relationships both within science, and between science and business. In Europe and the USA, for example, the boundaries between public and private sector are becoming increasingly blurred as both private companies and national governments recognize the economic importance of knowledge and the need for greater collaboration in its production and use. This new architecture of innovation has emerged in the developed world for a number of interrelated reasons:

- Advances in the biosciences that have both economic and social relevance particularly in health and agriculture
- The new possibilities that this presents for ownership of biological materials and processes, coupled with strengthening intellectual property regimes
- The changing role of the State and the emergence of the market as a major decision-making institution
- A growing understanding of the importance and role of new knowledge and innovation in economic development

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- An increasing focus on innovation policy and the associated need to encourage greater connectivity between scientific and entrepreneurial elements in national innovation systems.

These same issues and possibilities are starting to impinge on developing countries. While there is little doubt that biotechnology has enormous potential to make a significant contribution to poverty reduction, this will not happen through market mechanisms alone. As Byerlee and Fischer (2002) point out, while the private sector is the major global player – investing US$2.6 billion in agricultural research and development (R&D) – only modest private investments are taking place in the developing world. Furthermore, these investments tend to be in such niche areas as hybrid vegetables and cereals plus technological spillovers from their investments in major global commodities such as soybean (*Glycine max*) and cotton (*Gossypium hirsutum*). Social commentators such as Scoones (2002a) suggest that the political economy of the biotechnology industry in developing countries – both local start-up companies and multinational corporations – is such that the poor are unlikely to benefit from biotechnology unless there is specific public policy intervention in this arena.

Other groups fear that the risks from biotechnology are unacceptable and that the public should not be exposed to technologies and products that are derived from it, particularly genetically modified organisms (GMOs). Innovation analysts such as Clark et al. (2002a) suggest that biotechnology will fail to impinge in developing countries unless biotechnology capacity is developed locally. This often has less to do with numbers of trained scientific personnel and instead concerns greater connectivity within national innovation systems including partnerships within science, between science and public policy, between the public and the private sectors, and between science and society in general.

The emerging view is that the public sector must simultaneously continue to invest in R&D while seeking alliances with the private sector. At the same time it must engage in policy and regulatory issues that protect and promote the agendas of the weaker sections of society. The international community and particularly the Consultative Group for International Agricultural Research (CGIAR),[2] has a unique role in this process. However, it must first give careful consideration to the ways in which it approaches this task bearing in mind its own research-for-development goals. For example:

- How does the CGIAR initiate and evolve relationships with, the private sector and advanced research organisations?
- How does it ensure public access to proprietary (privately owned) technologies and processes?
- How does it maximize the public good nature of innovations jointly owned with the private sector?
- How does it negotiate new partnerships that ensure that all stakeholders including the poor stand to gain?
- How does it constructively engage in issues of public acceptance of biotechnology, simultaneously promoting new technology and protecting society from the unknown?
- How does it reach consensus with stakeholders on research priorities?
- How does it engage and build capacity in national and international policy processes relevant to exploiting biotechnology for pro-poor development?

These questions are part of the wider issue concerning how to integrate the CGIAR's work and agenda into that of others working across the science – development continuum.

Byerlee and Fischer (2002, quoting Morris and Hoisington 2000) make the point that while the CGIAR has focused on biotechnology R&D capacity development (its own and in its public partners in developing countries), it has paid less attention to the operating environment necessary to nurture the use of biotechnology. So, for example, the CGIAR has invested little in strengthening capacity in policy and regulatory issues related to the deployment of biotechnology products, and has shied away from active participation in public dialog surrounding transgenics (Byerlee and Fischer 2002) (although more recently a system-wide Biotech Awareness and Biosafety Support Unit has been established). It is clear that not only do these challenges need to be faced, but that there is also a strategic value to knowledge that deals with ways of enabling innovation in these new, dynamic, and complex relationships and institutional environments.

What conceptual and policy tools does the CGIAR have to assist with the policy and implementation questions associated with biotechnology? In the main the answer is very little. What it has are scarcely more than the neo-classical tools of research priority setting and rather simplistic notions of public and private goods and services. This lacuna is made all the more remarkable by the fact that there is a well developed set of concepts and tools available to help guide thinking on these issues. For inspiration one only needs to look at contemporary science and technology (S&T) policy as practiced in many of the Organization for Economic Co-operation and Development (OECD) countries. There, as the old-world order of public-sector, science-led economic growth has been eclipsed by more complex circumstances, so too the approaches to S&T policy have changed. Our main argument is that the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the CGIAR could usefully draw from this other, parallel policy paradigm. Of specific relevance is the ongoing analysis of innovation processes and the systems that support these processes (Hall et al. 2000). Not only has this allowed the debate to break out of the old linear paradigm of science-led innovation, it has also allowed a greater analysis of the institutional context that shapes research and innovation. In turn this has shed light on ways of planning this as an embedded process – ie, a process that is specific to and shaped by context, task, stakeholders, and institutional arrangements.

This paper reviews some of this parallel policy literature and reflects on the developments and challenges that face ICRISAT and the CGIAR in general. In the empirical section, the evolution of the culture of science at the Institute is discussed. The main argument here is that cultures and norms in science do change, and ICRISAT has begun to adapt to the contingencies of the pervasive importance of biotechnology and its institutional and policy implications. In essence this is a story about how CGIAR science is coming to terms with a new more interactive way of working with partners, particularly the private sector; how new business and legal competencies are becoming essential to public science; and how the role of organizations like ICRISAT is changing. Challenges lie ahead. These include the need for new governance structures with wider stakeholder participation. Closer to home, this also implies new incentive structures to encourage scientists to work in teams where conventional disciplinary boundaries and hierarchies need to be replaced by new disciplinary groupings and the working relationships required to exploit biotechnology effectively. The discussion section of the paper explores concepts and tools that may assist in this task. The paper begins by providing an overview of some of current issues in the biotechnology for development debate.

Biotechnology and international agricultural research

Promises and threats

Biotechnology and its potential to contribute to the developmental agenda of agricultural research has been widely debated for nearly two decades (see Sasson 1988; Kloppenberg 1988). It has a number of technical and institutional features that distinguish it from conventional agricultural technology, which means that it raises specific policy, ethical, equity, and scientific questions. There are four broad technical areas of biotechnology intervention for plant breeders:

1. Genomics. Diagnostic techniques that use an understanding of molecular biology to improve the speed, efficiency and precision of plant breeding while promising to address new goals not possible through conventional means.

2. Tissue culture. Techniques that allow rapid multiplication of disease-free planting material, embryo-rescue techniques that facilitate the recovery of hybrids from crosses between different species, and gamete culture techniques that allow rapid development of inbred material.

3. Transgenics. Genetic manipulation techniques that allow the transfer of genes from a wide range of sources, including across species. This can be used to introduce desirable characteristics that are either not possible through conventional means, or with a greater degree of precision. This area could be disease or drought tolerance, or such traits as herbicide resistance. This has been the subject of the greatest controversy in the eyes of the public, particularly in view of the ability of these techniques to transfer genes into our food from exotic plant species, animals, and even bacteria.

4. Bioinformatics. Computer-based techniques for structuring, accessing, and analyzing huge collections of genomics data (primarily sequence-based data). These are the tools that are linking many biological disciplines that were previously somewhat isolated, and thereby driving a paradigm shift in the ways biological research and product development are carried out.

The majority of techniques for gene transfer, and many of the most widely used genes in current transgenic varieties, are owned by private companies, mostly the few large multinationals that dominate the field. The reasons for this relate both to the high research costs of biotechnology, which are often beyond the resource of the public sector, and, of course, the novel possibilities for profitable business ventures that the private sector perceives to be possible as a result of the new technologies. Almost all transgenic varieties are privately owned, again mainly due to the extremely high cost of the biosafety testing required prior to government approval for commercial production. Public research organizations, including the CGIAR are, however, developing transgenic material using genes from a variety of sources: licensed, donated or acquired from the private sector, or generated through publicly funded research.

Risk, uncertainty and the public debate

While the arguments concerning the ability of biotechnology to provide agricultural technology for the world's poorest are well rehearsed in the specialist literature, there are also well recognized risks and uncertainties that are rarely given much air time in scientific conferences. These include both those associated with the contained use of biological processes and intermediate products in laboratories, as well as the risks and uncertainty of the impacts of products when released into the environment (Essegbey and Stokes 1998).

The real difficulty is that quite often there is scientific uncertainty of potential outcomes, ie, there is not enough prior knowledge to determine the probability of an outcome or impact. While it has always been recognized that technological interventions are associated with a certain degree of risk, conventional ex-ante methods of assessing this risk, such as social cost/benefit analysis, are less useful in the case of biotechnology. This is because scientific uncertainty, brought about by rapid technological and institutional change of the evolutionary type associated with biotechnology does not have the stable parameters required to make ex-ante judgements dependent on a set of reliable assumptions and probabilities.

This may seem a rather esoteric point, but its implications are at the heart of current public controversy over, for example, GMOs. It means that the concept of objective scientific risk assessment no longer necessarily holds true. Furthermore, a number of high-profile incidents that have called into question scientific objectivity have further undermined public trust (Tait 2001). Another perspective in this debate maintains that the public in general has little comprehension of the relative risk of, for example, walking down the road, or catching malaria whilst on holiday as compared to developing a life-threatening condition from eating transgenic food. This line of reasoning maintains that powerful lobbies with wide media coverage have convinced the public that they must be given absolute guarantees regarding the safety of transgenic food. Interestingly, if the same biosafety testing were applied to conventional foods, a very large proportion would probably be banned. While some of the public debate has also been ignorant of existing scientific evidence, it has raised ethical objections, which quite reasonably need to be factored into the decisions of risk and acceptability.

This concern over risk and uncertainty is embodied in the precautionary principle of the Rio Earth Summit Declaration (ref. principle 15, the World Summit on Sustainable Development, 26 Aug–4 Sep 2002). Scant advice, however, is provided on ways of implementing it. Clark et al. (2002a) argue that specific decision tools are unlikely on their own to play a useful role. Alternatively, support is growing for the solution proposed by Tait (2001) who calls for a constructive dialog among all interested parties so as to clarify issues and reach a social consensus on all the underlying problems. While this is a useful suggestion, ways of finding a common language to communicate issues in mixed groups of scientists and non-scientists remain a significant challenge.

The whole concept of risk is highly contextual, with society or groups in that society choosing what they wish to identify as risk. This is further complicated by the presence and effectiveness of organized lobbying groups generating awareness of different risks and promoting different agendas based on various ideological positions and other motivations. Examples of this in other contexts in North America include the tobacco lobby and the Pro-Life anti-abortion lobby. The Dark Green movement and the multinational corporations play a similar role in the context of biotechnology. The way forward is therefore to help negotiate the choice societies make when facing uncertainty in response to the perceived risks of biotechnology. There will still be a need to manage the competition between different groups of stakeholders in their efforts to define risk according to their own world views and to build trust in the regulatory process (Newell 2002). Instead of abandoning science, this consensus-building approach implies the need to recognize the limitation of science (as a decision tool) in a technological field that is evolving very rapidly. In addition, there is a need to define a more facilitative role for public policy in the regulatory process, strengthening links between science, society, and the policy process. To make the same point differently, there is no 'magic bullet' solution to these dilemmas. What is required instead is a public policy response that creates a process, which builds consensus between groups with different viewpoints, and helps make transparent choices that can accommodate the diverse agendas that exist. CGIAR centers could play a more active role in promoting a balanced debate of these issues.

Winners and losers

There is a long history of analyzing the equity implications of technologies from international agricultural research (reviewed comprehensively by Lipton and Longhurst 1989). The debate surrounding the Green Revolution pivoted around those who saw the main task as one of increasing food production and those who saw the task as one of better access to that increased production and the contribution of agriculture to wider livelihood goals. Tripp (2000) argues that opponents of agricultural biotechnology for development have mainly been NGOs. The core of their opposition concerns their perception that: 1. there is a need for more emphasis on distribution of resources (mainly food) rather than creating better production technology; 2. there are potential environmental and health risks associated with transgenic material through gene escape, toxicology, and allergenic problems, and the potential increase in the use of agri-chemicals (eg, through herbicide resistance); 3. an increased dependence on seed companies and a threat to farm-saved seed through new intellectual property regimes will be created; and 4. there will be abandonment of traditional techniques and biodiversity that have served farmers well in the past. Tripp argues that NGOs have little evidence to support their advocacy for low-input agricultural techniques, or its appropriateness to evolving livelihood aspirations. Furthermore, the advocacy on both sides of the debate seems to be founded on little empirical evidence of farmers' and consumers' perception about biotechnology in developing countries – although this is changing. A citizen's jury approach recently used in India (see Pimbert and Wakeford 2002), that purported to demonstrate farmer resistance to GMOs, was dismissed by the director of one of the (UK) organizations involved as methodologically flawed.

Public–private sector partnerships

There are a number of credible concerns over the equity implications of the dominant private sector involvement in biotechnology (see, for example, Scoones 2002b). It is, however, for the same reasons of prominence and ownership of technologies that the public sector will have to increasingly court private partners. This is particularly so for public plant breeding research, which must increase interactions with the private sector in sharing biotechnology techniques and materials, most of which have been developed in the private sector (Tripp and Byerlee 2000). Hall et al. (2002). Many others argue that the public sector's relationship with the private sector needs to expand on a number of fronts that include, but also go beyond access to technology. This will include a range of relationships: private distribution of public technologies; private purchase of public research services and technologies; public use and purchase of private materials, methods, and services; and public–private research collaboration involving cost and resource sharing, including genes and protocols, business incubation, and various kinds of product and profit sharing. The complementary nature of the two sectors' assets is summarized in Table 1.

Table 1. Assets of public and private sectors in agri-biotechnology research

	Public sector	**Private sector**
National level research organization	National agricultural research systems (NARS)	Local seed companies
Key assets	Local diverse germplasm Local knowledge Breeding and evaluation programs and associated infrastructure Access to delivery systems including extension Upstream capacity (in more-effective NARS only)	Local knowledge Breeding programs and infrastructure Seed delivery systems Marketing network
Regional and global level organizations	CGIAR international centers	Global life science companies
Key assets	Diverse germplasm Breeding and evaluation programs and associated infrastructure Global germplasm exchange and evaluation networks Economies of market size Up-stream capacity in a few centers Mostly positive public image	Biotechnology tools, genes, and know-how Access to capital markets Economies of market size Skills in dealing with regulatory agencies Flexibility and speed in decision making

Source: Byerlee and Fischer 2002.

Capitalizing on complementary assets and new types of arrangements will require new capabilities in partnering to help rapidly develop a range of public–private sector partnerships. Fischer (2000) suggests that regional networks of public research organizations may be required to strengthen their bargaining position and skills. These developments also raise a series of questions concerning the changing role of public research organizations and ways of ensuring that the developmental mandate of the international agricultural research centers (lARCs) is maintained. Tripp and Byerlee (2000) caution that while there is significant pressure to partner with the private sector as a resource mobilization strategy, this in itself will not improve the effectiveness of agricultural research unless it is guided by specific and relevant opportunities that private partners can provide.

Intellectual property management

The combination of the proprietary nature of much agricultural biotechnology and the related need to engage in new forms of partnership with the private sector means that public research organizations are going to have to deal with intellectual property (IP) issues. For example, Cohen et al. (2002) in a survey of CGIAR centers recorded 166 applications of proprietary research inputs. These included: selectable markers (44); promoters (35); transformation systems (29); insect-resistance genes (19); disease-resistance genes (11); genetic markers (10); diagnostic probes (3); and others (15). The CGIAR as a whole adopted guiding principles in 1996 reaffirming that resources maintained in gene banks should be freely available and that legal protection (so called defensive patenting) of innovations would only be used where necessary to ensure that developing countries have access to new technology.

IP management expertise was established in the late 1990s on a system-wide basis within the CGIAR through the creation of the Central Advisory Service on Intellectual Property Rights (IPR). Around the same time individual centers began to develop similar in-house expertise, with each center developing its own policy governing its products and the use of those of others. This is an area in which the CGIAR recognizes the need to invest in more resources as a response to the growing importance of legal issues in agricultural science (Tripp and Byerlee 2000). While Cohen et al. (2002) argue that the costs involved in developing a management capacity suggest a system-wide approach, there is evidence that individual centers are developing their own capacities, including a range of IP strategies to suit their own contexts and agendas. It is quite clear that IP is set to become an integral component of the use of biotechnology for development.

Capacity development in biotechnology

lARCs have historically played a large role in capacity-development efforts in their counterpart programs at the national level. This has included research infrastructure development, particularly training and human resource development. A capacity-building agenda also needs to accompany biotechnology. However, these efforts should be different in three respects. Firstly, biotechnology is likely to be more generic than previous scientific paradigms, where basic research capabilities will be relevant in both health and agriculture sectors. Secondly, capacity will be in both the public and the private sectors (currently more so in Asia, less so in Africa) and will involve both national companies and multinational corporations and NGOs. This raises challenges for conventional approaches that rely heavily on advanced training (often in developed countries) for public scientists. The third difference concerns more fundamental questions about capacity-building approaches and the desirable characteristics of technological competence in national and international settings. Arnold and Bell (2001) and Velho (2002) argue that increasingly, capacity development in development assistance programs needs to be thought of in total systems terms. That is to say, that what is important is not the individual blocks of scientific expertise per se, but rather the way this links together and integrates with users of technology, including consumers, markets, private industry, and policy processes in specific national contexts. This approach suggests that South–South partnerships will be an increasingly important aspect of capacity building – ie, networking together local scientific, technical, and entrepreneurial resources. East African Bio-Sciences Initiative – a cross-sectoral clustering of scientific organizations related to agriculture and health – is an emerging example of this model. Developing total system capacity has its own challenges, even within individual organizations. Haribabu (2000), arguing that the problem can be as basic as getting molecular biologists to interact with plant breeders, suggests that divergent cognitive empathy is to blame.

Clark et al. (2002a), exploring a case of agricultural biotechnology capacity development in India, demonstrate the way these systemic capacities build up slowly over time. The role of the donor in this successful case was to provide the professional space to allow scientists and others to experiment with new institutional arrangements that promote learning and innovation in the area of biotechnology. In another exploration of this theme, Clark et al. 2002b argue that developing countries often have well trained scientists, but lack the links with the policy process, causing biotechnology policy in many countries to be extremely weak. Consequently, enabling frameworks such as bio-safety and IP regimes develop slowly. This is revealed in the unduly cautious approach of some countries and is restricting the rapid deployment of biotechnology advances (Paarlberg 2000).

Again this suggests that stronger connectivity between science and research users, including policy makers, is required. But it also requires an expansion of the professional mandate of both scientists and administrators in ways that promote a broader understanding of science. This needs to be tackled at many levels, starting with the curriculum of tertiary education so that disciplinary expertise is coupled with an appreciation of the wider context of science in society. The CGIAR centers could play an important role in this more holistic vision of capacity development.

Frameworks for promoting new architectures of innovation

Linear and systems architectures of innovation

At the heart of the challenges that the CGIAR and ICRISAT face with respect to biotechnology is the implied need to embed technology and capacity development in a much broader set of relationships and contexts. The CGIAR is no longer the primary source of new knowledge in this field. Neither can it continue to rely on old architectures suited to the independent development of research products that can then be transferred to others. The challenge facing the CGIAR is to find new architectures to structure its relationships with a range of novel and conventional partners and stakeholders. And to do so in ways that best exploit frontier science for the good of society, particularly the poor.

This challenge is not unique to the CGIAR. Science and technology policy in many sectors around the world has faced the need to redraw conventional approaches to promoting economic and social development in an era of rapid technological and institutional change and increasingly complex techno-economic systems. In response, an important policy shift has been an increased emphasis towards promoting innovation rather than focusing on research alone. As distinct from research and invention, innovation is a much more complex process often requiring technical, social, and institutional changes, and involving the interaction of organizations across the conventional knowledge producer/user divide. Emerging as a useful way of thinking about this is the concept of an innovation system. Here the policy focus is on whole systems and processes of change. This view has overshadowed the earlier science and technology policy preoccupations of resource allocation (Vehlo 2002). Table 2 summarizes the way emphasis has changed in different paradigms of science policy.

Innovation systems thinking

The origin of innovation systems thinking can be traced to the idea of a national system of innovation proposed by Freeman (1987) and Lundvall (1992). The concept brings together thinking from a broad set of theoretical debates[3] that view development and change in systems terms. More importantly it is based on empirical observations of 'good practice' in different countries and technology sectors. At its heart lies the contention that change – or innovation – results from and is shaped by the system of organizations and institutions (in the rules, norms and conventions sense), and in particular by locations and points in time. An innovation system includes organizations involved with research and the application and adaptation of research findings, as well as intermediary organizations that promote knowledge transfer. Lundvall (1992) identifies learning and the role of institutions as critical components of such systems. He considers learning to be an interactive and thus socially embedded process, which cannot be understood without reference to its institutional and cultural context, usually in a national setting.[4]

This has many analytical implications including the need to consider a range of activities and organizations related to innovation and how these might function collectively as a system, and the need to locate research planning in the context of the norms, culture, and political economy in which it takes place, ie, the wider institutional context. Similarly, it is no longer useful to think of institutional and organizational arrangements for research and innovation as fixed or optimal – clearly these must evolve to suit local and changing circumstances. In the same way, the evaluation of innovation performance also becomes much more context-specific, relating to the perspective of stakeholders and current imperatives, rather than either scientific peer review or economic justification alone. Douthwaite (2002) believes that these types of perspective hold true in technological contexts ranging from rice drying in South Asia to wind turbines in Europe and North America. He shows how innovative success is a complex process of learning and adaptation. The innovation systems concept is now widely used in the policy process in developed countries, but has only recently started to be employed in relation to research policy in the South (see, for example, Hall et al. 2001a; Byerlee and Alex 2003).

Applying innovation systems concepts

The innovation systems concept provides a framework for: 1. exploring patterns of partnerships; 2. revealing and managing the institutional context that governs these relationships and processes such as learning and change; 3. understanding research and innovation as a social process of learning; and 4. thinking about capacity development

Table 2. Policy concerns under changing paradigms.

Period/ paradigms[1]	Conception of science	Who produces scientific knowledge	Model of technological change	Policy framework and policy tools	Policy analysis and research evaluation tools	Model of North/ South Cooperation
Post-war period until beginning of 1960s Science as an engine for progress	Historically and socially neutral, follows its own internal logic	The Scientists (Republic of science)	Linear relationship: basic research, applied research, technological development, innovation, diffusion, economic progress and social welfare (science push)	Focus on science policy: large-scale science funding; allocation of resources through institutional normative mechanisms, scientific merit	Peer review (sooner or later the good science finds out its practical application. Input indicators	Problem-solving phase: find quick solutions to development problems through the use of human and financial resources of the Northern countries
1960s and 1970s Science as solution for problems (and also as cause of problems)	Disputes about the neutrality of science	The scientists (but they must be directed and put in contact with the demand)	Linear relationship (the same as above, but demand–pull)	Science policy and technology policy emphasis in resource allocation in terms of priorities (often by sector of activity) Science had to find a way to be used by technological development	Peer review plus output indicators (basically bibliometric) studies: role of S&T in economic growth; history of technology innovation at firm level	Developing indigenous capacities of individuals (problem-solving and research capacities) in the recipient countries
1980s and 1990s Science as a source of strategic opportunity	Science wars (dispute between realism and relativism/ constructivism)	Scientists directly influenced by a complex network of actors and its interests	Complex – includes several actors, a diversity of institutions and processes (Technological trajectory subjected to lock-in – somewhat deterministic)	Emphasis on resources administration and allocation to strategic programs, interdisciplinary and collaborative research (national, institutional and disciplinary level) alliances Technology policy	Intensification of the peer review process, program assessment (concern with the impacts), prospective and foresight	Generate new collab-orative partnerships that benefit both sides, from supply-driven to demand-oriented (involvement of stakeholders by using participatory methods)
21st century Science for the benefit of society (back to the Baconian ideal)	Socially and culturally constructed, national styles	Actor network composed of scientists and non-scientists – configuration varies according to each event	Complex multifaceted (technological trajectories reversible according to social choice)	Emphasis in co-ordination and management. Accountability, maintenance of an independent scientific basis. Innovation policy	Peer review + direct public participation (emphasis given to the process), scenario building with ample social participation - foresight	Learning in a sytems innovation (SI) framework. Co-ordination of donors, competitive funds for research and technology development (RTD)

1. This periodization is based on Gaillard (1998).

Source: Vehlo 2002.

in a systems sense. On this last point, Velho (2002) observes that national systems of innovation – made up of actors that are not particularly strong, but where links between them are well developed – may operate more effectively than another system in which actors are strong but links between them are weak.

Increasingly emphasis is being placed not only on knitting together different elements of national innovation systems, but also on embedding the planning of such endeavours in a wider constituency than only key scientific stakeholders. While these undoubtedly do include the private sector both as an entrepreneurial agent as well as an R&D player, it also includes stakeholders representing wider society. As a result the innovation systems approach treats such issues as biotechnology not only as an issue of nurturing technical and entrepreneurial innovation, but also as developing an institutional and policy environment that mediates between, or regulates, the potentially conflicting agendas of the constituent stakeholders including society at large. While one could argue that national governments in developed countries have not always been entirely successful in their innovation policy efforts – witness the continuing polarization of the transgenic debate in Western Europe – there is also evidence that such an approach offers a potentially large economic advantage (OECD 2000).

Organizational culture and institutional learning and change

One of the important points that the innovation system concept makes is that institutional learning and change are key characteristics of organizations in effective innovation systems. This allows systems to reconfigure in an iterative way as organizations and their partners build up knowledge about ways of dealing with constraints or exploiting new opportunities. The emergence of biotechnology is a good example of an instance where institutional learning and change are required to reconfigure the relationship between different players in the innovation system – particularly between public and private sectors, but also more generally between science and society. Institutional contexts and cultures within organizations are an important determinant of the ability of an organization to respond effectively to emerging challenges. Research managers planning the transition to new technological fields where multidisciplinary and partnership modes of working are required – such as biotechnology – need to pay much greater attention to the culture of their organization and the incentives it provides for the change process and new ways of working (Feller 2002). A key challenge is lowering barriers between disciplinary units, particularly where these have been the focus of measures of professional performance. Often the primary shift required is that from an inward-looking hierarchical mode of management that emphasises administrative control, to one characterized by ‘adhocracy’ that emphasises flexibility in reporting relationships and external orientation (Cameron and Quinn 1999). Feller (2002) provides a useful typology (see Figure 1) to help research managers assess their organizational culture and the possible changes required. The suggestion is not that organizational cultures should resemble any of the four typologies. Instead cultures need to be multifunctional and dynamic, recognizing that an adhocracy is needed to deal with some circumstances, whereas other issues will need to be dealt with in a hierarchical way. Of course the challenge is managing the transitions and conflicts between these different working

Figure 1. The organizational culture profile.

Flexibility and discretion

Internal focus and integration ← → **External focus and differentiation**

Clan Culture A very friendly place to work where people share a lot of themselves. It is like an extended family. The leaders, or heads of the organization, are considered to be mentors and perhaps even parent figures. The organization is held together by loyalty of tradition. Commitment is high. The organization emphasizes the long-term benefit of human resources development and attaches great importance to cohesion and morals. Success is defined in terms of sensivity to customers and concern for people. The organization places a premium on teamwork, participation and consensus.	**Adhocracy Culture** A dynamic, entrepreneurial and creative place to work. People stick their necks out and take risks. The leaders are considered innovators and risk-takers. The glue that holds the organization together is commitment to experimentation and innovation. The emphasis is on being the leading edge. The organization's long-term emphasis is one of growth and acquiring new resources. Success means gaining unique and new products or services. Being a producer or service leader is important. The organization encourages individual initiative and freedom.
Hierarchy Culture A very formalized and structured place to work. Procedures govern what people do. The leaders pride themselves on being good coordinators and organizers who are efficiency-minded. Maintaining a smooth-running organization is most critical. Formal rules and policies hold the organization together. The long-term concern is on stability and performance with efficient, smooth operations. Success is defined in terms of dependable delivery, smooth scheduling and low cost. The management of employees is concerned with secure employment and predictability.	**Market Culture** A results-oriented organization whose major concern is with getting the job done. People are competitive and goal-oriented. The leaders are hard drivers, producers and competitors. They are tough and demanding. The glue that holds the organization together is an emphasis on winning. Reputation and success are common concerns. The long-term focus is on competitive actions and achievement of measurable goals and targets. Success is defined in terms of market share and penetration. Competitive pricing and market leadership are important. The organizational style is hard-driving competitiveness.

Stability and control

Source: Feller 2002.

styles. In the next section we shall see how the organizational culture of the CGIAR and the values that it implies have been a critical area of concern during its attempts to reconfigure itself into a new architecture of innovation more suited to the contemporary context of international S&T.

The evolution of international agricultural science

The history of the emergence of organized agricultural sciences in the form of national research programs and subsequently in the form of the international centers is well known. However, the main points from this history are repeated because the patterns of institutional development explain many of the issues we are facing today. To a very large degree the establishment of the early CGIAR centers reflected the prevailing political and ideological context of the time.[5] Anderson's (1991) discussion of the establishment of the

International Rice Research Institute (IRRI) usefully demonstrates this. The origins of IRRI – and the International Wheat and Maize Improvement Centre (Centro Internacional de Mejoramiento de Maíz y Trigo, CIMMYT) – stemmed from the funding of agricultural research by The Rockefeller Foundation and later The Ford Foundation. It was closely associated with an American foreign policy that saw that food security problems, particularly in Asia, could lead to political instability and the spread of Communism.

The Rockefeller Foundation took the decision that the drive to increase food supply should be technology-led with yield per hectare as the key dependent variable. Complex issues associated with farm size, access to inputs, applicability, and socio-economic relevance were placed to one side in order to focus thinking and resources on the one key objective, transforming agricultural productivity by means of improved germplasm. The focus was on so-called isolable technical problems[6] – isolable in the sense that they could be isolated from the socio-economic context of farmers and the political context of target countries. This dictated to a large degree the central strategy of the early CGIAR centers. The strategy was science-led, with mission success depending on narrow goal specification combined with rigid adherence to the best technological means of achieving the goal as quickly as possible.

The other notable feature of the CGIAR centers was that they were set up at a time when it was quite reasonable to assume that the public sector would play the dominant role in supplying developing-country farmers with yield-enhancing technologies embodied in improved crop and livestock varieties. Indeed this belief was implicit in the relationship that many of the centers had with the NARS in the countries in which they were hosted. The CGIAR's primary partner was seen (appropriately at that time) as the national public sector, and the relationship conformed to a linear hierarchy by which research led to technology, which in turn was passed down from the international centers to national programs, then extension services, and finally to farmers. This greatly restricted the diversity of partners involved in CGIAR research, notably farmers, private industry, and NGOs. Furthermore, as these assumptions replicated themselves over the years, the organizational culture of the CGIAR centers continued to reflect some of the institutional hangovers from the earlier years (Hall et al. 2000). While slowly over the intervening years things did start to evolve, a stereotype of this organizational culture at that time might include the following:[7]

- The main task was increasing food production. This could best be achieved by focusing on increasing yield per unit area under optimum conditions and this was the central criterion for judging success
- Public good research should be undertaken by the public sector unsullied by any commercial interest. The corollary being that interaction with the private sector is highly suspect and should be avoided
- Technologies developed were good and it was the failure of others to transfer these to farmers that was the cause of weak farm-level adoption
- The NGO sector was at best scientifically suspect and perhaps even anti-science, particularly in the latter regard in its attitude to biotechnology
- Research priorities should be set, with the help of economists, by scientists themselves. Analysis of economic rates of return to research investment is the method of choice for assessing research performance

- Impact on the poor, and development more generally, is a presentational problem and the main role of social scientists is to legitimize through impact assessment the good work done by scientists.

We deliberately polarize these points for illustrative purposes. Organizations and their cultures have changed. It is important to recognize, however, that it is this broad position from which many CGIAR centers are moving forward. It is also the stereotype carried around by many of the CGIAR's critics and potential partners, including the private sector and NGOs. The centers are thus double-burdened as they strive towards a new architecture of innovation.

The evolving culture of science at ICRISAT

Historical perspectives on organizational culture

ICRISAT, established in 1972 with a mandate for crops of the semi-arid tropics, was typical of the second wave of CGIAR centers. Although it clearly had a very strong eco-regional focus it was established primarily as a commodity improvement center for its five mandated crops – sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*), and groundnut (*Arachis hypogaea*). The institutional model of ICRISAT was very much of its time. In India the partner organization was the Indian Council of Agricultural Research (ICAR), which was also the main conduit for technology transfer and access to farmers. The private sector (input supply and food and feed industries) was seen to operate in a separate domain in which it had comparative advantage. The Institute adhered, at times quite strictly, to the role distinctions that this design implied – often encouraged by the Governing Board who felt the need to conform to memoranda of understanding with host governments.

It can therefore be seen that the organizational culture of ICRISAT conformed to a linear model of innovation whereby technology is developed and then passed to others for further development and transfer. An area of discourse in the organization that illustrates this is the perennial references to the technology shelf – the mythical repository for research products that are yet to be adopted.[8] In 2001, Hall et al. (2001b) found that despite the continued discussion of this concept as the rationale for establishing new partnerships, interviews with private-sector seed companies revealed that they were less interested in partnering to gain access to technology alone, but instead wanted access to expertise and research infrastructure. In their words it highlighted that there was a need to match what ICRISAT had to offer with what its new partners wanted. This implied the need for a totally different type of relationship that was more consensual and where agendas and priorities were negotiated bilaterally.

Early partnerships with the private sector

Indeed it was against this backdrop, of a rather conservative public-research sector organization that in 1997 a new Director General[9] joined the Institute with the mission to introduce a much more entrepreneurial, forward-looking culture. The new Director General found, however, a number of institutional restrictions to implementing new ideas and, frustrated by the slow process of change, he left. During his short time as Director General, this visionary character seeded the need for change in the organization, although there was still a long distance to travel before this vision could be implemented. Thus, in 1998, two of the Institute's plant breeders, encouraged by the then Head of the Genetic Resources and Enhancement Program, began their 2-year struggle to establish the first research initiative funded by the private sector. The two breeders knew that the Institute had to move on from the paternalistic support that it had been providing to the emergent private-sector seed industry and that a type of contract research was the way forward. However, what they found was that not only were there uncertainties over IPR, but that there was also an uncertainly as to whether the Institute was actually allowed to enter into such an arrangement at all. As such there was hesitation on both the part of the private-sector seed companies and the Institute.

The seed companies' main concern was that of gaining exclusive rights on the products they were to fund ICRISAT to develop – improved inbred parental lines of sorghum and pearl millet for production of commercial hybrid varieties. ICRISAT IP policy allows free access to all germplasm through a materials transfer agreement, thus disallowing an exclusive arrangement. This was finally resolved in two ways. Firstly, the funding was organized through a consortium, thus lowering costs for companies involved, making exclusivity less of a concern. Secondly, the companies were assured that although there would be public access to improved hybrid breeding lines, the companies could take ownership of subsequent materials that came from crossing these with their own lines.

The next hurdle was to get this arrangement approved by ICRISAT Management and the Governing Board. The details of this process clearly indicate that there was a great deal of uncertainty over whether this was something that was appropriate for the Institute (see Reddy et al. 2001). It was passed on to ICAR for their comment before being passed back to ICRISAT where it was rejected – mainly because the sums of money where felt to be insignificant. Possibly one of the most significant points of departure in this story was the change in attitude that took place with the assignment of an Acting Director General[10] who quickly pushed the issue through, commenting that the financial magnitude of the seed consortium was less important than the value of the partnerships it was establishing. It is the vision and conviction of this one individual that marked the beginning of ICRISAT's liberalization with respect to developing partnerships with other organizations. His decision was fully endorsed by the incoming Director General who signed the agreement with the private consortium.

A more recent hurdle that the Institute has faced concerning the principle of partnerships with the private sector, involved creating joint ventures with the private sector and hosting commercial companies within a proposed Agri-Science Park (ASP). The new Director General is firmly behind this concept, but there were difficulties in doing so in relation to the Institute's founding agreement with the Government of India. However, a shift has taken place via interest from the local State government for ICRISAT to host the agri-biotechnology wing of the State-sponsored Genome Valley Science Park, thereby legitimizing the Institute's desire to work intimately with a wider array of private-sector partners through an income-generating model.

Institutional changes and opportunities associated with ICRISAT's applied genomics facility

While ICRISAT has been working on a number of aspects of molecular biology since the mid-1990s, the Institute's biotechnology capability was substantially increased through a US$1 million dollar capital investment in genomics during 2000–02. The Institute was given a substantial grant from the Asian Development Bank to establish marker-assisted selection systems in sorghum, groundnut, and chickpea in collaboration with the NARS of Bangladesh, China, India, Pakistan, and Vietnam. A scientist from the commercial plant-breeding sector in Europe was recruited to establish and manage this facility and the integration of its activities into plant breeding programs in Asia and Africa. Three internationally recruited post-doctoral fellows were also employed to co-ordinate the high throughput genotyping facility. The manager of the facility began a series of initiatives (with mixed success) that involved developing a new relationship with the private sector, including outsourcing, collaboration, and joint ventures.

The first innovation was to initiate outsourcing of research to biotechnology companies in India and Europe. The rationale for outsourcing was to save time and to free up ICRISAT staff to concentrate on more conceptually challenging genomics research: to evaluate a range of national and international service providers in a consistent manner and to relay this information to the plant breeding community. While it was recognized that in the beginning outsourcing may not offer substantial time and net benefits, it was considered an important contribution to capacity building in the region. A similar initiative has also been established for alternative suppliers of training such that ICRISAT staff could become trainers of trainers and thereby release more time for intensive research activities. Again this was the first time that this type of arrangement had been used at ICRISAT and perhaps not surprisingly it took around one year (during 2000–01) to pass through the Institute's approval system and finalize the contractual terms. The scientists driving this initiative bore the brunt of the work, preparing contracts and negotiating with the company (mainly on IPR issues) and, later on, monitoring and backstopping the progress of the research. However, one of the outcomes was that ICRISAT learned a lot about contracting the private sector that it had not previously known. This in turn led to a broadening of private-sector interaction and an appreciation within the Institute of the need to establish dedicated in-house capacity for IP issues. Thus, in 2002, an IP Management Office was created in ICRISAT.

A full-time administrator co-ordinates the IP Management Office with technical backstopping from the Deputy Director General and the Global Theme Leader for Biotechnology. To help him adapt to the new role he took a part-time diploma in patent law. At the time of writing, the Institute is now investigating means of recruiting a full-time lawyer to lead this Office. A great deal of specific legal activities can be effectively outsourced in India. Nevertheless, the presence of a minimum critical mass of in-house expertise is considered essential to enable the Institute as a whole to evolve a much more strategic perspective toward IP management. In addition, as most legal experts focus entirely on legal issues from a commercial perspective, it is critical to establish an institutional capacity to approach these issues from the perspective of a non-profit institution. Part of a longer-term vision here is that IPR may become one of series of expert services, along with bio-safety support, innovation, and partnership policy and strategy, which the Institute can offer to others – either with a view to capacity building under donor support or on a cost-recovery basis. These skills are clearly co-products of current institutional developments taking place at ICRISAT, emerging as the Institute's role and competencies evolve.

ICRISAT's Technology Innovation Center

The Technology Innovation Center (TIC) at ICRISAT is part of the overall vision associated with enhanced linkages and capacity development of the Indian national agricultural industry. Initially, in 2001, it was envisaged to establish an Agri-Biotech Incubator; however, the Indian Department of Science and Technology (DST) approached ICRISAT with a proposal for a broader initiative that was subsequently named Agri-Business Incubator (ABI). Although the ABI has several potential biotechnology components, it is also involved in many other agricultural technology issues (see next section for further details). On this basis, ICRISAT's emphasis in turn moved to a larger initiative for biotechnology that is now encapsulated in the Agri-Scince Park (ASP), which has gained favor with the State government who plan to include it as a wing of the spatially decentralized Genome Valley Science Park (see section on the ASP below for further details). With such a rapid evolution in initiatives driven both internally and externally, it was decided that an umbrella structure should be created to form a single point of access and vision for all private-sector partnership initiatives at ICRISAT.

In order to handle the anticipated cluster of partnership arrangements that the ABI is expected to bring with it, ICRISAT has established what it refers to as a TIC. In fact, not only ABI activities will be handled through the TIC, but also a number of other partnership-based initiatives ranging from biotechnology to rural development. In time this will also include the science park initiative. The purpose of the TIC is two-fold. Firstly, to provide a special-project institutional environment where such different working norms as income generation can be pursued independently of the rest of ICRISAT. Secondly, to act as a clearing house for proposals and establishing principles. To this end a committee has been constituted in ICRISAT.

Agri-Business Incubator (ABI). The related idea of an ABI has crystallized. Whereas the science park mainly concerns capacity development and collaboration on pre-competitive research,[11] the ABI sits firmly in the domain of commercialization. The rationale here is that ICRISAT and its public partners have a range of existing technologies that can be exploited by private companies if the combined efforts of entrepreneurial and scientific skills are incubated. The origin of this initiative was an approach by the DST requesting ICRISAT to apply for a scheme under its National Science and Technology Entrepreneurial Development Board. The scheme provides a grant that ICRISAT had to match. This grant is then used to support private companies in their attempts to develop and commercialize promising technologies.

The ICRISAT scientists involved in making the application (a molecular biologist and a bioinformatics specialist with extensive previous experience in physiology and agronomy) had for a number of years seen the need for and opportunities associated with working with the private sector. However, in the past they had found that there was no framework for negotiating a working arrangement with the private sector. The ABI provided that framework, normalizing an arrangement whereby the Institute could recover costs associated with a joint venture that promotes the development and uptake of ICRISAT science, while at the same time provides a profit-making opportunity for the private sector. The framework also makes provision for ICRISAT to have equity holding in the companies involved. Bureaucracy has been kept to a minimum, with the Director General of ICRISAT having authority to approve any new initiative he sees fit under the ABI.

An example of this arrangement was a gene gun developed at ICRISAT. The equipment had a lower performance than commercially available equipment, but could be made for a fraction of the cost. An ex-ICRISAT employee (previously a technician involved in the gun's development) has set up a company to manufacture this equipment. Under the ABI, ICRISAT scientists helped modify the design and made it a viable and cost-effective choice for the Indian market. ICRISAT was paid for the additional research expenses and it also gains goodwill from its involvement.

The ABI is still at an early stage, having had funding approved at the time of writing. Once again, this is new territory for ICRISAT and will require new tasks and norms to make it work. One new task will be to match technologies with private sector partners wishing to commercially exploit them. ICRISAT is approaching this with two innovations. Firstly, it plans to recruit a manger for ABI. This will be somebody with a business management background whose task will be to identify partners, negotiate terms, develop business plans, assess viability of product options, and provide support to the company during the incubation phase. Secondly, it is recruiting staff, with legal expertise, particularly relating to intellectual property issues. While ICRISAT has done some of these things before, it has never employed a professional in this area. This is therefore another important departure in the evolution of science culture at ICRISAT – specifically, that it (formally) recognizes the complementary importance of science, business acumen, and skills relating to negotiation and relationship building.

Agri-Science Park (ASP). Biotechnology-based companies in India are being encouraged to establish ventures at ICRISAT. A primary driving force was the substantial excess of capacity currently available at ICRISAT Headquarters in India. At the same time it was realized that almost none of the plant breeding programs in India can muster capital investment to the level dedicated at ICRISAT for high throughput genotyping in support of plant breeding. Indeed, ICRISAT had invested in capacity beyond its own immediate need. This been done explicitly to enable leasing excess capacity to NARS and private-sector breeding programs to provide a low-cost entry point in to this new paradigm of plant breeding. The idea here was that a broad range of companies would be attracted to establishing biotechnology activities at ICRISAT. These might be start-up biotechnology companies, breeding companies wishing to move into biotechnology activities, or international companies interested in expanding their outsourcing activities. The availability of laboratory, greenhouse and field facilities and ready access to ICRISAT expertise were expected to be a major points of attraction to all these ventures.

An organizational culture in transition: decisions on the road ahead

The organizational culture of ICRISAT has quite clearly changed in recent years, with an increasingly liberal policy towards partnerships with the private sector. A variety of fundamental changes in the way science is conducted have flowed from this policy shift. For example, there has been an expansion in the legitimate professional skills that need to be part of modern scientific endeavor. This has particularly been so in the area of legal and business development issues but also in terms of the type of relationship scientists have with the private sector and others from outside the Institute.

The change process

Implicit in many of these developments has been the recognition that the culture of the organization had to change to accommodate new ways of working. So, for example, underlying the idea of the ASP was the hope that the presence on campus of young dynamic professionals from the bio-/agri-enterprise sector would expose ICRISAT scientists to different perspectives on science and ways of working. This in turn was viewed as supportive of agricultural technology development in an emerging paradigm of R&D that involved much greater collaboration between public and private sectors. As part of its wider agenda of change, ICRISAT believed that it could also support the positive evolution in national programs through opening its doors to three-way partnerships (ICRISAT–NARS–private sector). The approach has been cautiously received by scientists within ICRISAT and the international donor community. However, the very positive response from private-sector companies and State government suggests that it may be successful if appropriate and sufficient changes in public-sector mindsets can be achieved in a short time. For this reason, pilot projects with limited IPR concerns have been chosen for proof-of-concept initiatives.

Viewing the private sector as an important partner and critical conduit for impact has not always been readily accepted by all stakeholders from national public research programs. Thus the need for an international public goods organization to be involved in capacity building in the private sector becomes an even more daunting prospect. Finally the catalytic value of proximity and intimate relationships with product-driven researchers has been a particularly difficult rationale for some stakeholders to appreciate.

The learning process

The creation of the TIC at ICRISAT has been a powerful 'learning by doing' process for the Institute's Governing Board, management, scientists, and stakeholders. Again this learning process has been part of the task of changing the culture of the organization. Perhaps one of the most pervasive lessons that has been learned during this time, is the critical importance of process and the great difficulty that scientific organizations experience if institutional change is not driven and reinforced at the right level, in the right order, and at the right pace. However, not only are these issues highly intangible, they are also highly contextually specific. Inevitably this means that a successful process can rarely be designed (beyond a standard framework) but must evolve through a dynamic iterative process that is both time- and emotionally intensive for all concerned. Thus, although the rewards may be substantial, the investment is equally significant. Clearly, scientific organizations and their staff must be entirely convinced of the need and value of this investment if their collective goal is to have a reasonable probability of success.

The transition process

The transition in ICRISAT has not been easy for anyone – too slow for some, yet too fast for others. The time delays discussed above reflect the degree to which change has been contested. But note also that change is gathering pace as scientists and administrators become more comfortable with the new organizational culture that is emerging. Of course this acceptance has not been evenly spread across the staff at the Institute, with some disjunction between the Institute's professed policies and the personal attitudes of some of its scientists and administrators. Some view the private sector as the 'smash and grab' partner overly concerned about exclusive agreements, while others feel reluctance to enter the rapidly changing world of the private sector and the complexities of, among other things, negotiating IP issues. What is clear is that as biotechnology becomes a more pervasive force for change, ICRISAT will be increasingly drawn into relationships with new partners, not just those in the private sector but with a range of developmental stakeholders. New skills gained through building relationships with the private sector will be equally valuable for building partnerships with NGOs and civil society groups.

Decisions on the road ahead

Discussions with scientists reveal many opportunities and challenges. For example, stemming from the recent approval of *Bt* cotton in India, many smaller seed companies have recognized the importance of value-added products in a highly competitive market and are approaching ICRISAT for transgenic services. In turn, with greater investment there is an increasing eagerness to protect intellectual property and this is intensified by the strengthening of variety protection regulations. Thus, companies are approaching ICRISAT for molecular fingerprinting services for plant variety protection (PVP). It is expected that in due course they will move on to needing molecular fingerprinting services for distinctness, uniformity, and stability (DUS) testing and marker-assisted selection (MAS).

Should ICRISAT pursue these opportunities to develop a cost-recovery service that could perhaps cross-subsidize core research while at the same time bringing the Institute closer to the end-users? As mentioned earlier, ICRISAT is building up new types of expertise in IPR and partnership development and management. How can it best take advantage of this? This dilemma will not go away and in the future the private sector will continue to approach ICRISAT with an increasingly diverse array of demands. While this offers opportunities, these will be only exploited if both sides develop the skills needed to build partnerships. Scientists observe that it is difficult to establish dialog, often because there is little understanding of what either side wants, or is able to do. Here definitive contract development, although initially time-consuming, becomes critically important to offset subsequent wasted time or complete collapse of the partnership.

Frameworks for choices

Over and above these concerns, however, in an increasingly scarce funding environment it is all too easy to lose sight of the reasons the Institute is pursuing these new types of relationship. Resource mobilization alone cannot be the deciding factor. What is the framework for making decisions on these matters, particularly in terms of setting priorities that abide by the overarching goals of poverty reduction espoused by ICRISAT and the CGIAR in general? The ASP and perhaps to a lesser extent the ABI raise these question most profoundly. So while the Institute faces the challenge of developing ways of partnering with unfamiliar players, it also has the task of establishing new mechanisms to govern such arrangements and provide a framework for making informed choices relevant to the Institute's mission. In other words, it needs a way of identifying those new opportunities that truly strengthen its position and unique mission, and filtering out those that do not. The fact that the main thrust of these partnerships will be in the area of biotechnology also suggests that existing mechanisms for setting research priorities by scientists and economists will be inadequate. The reason for this relates to the on-going tensions between advocates and critics of biotechnology. While much of the debate is ill-informed, scientific defensiveness is likely to confound consensus building and agreement on ways to move forward. Developing broader acceptance of biotechnology, defusing public concerns, and building trust in the decision-making processes of ICRISAT will be needed if ideas such as a science park are to gain the widespread legitimacy they deserve. The key question therefore concerns how this can be achieved and what are the implications for the evolving culture of science at ICRISAT?

From patronage to partnership: towards a new architecture of innovation

In order to discuss ways to move forward we now review international experience in dealing with some of the issues ICRISAT is facing. We focus on two main questions: how to build linkages, and how to develop consensus across a broad range of scientific and non-scientific stakeholders. Returning to our earlier discussion of innovation systems, it can be seen that the desirability of viewing technology development and diffusion on a broader canvas of partners and institutions is a mainstream concern in many of the OECD countries. We will explore two mechanisms and comment on their implications for ICRISAT. Firstly, science parks, an idea already widely discussed at ICRISAT. Secondly, foresight, a concept new to ICRISAT but one that we believe has much to offer.

Science parks

The concept of science parks originated in the USA where the first science park, ie, Stanford Research Park, was established in 1952. Industry soon realized the advantage of site proximity to a university, a pattern that emerged in the late 1970s and 1980s. The flurry of building research parks in the 1980s represented the second wave of interest in the concept.[12] MacDonald (1987) lists the following defining features:

- A facility that allows businesses to locate in close proximity to (usually) public science
- Formally and operationally there must be at least one 'reservoir' of technology and expertise, usually universities or research institutions
- An organization that provides management support for its tenant companies.

Westhead (1997) claims that science parks reflect an assumption that innovation requires a catalytic environment that occurs when those involved in research interact both formally and informally with those involved in business and profit. Many of the science parks have incubators either separately managed or managed as an integral part of the park. An incubator is defined as a property with small work units providing a supportive environment for entrepreneurs and investors during the start-up stage of their business. But an incubator should be much more than just the premises; it should seek to build a culture of entrepreneurship by providing access to a wide variety of facilities, equipment, and expertise (if possible on a lease basis so as to offset the high capital costs barrier for biotechnology start-ups). Businesses are encouraged to leave the incubator when they have established sufficient market strength, and frequently relocate to a science park proper where relationships may be looser and of a long-term nature.

It is difficult to appraise the effectiveness of science parks because the objectives of the different partners in the parks may differ considerably (Monck et al. 1988). However, the general consensus seems to be that by virtue of its positive effect on the economy the science park has been variously employed by different investors: for example, by universities for transferring and commercializing technology; by the private sector for profit (as a type of real-estate business); by governments for job creation, building technological capability in the private sector, or accelerating economic growth, etc.

The concept of a science park addresses many of the issues with which ICRISAT and the CGIAR are dealing, namely the disjunction between research and private enterprise between technology developers and technology users. The concept is probably more suitable for scenarios where the private sector has an underdeveloped R&D capability but a good understanding of the market demand for products. A business incubator idea may also be appropriate where it is felt that ICRISAT and its NARS partners have potentially commercializable technologies that the private sector could adapt, refine, and promote. However, any initiative of this type needs to be approached bearing in mind two major caveats:

- Firstly, neither of these ventures can be entered into lightly, as significant financial and human capital investment is required for such ventures to work effectively
- Secondly, the concept is seductively appealing to those who view this as a relatively simple task of transferring technologies from the ‘shelf’ to the waiting private sector. The real significance and power of such arrangements is that they establish long-term relationships with the entrepreneurial sector. In turn, this opens up the possibility of jointly identifying research priorities and helping facilitate research–client iteration that is such a crucial element of the innovation processes. This closer relationship also holds the promise of such further institutional innovations as joint public–private ventures and other hybrid organizational types. While this may sound far-fetched, the close working relationships that science parks offer opens up a space for the discussion and negotiation of new working arrangements and related institutional innovations.

From the perspective of an international agency such as ICRISAT, partnership with the private sector is not necessarily a good thing per se. The question therefore remains as to what would be the most appropriate framework for governing such an arrangement in the light of ICRISAT’s wider developmental goals?

Technology foresight

Technology foresight is an increasingly widely used mechanism for linking science and technology more closely to the nations' economic and social goals (needs). Martin (1996) argues that with increasing pressure on government spending, there is a move towards greater public accountability, leading to an increasing need for alternative mechanisms to make choices effectively with the limited resources available in science and technology. While these themes reflect national concerns, they are familiar issues for CGIAR centers such as ICRISAT.

Yuthavong and Sripaipan (1998) state that technology foresight is a process of looking forward, and involves interaction between scientists and technologists responsible for the science and technology push, and sociologists, economists, other professionals, and laymen providing the market-pull, to produce a balanced perspective for the planners and policy makers. They further state that it focuses on the prompt identification of emerging technologies, still in the pre-competitive stage of development and often requiring government support because they have not yet reached the market stage. Technology foresight is therefore concerned with being able to maximize the foreseen benefits and minimize losses in the context of future societies.

The approach relies on establishing working committees and expert panels[13] from a broad range of scientific and non-scientific stakeholders to make predictions about future technology and society scenarios. It thus provides decision-makers in both public and private sectors with the background intelligence on long-term trends needed for broad direction-setting. By relying on broad-based participation to develop future scenarios – and note that it concerns multiple futures not a single vision – foresight has both product and process outcomes. Product outcomes in the sense that the approach provides working plans that enable technology planning to be based on wide consensus. Process outcomes lie not only in that they promote consensus and trust, but also because they build linkages between different elements in the innovation system. It is in this sense that technology foresight is a collective learning process leading to the building of new networks and 'wiring up' of national systems of innovation (Martin 1996).

Towards a consultative foresight process in the CGIAR

How does this concept have relevance to ICRISAT in particular and the CGIAR in general? In particular, how can it contribute to the CGIAR need to focus its partnership-based initiatives for poverty reduction as a guiding principle? One possibility is that a consultative foresight process is attached to the range of public–private sector partnership activities clustered under, for example, ICRISAT's TIC. Foresight stresses the need to canvas the opinion of what is in essence a constituency of stakeholders. For ICRISAT this constituency would certainly include national and international scientific partners from both the public and private sectors. But it would also include donor representatives, NGOs and civil society organizations, farmers federations, and farmer-operated organizations such as co-operatives. It could also include social commentators such as the advocates and critics of biotechnology. In other words it would bring together the whole spectrum of interests related to science, agriculture, rural development, and poverty reduction. The outcome of any discussion among such a diverse group would undoubtedly be a compromise, but that would be the objective – ie, to try and make decisions about research and technology policy that are based both on informed discussion and on consensus between science, business, and society. While foresight in these terms could be viewed as a governance structure dealing with accountability to stakeholders and a more consensual approach to priority setting, the process of foresight is equally important. For ICRISAT it would provide a mechanism for networking with a wider set of organizations than those with whom it would normally interact. Not only would this be valuable for developing scientific and business alliances, but it would also help break down barriers and build trust with critics and adversaries. There are convincing arguments that suggest demonstrating a shift to a culture of science that is truly driven by stakeholder consensus would be attractive to the more sceptical donors, as well as to private-sector sources of funding. While a foresight approach might sound both fanciful in its conception and painful in its execution, it is a practical approach to operationalize the rhetoric of partnership, consensus building, and poverty reduction that is now so widespread in the CGIAR system.

Conclusion

As a result of the new age of biotechnology, and probably as never before, the CGIAR centers are having to revisit the underlying principles that govern the way international agricultural research is conducted. While inevitably we are all prisoners of our own institutional histories, the culture of science in the CGIAR centers is evolving in valuable ways. The core of the dilemma is that while biotechnology has much to offer, this international public goods endeavor has to strike a new bargain with both private industry, who own much of the technology, and society at large who remains cautious and often ill-informed. Individual CGIAR centers such as ICRISAT are operating in specific contexts with their own threats and opportunities. In this paper we have seen the way the approach of the Institute is unfolding and how the culture of science is gradually changing. The broad message that we would like to underline is that there is no blueprint on ways to proceed. There are, however, well established conceptual principles, particularly regarding process, that can provide a framework for planning innovation and change – particularly the innovation systems framework. From this school of thought come such practical tools as the consultative foresight approach. We recommend that scientists, administrators, and policy-makers give these concepts and principles due consideration while planning the future of CGIAR science.

Endnotes

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2. The CGIAR (established in 1971) is an informal association of public and private sector members that supports a network of 15 international agricultural research centers. It is managed and core-funded by the World Bank.
3. Edquist (1997) provides a useful review.
4. Gibbons et al. (1994) makes a broadly similar point in their much-cited discussion of mode one and mode two production of knowledge.
5. For detailed discussion see Anderson (1991); Anderson et al. (1991); Reece (1998).

6. Anderson (1991) quotes the term 'isolable' from contemporary Rockefeller Foundation archive material.
7. Based on the authors' experience, this would have probably been typical 5–6 years ago.
8. The origins of this terminology may have emerged from an External Programme and Management Review that commented on unadopted technologies.
9. Dr Shawki Barghouti.
10. The then Head of the Genetic Resources and Improvement Program.
11. Research in which the private sector alone may not invest, either because of entry costs or because research products initially may not be sufficiently 'near market'.
12. There is no uniformly accepted definition of science parks and there are several terms used to describe similar developments such as research park, technology park, business park, business innovation, 'technopoles', science centers, center for advanced technology, technology business incubators, and similar versions of the same concept (Monck et al. 1988). The terms 'science park' and 'technopole' are used most commonly in Europe, while the term 'research park' is preferred in the USA and Canada.
13. Most foresight exercises use techniques such as expert panels, brain-storming scenarios, or commissioned studies from consultants rather than the Delphi surveys that were classically used in the pioneering efforts of the Japanese (Martin 1996).

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6. Strengthening science and technology policy in the field of environment and development: the case of the African Centre for Technology Studies Capacity Development Programme

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Abstract

A capacity-building program was undertaken over a 4-year period during the mid 1990s. The African Centre for Technology Studies Capacity Development Programme was established in 1994 to enhance policy analysis capacities in sub-Saharan Africa with special reference to issues of technology and environmental policy arising out of Agenda 21 at the Rio Earth Summit, 1992. A number of important features and lessons emerged from this experience: 1. the introduction of policy analysis directly to the recipients (government officials) and the providers of knowledge (research sector); 2. focus on the problem as the unit of analysis rather than the academic discipline; 3. combination of broad orientation lectures and seminars (to bring participants up to speed with basic issues and agendas) with field research project work (to show participants that there is much to be gained by interacting directly with those at the receiving end of public policy) 4. training in basic communications skills (verbal and written); and 5. focus on a specific set of policy issues (those arising from the Convention on Biological Diversity and the United Nations Framework Convention on Climatic Change). Despite some success with this approach it became clear that this a new form of capacity building that needs further exploration. The main lesson perhaps is that such initiatives should be tried out in other contexts. What is certainly true is that the need for this type of capacity building program is a sad reflection on the higher education sector in many countries.

Introduction

The African Centre for Technology Studies (ACTS) Capacity Development Programme [CDP] was established in 1994 to enhance policy analysis capacities in sub-Saharan Africa (SSA) with special reference to issues of technology and environmental policy arising out of Agenda 21 of the United Nations Conference on Environment and Development (UNCED). Agenda 21 was negotiated and agreed at the Earth Summit in Rio de Janeiro in 1992. It set out the goals and mechanisms designed to achieve sustainable development. Its main focus was to build capacity amongst public officials to implement sustainable development programs related to the major international environmental conventions with special emphasis on the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC). The CDP training courses were also made available to selected personnel

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from research institutions, the non-governmental organization (NGO) sector, and private enterprise. The concentration was on public policy analysis and the skills imparted covered policy research, formulation, implementation, monitoring, control, and evaluation. Over the 4 years between 1995 and 1998 nine courses took place, including an initial trial course early in 1994. Some 60 people in all benefited from the training. Typical issues covered included intellectual property rights (IPR) protection and technology transfer promotion, protection of indigenous knowledge, regulation of access to genetic resources, biosafety regulation, environmental planning, the valuation and sustainable use of biodiversity, local incentives for environmental protection, and the transfer and adoption of 'clean' technologies.

This paper has been included in this book for two reasons. Firstly, it represents an innovation in technology development; as far as we know nothing similar has been attempted previously. Secondly, it is an example of a consortium of organizations getting together for a common purpose and then learning how to do things better as the project proceeded. In fact the CDP as a whole was a learning experience and for this reason evolved significantly over the period from 1994–98. Several early assumptions and procedures were found to be misplaced and corresponding changes were put in place. The second section attempts a definition of capacity building and explores how it was becoming increasingly important in the period before the CDP was launched. The third section describes in detail why the CDP was started, while the fourth section outlines how the CDP was structured and implemented. The fifth section deals with finance and administration, and the sixth explains how the training course received academic validation from a Northern university with relevant expertise. This is followed by an overall evaluation, and finally some overall conclusions about partnerships and the need for institutional reform are drawn.

Capacity building

The notion of capacity building has come on to the developmental agenda comparatively recently and is now enshrined as a primary objective in the mission statements of a number of relevant international bodies. Discussion of 'capacity' probably goes back to the Berg Report of the early 1980s (World Bank 1981) when it seems to have been used as a 'catch-all' concept to denote the need for many Third World countries to take charge of their own developmental destiny. Later on, perhaps the agency that has made it most central to its mission statement is the United Nations Development Programme (UNDP), particularly in relation to environmental conservation. The mission was launched at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 as Capacity 21 and was hailed as the 'main post-UNCED international effort to take forward the principles that were agreed at Rio [to] assist countries to attain sustainable development' (UNDP 1994). UNDP define capacity building as the 'sum of efforts needed to nurture, enhance and use the skills of people and institutions to progress towards sustainable development' (UNDP 1994). In 1993 UNDP instituted a funding program to enhance this capacity. This was a program designed specifically to involve as wide a spectrum of 'stakeholders' as possible. A typical project under this program was one for Swaziland, designed to integrate environmental management strategies into the National Development Strategy and to do so using 'new participatory processes'. Another was a project co-sponsored with the

United Nations Environment Programme (UNEP) designed to build capacities in the field of environmental law; such capacities are needed for the implementation of national obligations incurred under various international protocols.

Environmental management has increasingly come on to the international policy agenda as a result of UNCED and the subsequent meeting at Kyoto in 1997. The problem is that, despite good intentions on the part of politicians who sign up to international agreements, the 'capacity' of governments to fulfill resultant obligations at the national level is often weak. Administrative organizations are accustomed to the applications of fairly standard policy instruments such as those associated with monetary and fiscal interventions, but these have difficulty in coping with issues involving the natural environment. Thus, for example, Clark and Juma (1998) have criticized the 'incremental cost' rule used by the Global Environmental Facility (GEF) in decision-making about projects designed to fulfill such agreements at the national level. Their proposition is that measures to deal with environmental degradation cannot rest solely on a project basis that is informed only by such a rule, analytically useful though it may be. Economic systems are complex things that evolve in unpredictable ways and whose development is of central importance to those who live and work in them. Donors are sometimes curiously ambiguous on this point. On the one hand they prefer lending rules that are bureaucratically easy to administer, while on the other hand they would like recipients to behave in ways that reflect their own political agendas, which in turn reflect pre-dispositions about how development really takes place. What they tried to show, however, is that since economic systems evolve unpredictably (at least relatively so) there is a prima facie case for capacity-building at the policy level to accompany project decisions that are environmentally related.

A similar point has been made by Hayes and Smith (1993) who point out in a detailed survey of relevant contributions that "a greenhouse regime must be flexible enough to demonstrate what is possible rather than to strive for final policy commitments that are simply ignored" (Hayes and Smith 1993). There is little point, for example, in relying on the importation of (environmentally) clean technologies (through project aid) in the absence of the capacity to understand what these technologies are, and how they may be diffused throughout the economic system. Instead they call for donors to "accept longer time horizons and invest in long-running training programs rather than (rely only upon) traditional aid projects" (Hayes and Smith 1993).

But what exactly is 'capacity' and how can it be defined? In its earlier guises it was mainly about management of structural adjustment through local ownership of resources, local human resource development, and the relative avoidance of expatriate influences (eg, through consultants). In its more recent guises it has become more to do with governance and how institutional innovations can help ensure greater efficiency and accountability in the mobilization and control of national resources (King 1992). The CDP, however, was influenced by a yet more recent orientation, the technological capabilities that countries have (or do not have) to transform their economic systems. Although interest in this area is comparatively recent in the development literature it is arguable that capacity defined in this way probably underlies all other definitions, simply because it relates to the capacity of an economic system to transform itself. It therefore has the following broad properties:

- It is concerned with people-embodied skills and competences
- It carries with it the notion that such ‘capacities’ go well beyond expertise in the normal (reductionist) sense of that word. In particular they are not isomorphic with academic disciplines
- The idea of ‘capacity’ is often concerned with technology and technological transformation of resources for socio-economic ends
- There is a frequent, if tacit, assumption that ‘capacities’ are underrepresented in disadvantaged groups (ie, women, the rural labor force, the poor, etc)
- It is frequently stated (or implied) that more resources ought now to be channeled into ‘capacity building’, if necessary at the expense of such traditional instruments of economic development as higher education, major investment projects, or the employment of expatriate consultants.

Perhaps the best way of approaching the concept is through the recent writings of a school of economists who take inspiration from the writings of Joseph Schumpeter. Schumpeterians, although very few of them have actually paid much attention to Third World problems, start off from the position that innovation is the key ingredient in economic transformation, stressing the importance of a total systems approach to the development problem and, within this, the great significance of what have come to be known as ‘technological capabilities’. While there is no single accepted definition of this term, nevertheless a growing minority of analysts and practitioners have begun to realize that it somehow captures the essentially creative and non-linear realities of the change process, a process that it is essential to understand if the world is to proceed rapidly towards sustainable development (see Adeboye and Clark 1996 for a fuller discussion of this point).

Technological capabilities have recently been defined in various ways by a range of analysts. Lall (1992), for example, sees them as a range of capacities that allow an economic system to understand best-practice technology on a world scale and to use this understanding to promote more rapid economic growth than would otherwise have been possible. Such capacities are closely determined by indigenous technological efforts to master new technologies, adapt them to local conditions, improve and diffuse them within the economy, and then exploit them overseas by manufactured export growth and diversification, and eventually by the export of the technologies themselves. Bell and Pavitt (1993), for whom the notion of ‘capability’ is equally concerned with the capacity for change but express it rather differently, have suggested another definition: “We draw a distinction between two stocks of resources: **production capacity** and **technological capabilities**. The former incorporates the resources used to produce industrial goods at given levels of efficiency and given input combinations: equipment (capital-embodied technology), labor skills (operating and managerial know-how and experience), product and input specifications, and the organizational methods and systems used. Technological capabilities (on the other hand) incorporate the resources needed to generate and manage technical change, including skills, knowledge and experience, and institutional structures and linkages. We emphasize the distinction between the two because we are primarily interested in the dynamics of industrialization, and hence in the resources necessary to generate and manage that dynamism.” (Authors’ emphasis.)

Traditionally there was emphasis on the former because it was simply assumed that the latter would occur automatically as a kind of marginal ‘add on’ to direct foreign investment. However, nowadays it is slowly being realized that, with the growing knowledge intensity of production, that is not so. Indeed, if we can accept the historical research of authorities like Fukusaku (1992) and Fransman (1995), it was probably never really the case. Fukusaku shows how the technological development of the Japanese shipbuilding sector over the period 1880–1939 was heavily dependent on systematic investments in technological capabilities carefully orchestrated by both corporate and national policy. And for Bell and Pavitt (1993) it is therefore essential for policy to focus on this area. In particular they stress:

- The importance of direct foreign investment
- The growing importance of the science base, and therefore the need for heavy investments in education, training, and skills
- Appropriate incentives for innovation and imitation
- Favorable product-market conditions
- Institutions and policies that will encourage learning.

However, they readily admit that we still do not have much idea about the conditions for successful learning, arguing that "we have too few careful empirical studies in developing countries of the nature and determinants of successful learning at the level of the firm or industry, including the role of government policy and supporting institutions" (Bell and Pavitt 1993). What is common to both sources, and indeed to many others such as Hobday (1994a; 1994b), Weiss (1993), and Ernst et al. (1998), is that capacity-building in this (technological) sense has a number of specific characteristics which tend to set it apart from traditional definitions. These characteristics are that:

- The acquisition, validation, and use of knowledge is fundamental to capacity-building
- This knowledge is not freely available, but on the contrary, has to be sought through the committal of scarce resources
- It is not universally applicable across time and space but has to be adapted to the context in which it is to be used
- It can be held both by individuals and by organizations
- Its effective promotion and use in an economic sense needs to take place as close as possible to the process of economic production
- Its effective promotion will need new types of institutional structures.[4]

Programme rationale

As outlined above, the CDP began in 1994 although its planning began in 1993 under the auspices of the Second ACTS Medium Term Plan. Prior to 1993 ACTS had developed primarily as a contract research institution funded mainly through project grants and consulting income. The rationale for moving into human resource development as well was as follows:

1. Interdisciplinary research bodies breaking new ground have always had great problems recruiting suitable staff.
2. The existing pool has often been brought up in conventional ways, ie, learning analytical techniques in university systems structured on the basis of single disciplines.
3. By the time a student has proceeded to the graduate level (and gone on to obtain a masters or a doctoral degree) he/she usually has great difficulty in engaging in the kinds of activities needed by such research bodies as ACTS.

This problem was compounded in two further ways. Firstly, the idea of 'policy research' is extremely novel even in such industrialized countries such as the UK, so that temporary assistance from an international pool is hard to obtain, notwithstanding the normal difficulties associated with the acquisition of work permits. Secondly, many African universities have regrettably declined greatly over the past 15–20 years in terms of the quality of their educational provision. And this is particularly so at the postgraduate level where it is actually very hard to identify a school providing the types of empirical training necessary for the production of good quality research staff relevant to ACTS. All too often, for example, students appear able to obtain masters degrees without ever having engaged in sustained field research; the absence of this type of 'research culture' in graduate schools appears to strongly influence subsequent research performance. In short, ACTS was forced into 'growing its own staff' and the CDP was established partly for this reason.

It was also becoming clear at ACTS that despite considerable success in producing the normal output of a research institution (ie, through reports, articles, books, etc) these were not apparently having the direct impact on policy that was expected. In fact, it had become clear that policy advice is only acceptable if recipients actually understand it and since few apparently did, this meant that ACTS would need to begin to create its own 'constituency' of policy-makers. It was partly for this reason that the CDP concentrated primarily on building capacity amongst public officials to implement sustainable development programs associated with obligations incurred by national governments under recent environmental conventions. The focus was therefore to be on public policy (ie, on analysis, research, formulation, implementation, monitoring, control, and evaluation) pertaining to sustainable development in general, although subsequently the program narrowed down mainly to issues associated with biodiversity conservation. In addition it was expected that operating at a regional level would help to create a regional 'constituency across sub-Saharan Africa (SSA)'.

However, probably the most important factor was objective need. For it was already becoming clear that although much of Africa had signed up to Agenda 21 and the associated conventions, the actual implementation of associated action plans, policies, etc, would certainly be hindered because of lack of public policy-making capacity. If progress towards fulfilling the goals of the CBD was to be made, for example, national governments would need at the very least a cadre of trained people that not only understood the CBD but could also advise on its substantive implementation. Hence the need for suitable training courses was also self-evident. Indeed, subsequently, ACTS found that it is still the only international organization mounting policy-oriented courses to meet such a need.

Course format

Typically the CDP training courses lasted for 3 months. They normally specified a particular theme and were implemented on a dual-track approach. In the first place participants were introduced, through a series of lectures, workshops, discussion groups, and plenary sessions, to a range of topics of relevance to the overall theme of the course. In most cases these were provided by ACTS own training staff, although international experts were often brought in from such bodies as the World Resources Institute (WRI), Washington, at various points in CDP to provide up-to-date insights on specific issues and organizations. In addition, field trips were arranged to enable participants to visit institutions whose work relates closely to the implementation of international environmental agreements.

Besides this general orientation, emphasis was also given to a second activity, that of the preparation of a policy paper. Participants were expected to bring with them a problem of particular relevance to their own country that they then researched during the training course. All participants were assigned a personal tutor whose function it was to act as an academic adviser throughout the course. In particular, the personal tutor advised participants on developing their project proposals. During the course they were provided with relevant writing, presentation, policy research techniques, problem formulation, and other skills necessary to carry out this task. Participants also had available a series of specially selected texts in the ACTS library and were taken to the UNEP and the International Union for the Conservation of Nature (IUCN) libraries from time to time. By the end of the course they were expected to prepare and submit a policy paper and to present their findings at a final regional workshop.

International quality standards

Course certificates were validated through a special arrangement with the Graduate School of Environmental Studies (GSES), University of Strathclyde, UK (see further discussion below). This link was supported by a grant from the UK Darwin Initiative for the Survival of the Species. Besides supporting the travel costs of Strathclyde staff to Africa the Darwin Initiative also provided a number of fellowships to fund travel, maintenance, and tutorial costs for trainees who perform well enough on the courses to be considered for acceptance into the Research Degree Programme at Strathclyde. What was particularly innovative about the ACTS/Strathclyde relationship is that these research students spend most of their time (65%) in Africa on both fieldwork and supervised desk research.

Links to other ACTS activities

It is important to stress links to other ACTS programs. For example, through its regional workshops the CDP provided a forum for raising public awareness on international and national environmental policy issues. The research output of ACTS provided updated materials for the courses, while very often the policy papers of the participants contributed to ACTS published output. Finally, on returning home trainees began to provide a 'constituency' for ACTS policy research in many parts of the continent, since they provided a focus for the comprehension, interpretation, and implementation of associated policy recommendations.

Finance and administration

CDP had two types of funding: 'core' and 'fellowship'. The former was designed to cover the overhead costs of administration, while the fellowships covered the marginal costs of the individual courses. Core funding for CDP was originally supplied by the Norwegian Agency for Development Co-operation (NORAD). Subsequent core finance was provided by Norway (NORAD) and Sweden, the UK Darwin Initiative, and the John D and Catherine McArthur Foundation. Fellowships were supplied by Finland, NORAD, and the McArthur, Sasakawa, and Ford Foundations. These fellowships, worth some US$10,000 per participant, were normally split into two equal parts. One part was to meet the maintenance, incidental, and travel costs of participants, while the other covered the tutorial costs of the course.

Administration was handled by a program administrator under the guidance of a part-time academic director. This latter position has been filled since the inception of the CDP by the author of this paper under an arrangement with the University of Strathclyde, Glasgow. Besides providing an academic 'backstop' for the CDP he and his colleagues also collaborate on ACTS research activities.

Academic validation

Right from its inception the CDP decided that its training courses should have adequate academic validation and that the certificates on offer should be treated as internationally accredited postgraduate qualifications. The main reason for this was to give the program as a whole a high degree of credibility. It also acted as an incentive for participants to treat the courses more seriously than perhaps they otherwise might. The means used was to enter into an arrangement with a Northern university that would validate the ACTS certificate as part of its normal postgraduate operations. This is quite a usual activity these days and is used internationally in many contexts. Validation by a university had the added attraction that it created possibilities for the best participants to go on to register for a research degree, thus giving them another incentive.

The question then was – what kind of validating institution would be most suitable? Here the most important criterion was capacity to handle the interdisciplinary nature of environmental management. This is not so straightforward as it might appear simply because the knowledge needed for the policy-maker is often locked away in 'cognitive boxes' that are not only inaccessible to the intelligent lay person but actually also to different professional interests. For example, the issue of 'desertification' is about prices and resource allocation to the economist, stress responsiveness of different soil types/ aggregates to the soil scientist, the weather and its vagaries to the climatologist, the structure of power to the political scientist, etc. Sometimes they talk to each other. On occasion they even understand each other. But, regrettably, often they do not.

The reasons for this are well known. Academic life is still very much about reducing issues to narrow problems that are amenable to rigorous experiment, and this is reflected in how universities are traditionally organized. Small wonder then, that those actually responsible for environmental sustainability have difficulty knowing whose advice to seek on questions of public policy. To fill this gap we are beginning to see organizational innovations in the 'knowledge market' (the interaction between those who need the knowledge and those who supply and validate it). A key feature of these is the fostering of interdisciplinary training on the part of a small number of universities; training that often takes the form of postgraduate management and policy studies. In the end, after reviewing a number of possibilities, GSES was chosen because it most closely fitted what was needed.

GSES was established in 1992 to provide training facilities for those with a first degree or equivalent in any discipline (science, humanities, social science, engineering, etc) who are interested in developing skills/perspectives relevant to environmental management. GSES-taught programs over two semesters require students to take a constrained choice of 10 modules (out of the approximately 25 available). Those students whose grades are good enough are allowed to proceed to the dissertation phase, culminating hopefully in the award of a master's degree; those who do not proceed will normally qualify for a diploma. The modules are drawn from all aspects of environmental studies and range from straight environmental sciences and engineering (such as ecology and solid waste management) to more 'decision-making' subjects like environmental law and environmental economics. The dissertation is usually based on an empirical research project (often involving work placement) on a topic relevant to industry, local government, NGO, or regulatory authority interests. In this way the GSES is primarily focused to build policy capacity for the years to come. Its research interests include the international conventions, biotechnology policy, environmental economics, and decision tools for public policy. It also has a successful short course program.

Evaluation

As outlined above, the CDP as a whole was a learning experience and as such evolved significantly over the period 1994–98. The most important changes during its evolution were:

Choice of applicants

At the beginning ACTS underestimated the problem of securing suitable applicants. Reliance upon formal advertisements and circulars to ministries across the region tended to produce participants who were technically unsuitable, who saw the courses mainly as a means of making money, or in some cases, both. In extreme cases some participants were sent home. Of course, those who remained benefited to some extent but nevertheless the CDP put significant efforts into improving the quality and motivation of applicants. It learned to do this through: personal contacts, announcements at relevant fora (such as regional workshops), its own publications, and more conventional channels. As a result of these changes the quality of applicants certainly improved.

Period of stay at ACTS

The first training courses were only held in Nairobi. However, 3 months of intensive training proved hard, even for the most committed of participants. It was difficult to keep concentration levels up on the part of people who were not used to this type of activity, as was the case with the primary target group (government officials). In addition, there were often problems associated with absence from home for a long period (especially, but not exclusively, for women who had children). On the content side, although great efforts were made to ensure that policy problems were those encountered at home base, participants frequently lost touch with that reality since their research work was based on materials and people available in Nairobi. Even if they had been asked to bring relevant materials with them, they either did not do so, or they did not typically bring enough to deal adequately with their project requirements. Finally this original course format was very expensive in terms of resources, including staff time.

Need for research-based training

Right from its inception the CDP tried to ensure that the training activities would relate to relevant problems and issues in participants' home countries. What gradually became clear, however, was that the best results were achieved when participants were able to have direct 'hands on' empirical experience. All too often participants were found to have little field experience, being used to spending most of their time behind office desks in traditional bureaucratic pursuits. The chance to pursue fieldwork clearly enhanced both the knowledge and the motivation of participants, judging from their performances at final regional workshops. Conversely the earlier Nairobi-based courses tended to produce 'bookish' policy papers without much analytical or real policy content. There were still some residual problems about field supervision but with time, experience, and more staff these had lessened.

Policy/'politics' tension

One of the most pervasive problems encountered in the initial phases of the CDP was the assumption that 'policy' emanates from 'on high' and has to be implemented unquestioningly by subordinate civil servants. The notion that competent professional civil servants should be in a position to inform and advise their superiors on a range of policy options was not widely understood. Considerable time was therefore spent in dealing with this issue in interactive workshops and simulated discussion sessions, often based on an evaluation of selected case studies. In addition the participants were strongly encouraged to write up and present their final policy papers in such a way as to present findings as a series of policy options with accompanying prognoses of likely impact. The balance between 'chalk and talk' lecture sessions and workshop sessions also moved in favor of the latter 'training' mode over the period.

Background environmental knowledge

ACTS found that even comparatively senior civil servants have a very weak grasp of relevant background knowledge. For this reason rather more time was spent in actually introducing the international conventions, their history, institutional context, etc, than had originally been anticipated. In addition, efforts were made to leave participants with copies of overhead transparencies and lecture notes. ACTS began to produce specially designed 'readers' for some courses and these, combined with copies of suitable ACTS literature, were usually sufficient to bring participants up to speed with the necessary background to cope with course issues. A related point concerned participants with varying technical backgrounds when too much was initially assumed by the course organizers. Here experience showed that it is safest to assume very little prior technical knowledge on the part of participants, regardless of paper qualifications, at least at the beginning of courses. This was so even in the case of participants from the research sector since their specialized knowledge tended on the whole to be too narrow from a public policy standpoint. Starting from first principles at the very beginning had the added advantage of providing a common baseline for all participants.

Follow-up arrangements

These were not handled systematically and were therefore a weakness of the CDP. Originally it had been hoped that a database would be established that would include co-ordinates and other details of alumni, resource persons, relevant institutions, etc. Two problems stopped this idea from progressing. One was the ongoing lack of adequate IT facilities within ACTS. The second was the loss of the first programme administrator and the subsequent illness of her replacement.

Library facilities

The ACTS Library, while still in the process of establishment, was available to all participants during the period of their stay in Nairobi. Although there were problems in material access in the early years, ACTS became satisfied that sufficient literature was available for training purposes. This was helped especially through the ACTS Press.

Class size

Experience of the CDP showed that relatively small class sizes tend to be appropriate for training courses of this type. At first sight this may appear to be expensive in terms of resources. However, it was found that class sizes of greater than 8–10 students tend to lose cohesion and the quality of training tends to suffer. Quality was also positively influenced by the interactive and person-based training mode that the CDP found to be the most effective.

Conclusions

On the basis of its experience, ACTS came to believe that the CDP was a successful initiative that broke new ground in socio-economic development activity. Although mistakes were made, the positive features outweighed the negative ones, and even in the latter cases lessons were learned. On the positive side the features were:

- The introduction of policy analysis directly to both the recipients (government officials) and the providers of knowledge (research sector)
- The focus on the problem as the unit of analysis rather than the academic discipline
- The combination of broad orientation lectures and seminars (to bring participants up to speed with basic issues and agendas) with field research project work (to show participants that there is a lot to be gained by interacting directly with those at the receiving end of public policy)
- Training in basic communications skills (verbal and written)
- The focus on a specific set of policy issues (those arising from the CBD and the UNFCCC).

Nevertheless, it became clear that this is a new form of capacity building that needs further exploration. There is still some way to go. Undoubtedly the course organizers learned a great deal from their activities and indeed, continuously attempted to improve form and content over the duration of the CDP. But undoubtedly mistakes were made and the main lesson perhaps is that initiatives like this one should be tried out in other contexts. What is certainly true is that the need for this type of capacity-building program is a sad reflection on the higher education sector in many countries. At an individual level, while many African academics make a useful contribution to ACTS activities (and some have formal positions in the organization), one of the biggest problems faced by ACTS was how to involve African universities institutionally. Early on an attempt was made to establish a MoU with a Kenyan university, but this failed. More generally, problems appear to include: weaknesses at the postgraduate level, an apparent inability to deal with policy analysis, low empirical research capacities, and little experience of interdisciplinary work. One of the challenges for future programs is therefore how to build capacity within the African university sector. Ideally it should be the universities themselves who produce graduates able and willing to fulfill these sorts of roles in developing-country governance. The fact that they do not indicates the more general need for substantial reform in postgraduate education.[5]

The other main (and related) lesson learned is the need for new types of partnership to promote such activities. For example, as outlined above, academic validation for the CDP was provided by the link with the GSES. But the CDP benefited from a much wider range of links. Thus, considerable assistance was received from such local NGO bodies as IUCN, UNEP, and the Kenya Wildlife Service (KWS). These institutions regularly provided resource persons, library facilities and help on field trips that proved essential to CDP's success. Links were also established with a range of sympathetic donors and with many helpful government officials in ministries throughout SSA who assisted in numerous ways. And, despite the institutional problems mentioned above, many individual academic personnel from the university sector were able to contribute significantly to specific courses. In short, the success of programs like this one will always be crucially dependent on the orchestration of a wide range of expertise. Accessing and mobilizing such expertise will generally mean developing new types of partnership arrangements. In this sense institutional innovation must be a key component in capacity building for development in the Third World.

Endnotes

1. This paper is the output from a research project funded by the United Kingdom Department for International Development (DFID). The views expressed are not necessarily those of DFID [R7502: Crop Post-Harvest Programme].
2. A discussion of how these factors relate to governance issues in Africa more generally is contained in Juma and Clark (1995).
3. For a more detailed discussion of this and related issues see Clark (2000).

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7. Social science tools for use in promoting poverty reduction in natural resources innovation systems

Stephen Biggs[1] and Harriet Matsaert[2]

Abstract

This paper explores the use of actor-oriented approaches in natural resources (NR) based development. It begins by reviewing the need to bring an analysis of actor linkages, coalitions and information flows higher on the agenda in planning, implementation, monitoring and evaluation. A number of tools that could assist in doing this are introduced and their use is illustrated in case studies of NR based research and development (R&D) projects in Nepal and Bangladesh. The use of actor-oriented tools can change perceptions of development actors, encouraging them to engage with the social and political context of their activities in a productive way. Actor-oriented tools also provide practical ways to monitor, document, assess and thus legitimize crucial institutional strengthening activities. Policy implications include the following points. Actor-linkage analysis and coalition building for effective and sustainable development should be legitimized and rewarded. Development interventions should include actor-oriented tools in development planning, implementation, monitoring and evaluation. Development agencies should employ and integrate professional staff with actor-oriented social science skills (eg, applied anthropologists, evaluation specialists, applied ethnographers) into their mainstream activities.

Introduction

This paper focuses on development interventions in natural resources (NR) based innovation systems.[1] By innovation system we mean the system of all major social actors that affect the revealing, generation and diffusion of technical and institutional knowledge over time (see Hall et al. 2001, Nelson and Winter 1977; Freeman 1987; Biggs 1990; and Ekboir 2002).

Institutions are the formal and informal 'rules of the game', while organizations are the formal institutes that make up the system, eg, research institutes, private and public sector extension agencies, membership farmers organizations, registered NGOs, etc. When we use the term institutions in a general way we mean both the rules of the game and the formal institutions.

We are working from the premise that a strong, effective and sustainable innovation system is one where there are changing institutions that facilitate flows of information and good partnership coalitions between key actors over time. Powerful support for this view can be found in Douthwaite's recent analysis (2002) of a selection of innovation systems (ranging from crop varietal developments to computer software innovations).

One of his findings was that successful and sustainable innovations are invariably those which are developed in a system that can be characterized as a 'bazaar approach'. This is where users and manufacturers of technologies are always interactive with

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'researchers' and fully involved as equal partners, especially in adaptive research (Douthwaite 2002). This is similar to the findings of Norman Clark who stresses the importance of the interactiveness in dynamic science and technology (S&T) knowledge systems (Clark 1995). Biggs and Smith (1998) in their analysis of NR research systems also emphasized the importance of coalitions in R&D activities: 'the effectiveness of coalitions will often be a key determinant of long-term impacts of technical innovations'. These findings are supported in a recent review of innovation systems by Blumenthal and Jannink (2000) who observe that 'collaboration among multiple stakeholders can be crucial to the success of natural resources management'

While most of us acknowledge the importance of linkages between actors, coalitions, alliances and flows of information to successful innovation and to the development of sustainable innovation systems, these aspects of research are often not addressed systematically and explicitly in research management. All too often this results in the development of technologies which sit in research stations, and to mixed and contradictory messages from key actors concerning the reasons for the 'success' or 'failure' of past efforts, replication of effort, waste of resources, unproductive rivalry between different actors, etc.

This difficulty of making research more client-orientated is not new. So for example, many of the research findings an International Service for National Agricultural Research Systems (ISNAR) research study (Biggs 1989) on the outcomes of On-Farm Client Oriented Research (OFCOR) showed that although the 30 or so projects/programs reviewed were designed to seriously consider and address issues of poverty reduction, social inclusion, improvement of gender relationships, empowerment of poorer people and, capacity building, the actual outcomes showed that few of the interventions had had much effect on these goals (Merril Sands et al. 1989). The ongoing and continuous reviews of the current round of innovation systems advocacy and practice are hopefully revealing different outcomes about poverty, social inclusion, gender relations and empowerment of marginalized groups.

The need to address actor linkages and coalitions is becoming increasingly important for NR development actors today. Research funders and governments are actively encouraging new, pluralistic models of R&D and extension which bring together actors in the private sector, public and civil society sectors (Byerlee 1998).[2] Part of this new advocacy is that transaction costs should be reduced. However, how to 'implement' this new advocacy is often not addressed. Alongside this there is no lack of documented evidence of the difficulties and problems encountered by those who try to go forward in new partnership ways (ISNAR 2001).

Despite the need to look more closely at these aspects of NR development activities, there is a dearth of practical and user-friendly techniques, which address these institutional dimensions of innovation systems and are available to project managers. Mainstream planning, implementation, monitoring and evaluation tools such as the log framework tend to emphasize activities and products that do not relate to these actor linkage and processes issues.

In this paper we present a number of tools, which we have found useful in allowing us to focus more closely on the actor linkages found in innovation systems. To some extent our findings come as a result of our attempts to 'test' such tools as they were described in an earlier paper (Biggs and Matsaert 1999).

We are suggesting here that these social science and more qualitative tools should be seen as parallel, complimentary and interactive to the analytical approaches of NR research (experiments, surveys, etc) and the tools of quantitative economists (rates of return studies, resource allocation priority-setting exercises). For example, if an international crop research program were to conduct a systematic technical/economic analysis to establish priority regions in which to work, the tools of this actor analysis could be used to help systematically establish how such technical priorities might be 'implemented'. This might then be the 'action plan' and include how such an action plan would be changed as the endeavor progressed. This includes, as we shall see, emphasis on strategic learning and action as the project progresses. The tools then help address the issues of which actors would play what roles, and how, in different situations in the ever- changing political, cultural, economic, and institutional context in which S&T takes place.

We start by introducing these tools and go on to illustrate their use through a number of case studies from our recent work. Finally, we reflect on our experiences and make suggestions for others who are interested in developing actor-oriented tools to suit the context of their own work.

An actor-oriented approach

Introduction

This approach is concerned principally with mapping relationships and flows of information to provide a basis for reflection and action. These ideas and tools are not new. Their parents are many and include anthropological and social network research techniques (Long and Long 1992; Long and van der Ploeg 1989; Lewis 1998; Davies 2002), stakeholder analysis (Ramirez 1999; Grimble and Wellard 1997; ODA 1995), economic input and output models (Falcon 1967), agricultural information knowledge systems (Roling and Jiggens 1998; Berdegue and Escobar 2002), processes monitoring and documentation (Mosse et al. 1998), graphic theoretical techniques (Temel et al. 2003), communications systems (Mundy 2003), and the analysis of the behavior of disciplines in agricultural sciences (Raina 2002).[3] While there are exceptions, such as some of the references above and the work of Ramirez (1997) the systematic and effective application of these techniques by development actors within NR innovation systems is still not common.

Some actor-oriented tools

The first stage in all these exercises is to identify the key actors that bring about or prevent change in an innovation system. The breadth of the analysis can vary. One can look at a national system, a particular region, or at a particular group of actors, eg, farmers. One can disaggregate more or less depending on the breadth of the study. A national analysis might put all researchers in one box. In a separate analysis one might want to set up an actor map or matrix (in Microsoft Excel) just to look at the interactions between different types of researchers in the public and private sectors. On other occasions one might want to separate actors into those who are in the public, civil, and private sectors. Increasingly actor analysis is being used to analyze the role of aid donors, international research organizations, international non-governmental organizations (INGOs), etc in the same framework as looking at actors at the village and national levels. The framework can be used in an analysis of gender relationships. It should be pointed out that the emphasis is on identifying specific social groups or specific actors in a specific location at a given point in time. Consequently the actor approach differs from some economic frameworks where 'sectors' of the economy are defined by what is produced – the agricultural sector, the manufacturing sector, etc. In actor analysis the people who make decisions are what defines the groups. One would not have a group called 'economic forces', or a category called 'research'; research does not just happen – it is people who do research, so the category would be 'researchers'.

Actor timelines (see example in Case study 3)

Coalitions, relationships, and narratives of change processes can all change over time. Getting a group of key actors to construct an actor timeline of key past events for a particular innovation system can build a more comprehensive understanding of past change processes and a better understanding of the current situation.[4]

An actor timeline is a listing of key events in the evolution of an innovation system. The events are 'actor' events, eg, which actor made key important decisions at what time in the past? As in other parts of actor analysis the onus is on human actions. For example, the planning commission abolished restrictions on the imports of two-wheeled tractors. This is different from saying import restrictions were abolished, or structural adjustment policies were implemented. Wherever possible one has to be as specific as possible with regard to who took what decisions, when, and where. This helps to shift discussions out of the realm of generalities into the specifics of understanding the actual causational processes in a particular innovation system.

It also raises awareness in the group of the different perceptions amongst people about what caused things to happen in the past. It is sometimes difficult to get people who have strong views about past events (especially in regard to what caused what to happen) to see those events in a different way. Even when someone has been 'convinced' that there are different and legitimate alternative narratives about past events, one can still find 'old' views jumping out unexpectedly, and completely undermining an agreed way forward for a coalition. The group's construction of actor timelines is designed to help address this problem. When projects and development activities have become 'path dependent' it is sometimes because old uncontested narratives about past events have been used to maintain a 'business as usual' control over decision-making. Helping people to drop old ways of thinking and seeing things in new ways is one of the major challenges that the actor approach takes on. Again we recognize that this is not a particularly new idea. We can all think of occasions when we have seen timelines in a publication or a list of key events in the history of (or a plan for) a project or a program. However, the way we suggest actor timelines are used here is more as a learning and reflection tool, a way to establish new common ground in a coalition of partners, and as a tool to guide future action. The timeline can either be given as a list of events, with a date given alongside, or as a figure with a sequenced bar chart of actor events over time. The figure helps to reinforce the notion of time, sequencing, and the path of causation of past events. Used at the start of contextual analysis it can help identify the key actors in an innovation system. See Figure 3 in Case study 3 for an example of a timeline.

The actor linkage map

The actor linkage map is a useful starting point for discussing relationships and flows of information in an innovation system. Key actors are shown on a map with arrows between them indicating flows of information. In actor linkage analysis there is always an arrow going in each direction. Single two-headed arrows between different actors are never used, as one of the main points of the mapping is to examine power relationships in the control of flows of information in different directions. The intensity of these flows can be illustrated by the width of the arrows. In Figure 1 the thick arrow going from farmers to researchers illustrates a strong information flow. The fairly weak flow of information from researchers to farmers is shown by a thinner arrow (denoted by 1). The map gives rise to discussions of formal and informal mechanisms that are used to transmit and control information. It also highlights the issue of which actors and linkages are going to be included in the analysis. In the past many actor linkage maps in agricultural research and extension discussions have restricted themselves to public sector actors (eg, government research institutions, government extension organizations and 'beneficiaries' (eg, 'passive' farmers). In addition, few maps included such actors as 'funders of research' and an analysis of how these funding actors interacted with other actors, and how they often determined research agendas and research processes. Actor linkage maps are particularly useful when focusing on one actor and its linkages with other groups. As the number of actors increases however, the map can become too complex. At this point it may be useful to work with maps of part of the system or move to an actor linkage matrix (ALM).[5]

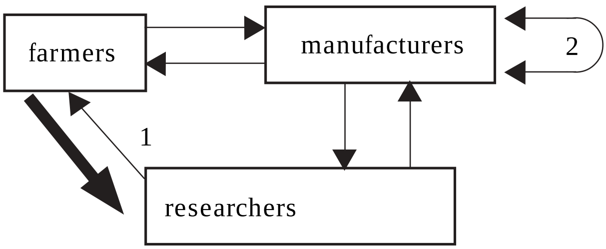


Figure 1. An actor linkage map (see also example in Case study 1.)

Actor linkage matrix (ALM)

The ALM is similar to a map in that it identifies all the actors and shows the links between major actors in an innovation system. In the matrix this is represented by listing actors along the vertical and the horizontal axes. The cells in the matrix represent flows of information from the actors in the rows to actors in the columns (see Figure 2 and the example in Case study 1).

Figure 2. An actor linkage matrix (ALM).

		A	B	C
	Actors	Researchers	Farmers	Manufacturers
1	Researchers		1	
2	Farmers			
3	Manufacturers			2

In Figure 2 cell 1/B refers to information flows from researchers to farmers. In Figure 1 this was arrow 1. Cell 3/C refers to information flows between manufacturers and other manufacturers. In the actor linkage map this was illustrated by arrow 2. In the matrix all cells are identified by their coordinates (numbers for rows and letters for columns). This tool does not lend itself so easily as the map to group work, however it has a number of advantages:

- It can deal with more complex situations and more actors (maps can get very complex and web-like, as more and more arrows are added).
- It has a cell for every possible linkage, and so encourages one to explore all possibilities, to think creatively and innovate! It helps to keep a 'holistic' perspective on the key actors who really determine what happens in a specific innovation system. This does not mean that all actors and linkages have to be looked at all the time. Quite the contrary, as it forces a realization that only certain linkages can be analyzed and worked on at any one time.
- It is a useful tool in helping to pinpoint particular links that are significant, eg, strong links, coalition groups, weak links, or opportunities. This makes it more useful than the map for planning, implementation, monitoring, and evaluating change.
- It enables users to quantify the strength of linkages using symbols in each cell. For example, plus(+) and minus(–), or letters such as s (strong), m (medium), w (weak). Symbols can be used to signify such things as dn for 'don't know'.
- It enables users to condense and store a lot of information about linkages in the spreadsheet ALM (each cell reference can be linked to a text). Consequently it is a useful tool for documenting a given situation or the outcomes of an event.

The ALM is best used with a small group, with people familiar with the technique, or after a discussion to summarize findings that are then circulated. For those familiar with the technique, as is the case of an ongoing research project in Bangladesh (see Case study 1) for group discussions the team uses a 'matrix board', that hangs on the wall as an alternative to a printout from a computer spreadsheet. Here linkages are indicated by placing tokens on small hooks, which represent linkages.

Actor determinants diagram (see example in Case study 1)

This tool is similar to the participatory rural appraisal (PRA) problem tree. It is intended as a group discussion (or individual thinking) tool to analyze the nature of a particular linkage.

The starting point is a cell of the ALM or a linkage on the map. Normally this would be one that is particularly significant (and might need to be strengthened, weakened, or learned from). The diagram maps weakening and strengthening forces on the linkage and helps a group to identify possible areas of intervention.

This tool can be used in a brainstorming exercise and obviously some 'areas for intervention' will be more possible to implement than others. However, this is one of the important reasons for using the tool. It helps open up a discussion about the feasibility of different actions within the current social and political context. It's a useful tool for building an action plan from the analysis of a particular situation. For this reason it is most usefully carried out with the key actors who would be involved in any future 'implementation' of suggested actions.

Actor learning and response analysis

The last set of tools concerns learning and action analysis on the part of coalition partners. We do not have a specific tool as such. What we have found though, in the projects where we have been working is that explicit attention needs to be given to ways in which partners can systematically collect information from different sources, analyze it, and draw up strategic local action plans as they go along. The existence of papers that document this analysis and the planned/actual outcomes can be used to monitor the innovative behavior of partners in the coalition. In principle, in all projects information can come from three main sources. Firstly, from planned activities, that might be experiments, development interventions, surveys, and/or meetings. Often in conventional projects the information from surveys, experiments, and meetings is not acted on locally. This is especially so when academic publications, and 'project requirements' are the primarily reasons for the planned data collection activities. The second source of information comes from 'unexpected sources' in the process of collecting planned information or conducting other planned activities. This kind of information is commonly found in projects. For example, in conducting a survey it is discovered that there is another project in the same region doing similar work. The third source of information comes from 'unexpected changes' in the context of the project. We have found that explicit attention to the ways information from these three sources is analyzed and used to draw up short-term action plans has become a major component in the actor-oriented approach. In the Bangladesh case study the ALM is used to formulate quarterly plans of action to address institutional linkage capacity building issues. In the Nepal Agricultural Research Council (NARC) case study the 6-monthly agreed plan of action against 'mid-term review' indicators served a similar purpose. In the power-tiller case study, the 6-monthly learning and action tables provided a similar framework. What is significant is that in all the cases it was the partners themselves that jointly agreed what they would plan to do over the following 3 months (in the Bangladesh) and 6 months (in the Nepal) case studies. The onus was on self-learning and appropriate actions on the part of the group itself, rather than making 'recommendations' to other actors on what they should do.

Case study illustrations of when and where actor-oriented approach tools have been useful

In this section we describe various contexts in which we have used and are using actor-oriented tools.

Case study 1 – Identifying linkages and coalitions to promote post-harvest innovations and market access for *char* dwellers in Bangladesh

The *chars* are river islands formed by siltation in the river deltas of Bangladesh. The people who live on *chars* are amongst the most physically vulnerable in Bangladesh to natural hazards, such as floods, and are also socioeconomically vulnerable, due to non-existent or unreliable government services and infrastructure. Because of the temporary nature of the islands most families are forced to move residence several times in their lives as well as to frequently migrate to the mainland in times of flood.

Despite the problems experienced by *char* dwellers, there are also great opportunities on the *chars* because of the annual silt deposits and high fertility of the land. Many *char* dwellers compare their situation favorably to that of smallholders on the mainland. When the floods recede, *char* dwellers farm the land intensively. The *chars* are particularly well known for their high-quality chillies, vegetable production, and livestock (thanks to the abundant grasslands).

While *char* dwellers believe NR-based production potential is their key relative advantage over mainlanders, they are relatively disadvantaged in their access to information and markets. Because they are often impermanent, *chars* tend to have scant infrastructure (roads, electricity and government offices are rare), transport can present a problem (dangerous boat crossings in the rainy season, long walks through sand in the dry season), and most development actors are reluctant to visit the area. So while potential for *char*-based production is high, the ability of innovation systems to respond with new technologies, market opportunities, etc, would appear to be weak in terms of linkages with key external actors (extension, research, NGOs, private sector, etc). DFID's Crop Post-Hharvest Programme (CPHP) has recently been focusing on strengthening sustainable innovation systems and on the importance of partnerships and coalitions in this work (Hall et al. 2001; Biggs and Underwood 2001). In the Bangladeshi *chars*, the CPHP has funded a research project to examine and strengthen Pro-poor *char*-based innovation systems for two key enterprises: chillies and livestock. The research asks three questions: 1. What is the status of the *char*-based innovation systems? 2. What linkages are made with other key actors at the national and international level? and 3. what opportunities exist to strengthen the *char*-based innovation systems through building linkages and coalitions?

The study is being carried out by a research coalition comprising a local NGO (Development Wheel), the Bangladesh Business Advisory Services Centre (BASC) who have an interest in building a farmer membership business association, an anthropologist with experience of knowledge systems in the *chars*, and an expatriate anthropologist/agricultural engineer with experience of developing and using actor-oriented tools.

This core research team is using actor maps and matrices with other key actors in chillies and livestock innovation systems to map out the current reality, and to identify strengths, opportunities and weak linkages. Through working together with other key actors the project team expects to build coalitions that can enhance the focus and sustained capacity of local innovation systems on pro-poor issues. The project team itself does not see itself outside of the process, and uses actor maps and matrices to monitor its own relationships and success (and failure) in building partnerships with other key actors through the project life. The research team has found actor-linkage maps (such as the one shown in Figure 3) easier to use in meetings with potential coalition partners than the matrix that is initially too complex for people to grasp.

However, for our internal teamwork and for compiling the information we are collecting on innovation systems we have found the ALM very useful. Team members have observed that 'the ALM makes things visible' and that 'it helps us to be aware of gaps in our knowledge and to identify linkages we haven't considered'.

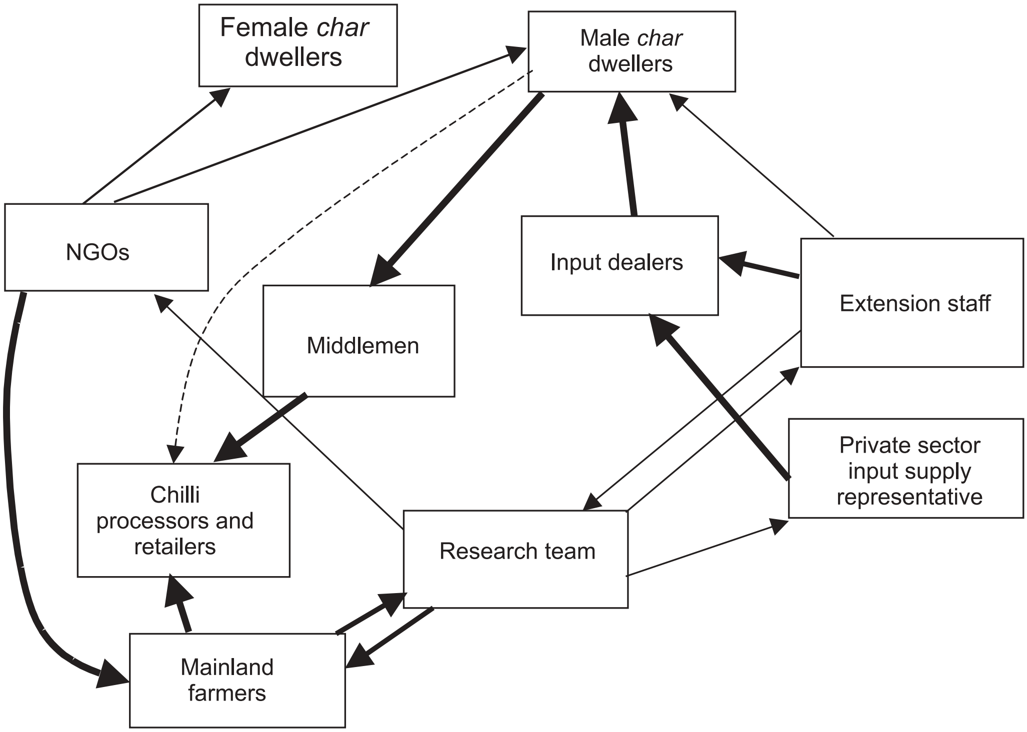


Figure 3. Map showing some key actors in the chilli innovation systems at the local (*upazila*) level.

In Figure 3, arrows refer to flows of goods and knowledge. The map shows that the strongest links between *chars* and the mainland are through the private sector. A key information source for *char* dwellers are the local input dealers who transmit information from private-sector companies and government extension services. Local middlemen play the key role in providing market access. However national-level processors and retailers are making efforts to develop direct links with 'contract farmers' (shown by dashed line)

The team experimented with different types of matrix beginning with a simple quantification of linkages, then developing a more complex system of quantifying linkages. After that they moved towards a more qualitative approach where information on key linkages were described in an attached text file to the spreadsheet. Current uses of the matrix include:

- Monitoring the team's progress in building relationships with other key actors. On a quarterly basis a matrix is drawn up to highlight useful linkages made, and to pinpoint linkages the team want to further develop in the next quarter
- Illustrating the expected impact (on building linkages) of a forthcoming workshop
- Documenting changes in significant linkages and coalitions observed in the innovation system through case study monitoring.

The research is ongoing, but to date the use of actor-oriented tools has resulted in a number of important outcomes. Using the tools with research and extension staff has helped discussion get beyond the formal structures – the organograms of formal relationships and the way things 'should happen' – to the reality of what is actually going on. For example, while officially the Bangladesh Agricultural Development Board (BADB) bulks chilli seed and provides it to farmers, a timeline revealed the uncomfortable reality that the time lapse between release and distribution (which has yet to occur) has been more than 10 years. In the meantime, the regular and effective introduction of new seed varieties is being carried out by a national seed company (who currently has no links with the Chilli Research Institute). Using the actor tools has encouraged the chilli researchers to confront the reality of the situation and to consider the implications. Should they, and how could they, form linkages with this dynamic private sector actor. (see Determinants diagram, Figure 4)

By using the tools to discuss the current status of innovation systems, we can already see how they can legitimize previously unacknowledged but vital activities by individuals. For example, in the same discussion at the Chilli Research Institute, the Director told us that his Institute had no links with private sector, farmers, or NGOs. However, one of his junior scientists then reminded the Director that he had recently, on his own initiative, begun to work with farmers on the *chars* and had already formed links with a local NGO there, inviting them and the farmers to visit the research station. When this activity was marked on the linkage map it emphasized how important the previously unacknowledged work of this scientist was to bridging the divide between the research institute and other actors.

There has been considerable interest in the actor-oriented tools by research and extension staff, and the research team provides briefings on the tools and 'learning by action'. In this way the team expects to provide research and extension managers with tools. Having recognized the need to focus more on building linkages, partnerships, and coalitions, they then can use these tools to draw up action plans and also monitor their own progress in this area (for description see Biggs and Matsaert 1999; Matsaert 2003).[6]

The ALM has also helped the research team in the analysis of its own relationships with project partners. In monitoring their activities in the first quarter, the team used an ALM to show the linkages made with key actors. The ALM highlighted the fact that most linkages had been between the project team and a single actor. To make a sustainable impact the team had to think of ways to promote linkages between other key actors in the system. By making the team one of the actors being analyzed, it helped them to be more reflective and think about how they could do this in a practical way. The matrix

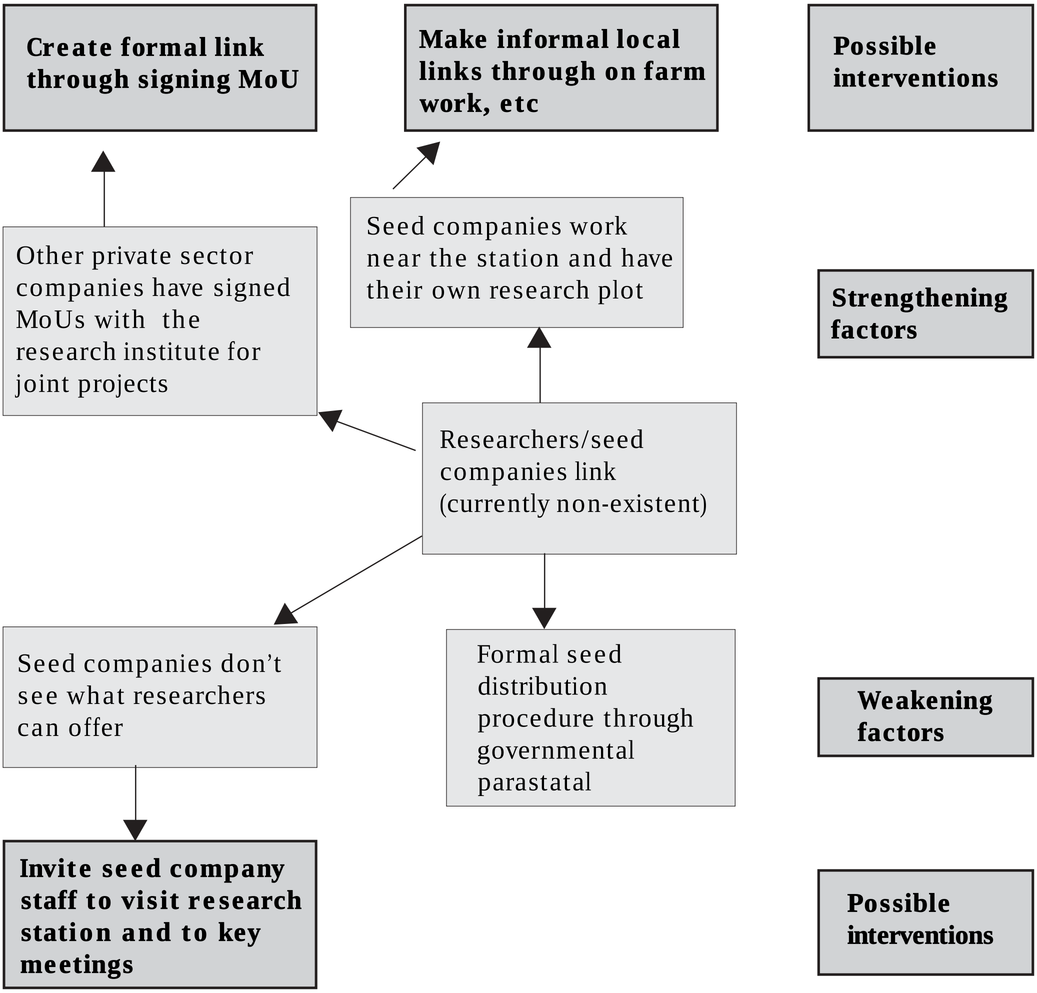
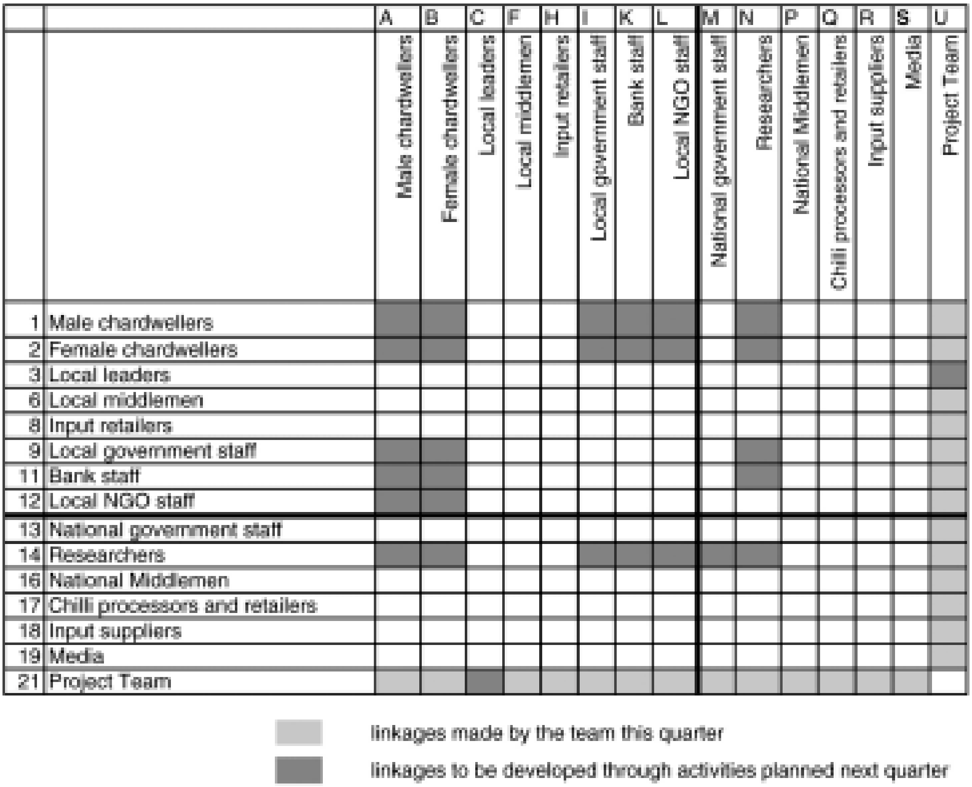


Figure 4. Determinants diagram exploring the linkage between chilli researchers and private sector seed companies and possible areas for intervention (in bold type).

shown in Figure 5 shows how a meeting was planned that would build relationships not only between the project and key actors but also between other key actors who rarely interact.

It should be said that the use of these tools is not without its predictable hazards. On one occasion the research team was highly criticized by agricultural extension staff when they presented an ALM indicating that the extension field staff never visit the research area. Agricultural extension staff are very proud that they are the only Ministry to work in every area of the country. To contradict this essential part of the identity of the Ministry's staff was unwise and unproductive. The research team later became aware that the farmer group with whom they were working were keen to represent themselves as isolated and receiving no services from the Government as they felt this would

Figure 5. Actor linkage matrix (ALM) showing links made by the research team in the first quarter, used to monitor partnership building and the links to be promoted through a planned meeting.



Note: The matrix has been simplified, all actors are not shown.

increase their chances of receiving inputs from the researchers. The reality lies somewhere between the two. Since the difficult meeting with the extension team, researchers have noticed that the extension 'block supervisor' now makes regular visits to the focus *chars*. Thus, to some extent in this case the project has helped to bring about a change in the culture of the local-level staff in the Ministry. Regular actor-oriented monitoring would acknowledge and reward him for strengthening these linkages, and also to note that the mechanisms being used that are within the current budgets and reward systems of the public-sector extension service.

David Lewis (1998) and Brigitta Bode (2002) have recorded similar experiences in Bangladesh where they revealed information that was different from the way a powerful organization was presenting itself. Lewis describes how his involvement as an 'outside' process monitor in a research project came to a premature end when the organizations he was partnering began to find the information he was uncovering about them was uncomfortable.

In the actor approach we are suggesting here there is no 'outsider' process monitoring. All actors in the coalition (including the research team) are on the 'inside'.[7]

Case study 2 – Restructuring the national agricultural research system in Nepal

The Agricultural Research and Extension Project (AREP) in Nepal, funded by the World Bank, was first conceived in the early 1990s. In the mid-1990s it was designed along fairly conventional lines with a strong onus on Master's and PhD training and construction work. One of the major organizations in the project was NARC. Two of the project's key restructuring goals were: 1. the encouragement of more participatory technology development (PTD) in NARC, and 2. the promotion of linkages and partnerships between NARC and a whole range of government and non-government partners.

Actor linkage maps were used extensively at the national and regional levels to analyze the behavior of actors in different innovation systems. They were then used for strategic planning and action purposes. They were also used in some commodity programs (wheat and maize) to analyze the actual roles of past actors and for regular strategic planning and action exercises. The maps helped to examine and understand existing relationships/partnerships and to focus attention on linkages that needed strengthening.

Earlier project documents had seen the lack of PTD activities in NARC as a major problem. However, as NARC staff actively searched for examples of linkages and working relationships they found many examples that had not been reported through the usual research monitoring and documentation processes. One of the reasons for this was the official perception of what constituted PTD in NARC. The official view was that 'on-farm' and PTD research only took place in NARC's Outreach (OR) Division. This division was involved in a range of standard activities arising out of the conventional farming systems transfer of technology (ToT) approach (benchmark surveys, village meetings, final stages of varietal screening, the management of a number of 'representative' outreach sites, formal impact/adoption/evaluations studies, etc). However, on closer analysis of who was actually doing PTD in NARC it was revealed that a far greater number of scientists than those in the OR Division were involved in a wide range of innovative PTD activities.[8] This information had not been reported in the past because much of this type of PTD came under special projects. It was often conducted with a large range of international and government partners and with a number of local R&D NGOs. For years these special projects had made up a very substantial part of NARC's work. The inclusion of these data gave a very different perception of the PTD situation in NARC. The actor linkage analysis helped reveal a whole range of activities and linkages that were generally not acknowledged in official documents, or seen by 'outsiders' who did not know of this work. In some ways many of the PTD prescriptions in the original project design were already in place, but had not been seen and acknowledged. From a new start based on what was actually happening in NARC, discussions could take place on how to encourage and facilitate new PTD activities. This focused on how future PTD activities could be managed primarily by other actors in the overall national agricultural research system (NARS). Figure 6 provides one of the actor linkage maps that was used to direct attention at these issues (Biggs and Matsaert 1999). It should be noted that since these earlier discussions, NARC has gone further in institutional restructuring that includes separating its policy and facilitating functions from the research provider role.[9]

Figure 6. Actor linkage map for the Nepal Agricultural Research Council (NARC).

A second goal of the AREP project was to promote linkages with a whole range of non-government partners, such as local and international NGOs, international agricultural research centers (IARCs), the private sector, etc. Again it was found that a great number of partnerships/linkages already existed but were not revealed or acknowledged. However, in this case the use of actor linkage maps, where NARC was placed in the center of the page and circles around NARC represented other existing and potential partners, helped focus attention on the need for new types of mechanisms for linkages with different categories of partners. One of these actors' maps for NARC is shown in Figure 7. To go forward with the institutional reform program NARC organized workshops at the national and regional levels to address these issues. One set of workshops looked at NARC/NGO linkages and another set discussed NARC/ private sector linkages (Gauchan and Joshi 2000).

Actor linkage maps were used in a similar way to encourage regional stations to think about how to change their role from being a conventional public sector research provider, to being a promoter and facilitator of a strong regional agricultural and natural resources innovation system. Regional Technical Working Groups were established to foster partnerships between a wide range of private, government, and NGO actors.

Regional stations chiefs found the work of keeping updated inventories of all R&D and development actors in each region, and promoting/facilitating regional networks of R&D actors, very different from being in charge of a conventional public sector regional research station.

The actor linkage maps helped introduce a change in institutional behavior on the part of NARC towards its old and new partners.

Another way actor maps were used in the restructuring of NARC was to help raise awareness about the diversity of actors and linkages in different technology innovation systems. The overall agricultural research and extension system in Nepal is dominated by the conventional crops-oriented ToT conceptualization of R&D processes. This is partly due to the long-term connections with plant breeders from the IARCs for the major food crops grown in Nepal: rice, wheat, and maize. This mainstream plant breeder paradigm is very persistent and often, unthinkingly, gets applied in policy discussions to such other technologies as livestock, horticultural crops and agricultural engineering technologies, and even to applied social science action research. Actor linkage maps were used in a series of workshops to bring out the diverse nature of different innovations systems. For example, the actor linkage map of the Nepal horticultural innovation system diagrammatically showed that NARC was a fairly minor actor, while those private-sector actors that brought seeds from India and elsewhere played a major role in the existing system. In the case of the livestock innovation system, the maps

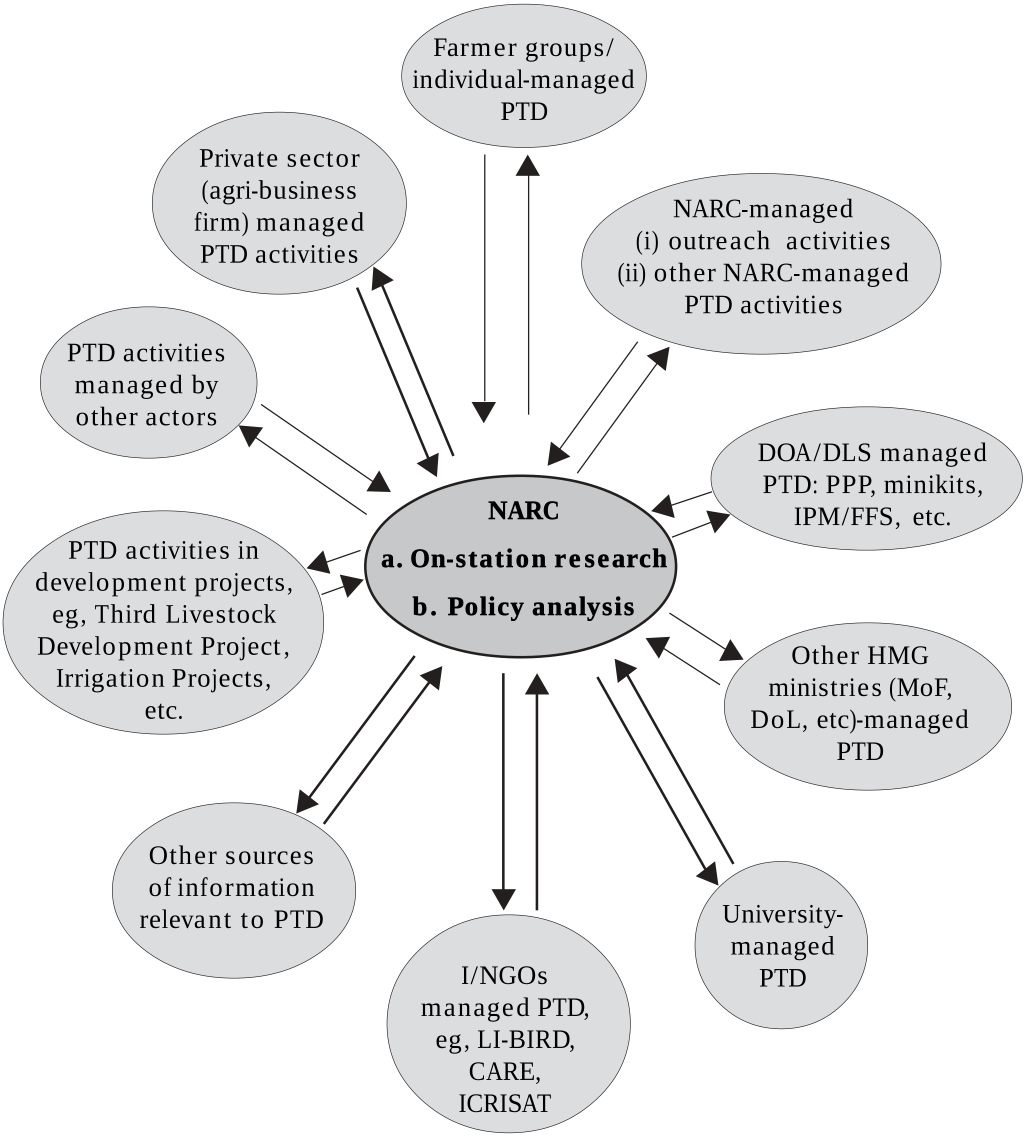


Figure 7. Suggested framework for NARC participatory technology development (PTD) and multiple linkages program. Source: Gauchan et al. (2003).

revealed that the Department of Livestock (DoL) had a significant research capability as did some livestock development projects. The actor linkage maps helped reveal these different institutional realities in various parts of the overall agricultural and NR innovation system in Nepal.[10] While there were often lively discussions about what the future role of NARC should be in each of these innovation systems, the actor linkage maps helped keep the reality of the current situation prominent and provided a framework for thinking about future policies and programs in a more open and outward-looking way.

An interesting development in monitoring the AREP project occurred in the mid-term review. Up to that point the project had been going very badly and there was even talk of terminating the loan. The regular monitoring missions from the World Bank had written a series of uncomplimentary reports. Members of the review missions had often changed and sometimes had little knowledge of working in Asia. They mainly kept to the original project blueprint that had been drawn up many years ago. However, for the mid-term review the World Bank included two review team members who were very experienced in the analysis of research and extension issues and practice in Asia and also in Nepal. They were up-to-date on contemporary thinking in pluralistic approaches to research and extension practice. The head of the review team also had extensive experience in Asia. With regards to monitoring and change in the project, one of the important outcomes of the review for NARC was the joint drawing up of a limited number of action plans that would be monitored and reviewed every 6 months. The old confrontational culture between the World Bank and the project changed to being one of a supportive partnership in addressing the difficult job of restructuring the Nepal agriculture research and extension innovation system.[11] For it's part the World Bank agreed to retain the same reviewers who would visit regularly every 6 months to discuss how NARC was progressing in implementing its own plans, and what new actions needed to be included. For the World Bank, keeping the same reviewer who knew the context in which understandings had been drawn up, was apparently a novel idea. However, the Bank is honoring its commitment, although it has meant on occasions another donor, who was interested in strengthening the capacity of NARC had to provide funds for part of the reviews. The data from those 6-monthly reviews, mainly empirical evidence of institutional change taking place in the innovation system, has been summarized by Joshi et al. (2000).[12] This is an excellent example of 'process documentation' by 'insiders' who were creating the information as they went along for project management purposes. In a sense the mid-term review changed monitoring from being an 'outsider' confrontational evaluation exercise to a more useful activity, that resulted in both the World Bank and NARC playing a more constructive role in a difficult task. In summary, the use of actor linkage maps made a number of important contributions to the project's aims. They provided a way to investigate, document and legitimize existing linkages, eg, the PTD work. They provided a framework that encouraged NARC scientists to think in new ways and develop long-term changes in organizational structure and institutional behavior. The 6-monthly reviews based around the changing local action plan resulted in substantial changes in the direction and content of the project. As in all innovation systems the processes of institutional change never end. At the present time it is hard to forecast what the institutional characteristics of the overall Nepal agricultural and NR innovation system will be in a few years' time. However, it can be predicted with confidence that a return to old government research/extension institutional models is highly unlikely. Also, a return to the expatriate/international science-led institutional models of earlier years is unlikely. Pluralistic institutional models are more likely to emerge, and the actor linkage maps, used to date in NARC and other agencies in Nepal, are likely to continue to provide a useful framework for institutional analysis and action.

Case study 3 – Changing power tiller innovation systems in Nepal

An actor timeline has recently been used in another project in Nepal. In the early 1990sa conventional ToT farming systems project was started on the *Terai* (plains), where farming is dominated by rice/wheat cropping systems. The project concentrated on the introduction and development of resource conservation technologies (RCTs). One of the principal technologies in the project was the introduction of the Chinese power tiller (PT) (two-wheeled tractor/walking tractor/mobile power unit) that can be used for minimum and zero tillage. The project has changed over the years and now has far more of an interactive PTD orientation. It now concentrates more on poverty-reduction and gender-equity issues. A feature of the earlier PT projects on the *Terai* was that they were not linked in any systematic way with the strong, robust PT innovation systems that have existed in the hills of Nepal in the Kathmandu and Pokhara valleys for many years. To some extent the work in the *Terai* PT project has proceeded as if the PT innovation systems in the hills had little to offer to the project on the *Terai*. Some of this attitude was due to a perception that the PTs in the Kathmandu and Pokhara valleys were used only to haul construction goods and not for agricultural purposes. One of the ways of getting this project assumption (narrative) questioned was to involve core members of the *Terai* team in a discussion and with writing a paper about the changing overall PT innovation system in Nepal (Biggs et al. 2003). In this exercise a timeline was constructed (see Figure 8).

Each of these phases is associated with a particular coalition of donor agencies and local and international actors. For example, the one that stretched from the end of the farming systems phase up to the current phase has been facilitated to a major extent by a large coalition that included the United States Agency for International Development (USAID), the UK Department for International Development (DFID), the Asian Development Bank (ADB), New Zealand, the International Fund for Agricultural Development (IFAD), the Centro Internacional de Mejoramiento de Maíze y Trigo (CIMMYT) and NARC. The timeline has helped the current promoters of PTs to investigate the outcomes of earlier projects and put their own work into an overall historical and contextual perspective. One of the activities to which this led was a brief exploratory survey by the current team of the PT innovation system in the Kathmandu

Figure 8. Timeline of major phases in the spread of power tillers in Nepal.

1970	1980	1990	2000	2010
	Japanese Phase			
	First Chinese Phase			
	Korean Phase			
		Farming Systems Research and Extension (FSR&E) Phase		
		Participatory Technology Development (PTD) Phase		
		Second Chinese Phase		
			Equitable Access and Gender Phase	
			Poverty Reduction and Innovation Systems	

valley. They investigated ownership patterns, usage patterns, service rental arrangements, etc. This exploratory activity has already led to a major change in the perceptions by the team of the Kathmandu PT system. They found that there was a high degree of integration of PT use during periods of peak agricultural use with their use for construction haulage work. This helped the *Terai* project staff to change emphasis in their work and encourage the use of PTs for both transport and agricultural purposes. The *Terai* group also learned that PTs in the Kathmandu valley were owned by entrepreneurs (often rural entrepreneurs) who mainly hired out PT services for agriculture and haulage. Sometimes the rural entrepreneurs had some land of their own, and the PT was used first on this land at peak agricultural use times, before being hired out to others. Generally PT operators were hired to operate them. This quick analysis of the Kathmandu system led the *Terai* project staff to investigate more fully the rural entrepreneur/service provider dimensions of PTs in their own work. The *Terai* team has quickly learned a lot more from the Kathmandu system. This includes information on how PTs have been maintained over many years with little access to international markets for spare parts, and how local industries have developed and manufactured locally relevant equipment. Getting the project staff to stand back from busy day-to-day activities has been a challenge. However, investigating the history of the spread of PT technology and learning from these other ongoing and changing innovation systems in Nepal has resulted in the project making better use of relevant local knowledge that is already available in Nepal. The timeline helped play a role in this reflection and learning process.

One of the features of the PT project is that it has partners from a wide range of different institutions; PTs are also part of other projects with different management, monitoring and reporting structures. In order to manage the poverty-reduction PT part of these different components, the 'coalition' around this set of interests has established for themselves a simple strategic learning and action tool.. Every 6 months they meet and decide what they have leaned from planned sources (surveys, experiments, and other planned activities), from other information picked up while doing their planned work, and from unexpected changes in the contextual environment. They then decide what the implications of this information are, and draw up a plan of action for themselves for the next 6 months. The team has found that this simple table helps them to focus on which strategic changes to make to the project over the following 6 months. The action plan is for themselves, and does not include recommendations about what 'policy makers should do' or what 'others should do'. Illustrations of how this mechanism and the simple strategic learning and action table have helped in the project can be seen from the following examples:

Example 1. At one point some of the agricultural engineers wanted to continue with the on-farm experiments to show that zero and minimum tillage was a good resource conservation technology. Others in the group said: "we know that, we have learned that from the on-farm trials we have already done. In addition, the technology is rapidly spreading in the areas where the on-farm research has been done. Hence we do not need to do more experiments of this type. Maybe different ones might be justified, but we don't need to do more of this type, even if they are budgeted in one of the related projects." The staff members that were against unnecessary repetition of trials were saying so for strategic reasons – the project now needed to concentrate on methods of dissemination of this 'proven technology'. Plans for the next 6 months included ways to use e-mail to disseminate the technology to relevant public-sector extension agencies and contacts with major donor and NGO development projects. One example of picking up 'unexpected' information was that while engaged in their on-farm activities, members of the team started to hear about PTs spreading in adjoining areas and districts. This was taking place outside of any earlier planned activities. The outcome of this unexpected information was that a quick exploratory survey was planned for the whole team. There was a great deal of interest in what was currently happening, and what could be gleaned by the project from these adjoining areas. Significantly the group did not send a socio-economics team off to investigate and write an adoption report!

Example 2. There was talk in some government quarters of introducing a tax on the import of farm machinery. This was a totally unexpected possible change in government policy. In order to inform the debate on future changes in government policy the team decided to divert resources to work with some existing and new partners to produce a policy discussion paper on rural mechanization in Nepal and distribute earlier papers and reports to policy-makers. This was done quickly and the reports were distributed widely amongst those who influence policy processes and practice.

The team is now finding that the learning and project response table is helping them to focus on changing priority issues, and manage their work accordingly. An analysis of the content of the tables at some future date will enable an assessment of how innovative the project has been in learning and responding to new information and opportunities as it goes along.

In summary, this case study has illustrated how actor timelines and a strategic learning and action tool has helped the project to:

- Change the perceptions of its work
- Start learning from local knowledge that had earlier been unrecognized as important,
- Discover how to increase the learning and responsiveness of the project to information as it becomes available.

Some might well argue that we are talking about nothing new here. This may be true, but we argue that the actor-oriented tools described have shown themselves to be useful, and might be useful to others.[13]

Discussion and reflections

Actor-oriented tools have helped us to:

- Visually map a given innovation system and analyze strengths, weaknesses and opportunities in the system in terms of its key actors and their relationships
- Encourage technology users to look at existing (often unexpected) strengths in an innovation system and analyze their institutional implications
- Provide a framework whereby actors in a specific innovation system have been able to change their perceptions of their role and relationships to other actors in the system
- Provide tools for planning, monitoring, and evaluating coalition building and information flows

- Provide tools that are appropriate for use by groups (as part of coalition building).
- Keep a pro-poor, socially responsible orientation to the work of the group.

We have found the tools to be valuable in keeping partnerships, relationships, and sharing information high on the research agenda. Their use helps to legitimize and reward actors who actively build linkages in their work. They often provide a more structured way of strengthening institutional innovations that are already taking place, but the importance of which has often been unacknowledged. As the case studies show, the approach we are advocating is not about observing and analyzing innovation systems from the outside. We are concerned with developing approaches that can help actors and ourselves as non-neutral actors, to reflect and learn as we act on the inside. Our experiences of working with these tools have raised a number of issues, that are important to consider when using these tools in the future.

1. Political issues in using actor-oriented tools

These tools are all about human relationships and therefore cannot help but be political. They need to be used with sensitivity, awareness, and with an acknowledgment that the user is never neutral. Actor-oriented tools may reveal information that some actors may not find easy to accept. It is also important to realize that different actors may have different interpretations of reality, and that these interpretations may be politically motivated. The actor timelines help to reveal some of these orientations in perceptions. To some extent the actor approach is enabling some topics, formerly seen as 'academic' political economy subjects, to be brought out into the open and analyzed within the framework of development activities.[14] In the past the analysis of natural resources and agricultural innovations systems were often 'deinstitutionalized' and 'depoliticized' by using actor linkage maps which only showed 'Farmers (beneficiaries)', 'Researchers', and 'Extension Department', with two-headed arrows between them. Often the funders of research were not on the map and the motives and reward structures within those and other organizations were not systematically analyzed. Another way of depoliticizing and deinstitutionalizing the analysis of innovation systems was to restrict planning and evaluation exercises to narrow types of financial and economic analysis. The actor approach we are suggesting here enables one to break out of these depersonalized, depoliticized, and deinstitutionalized frameworks of analysis.

Because of the political nature of this approach, when planning the use of these tools it is important to begin by being self-aware of your own aims and to use the tools accordingly. These are not tools to be added to the tool bag of PRA, etc, to be taught in a short-term training course.[15] If the tools are being used for project planning, and to prepareand build coalitions, it is particularly important that they are used in a constructive way. Like all tools, they can be use for a wide range of purposes. For example, we found in some situations that quantifying linkages (something that is very tempting) can be unproductive as the value given to a linkage is somehow 'set in stone'. It seems to be less controversial and thus more productive to identify strengths and 'areas where there are further opportunities for intervention' rather than to give quantitative weights to strong or weak linkages. In addition, this is not 'just a matter of semantics'. The way things are spoken about and used is important. The quantification of some linkages in an objective way can also sometimes lead to an unjustified confidence in the figures that are produced.

2. Importance of events and key locations

Events such as a fair or a seminar, or such locations as market places, can be critical in developing linkages and coalitions. We have found it useful to identify key events and locations at the same time as doing our 'actor analysis' to identify key actors. The actor event timeline also helps to pinpoint why key events in the past were effective in some way. It also makes the team more aware that to be effective in bringing about change in the innovations system meetings, platforms, workshops, or seed fairs, have to planned with great thought. We are not talking here about 'ritualistic' meetings, that are planned and organized for a whole range of other reasons.

3. Importance of individual actors

In her study of power systems in rural Bangladesh, Bode (2002) recognizes the enormous power of local elites and recommends that NGOs identify the 'good kings' amongst the elite who can work with them and patronize their activities. The work of Tendler (1997) in analyzing 'success stories' in technology diffusion in Brazil also points to the importance of key individuals in some processes. The actor approach enables us to move beyond structural linkages to unique opportunities that may depend on a particularly innovative or dynamic personality. The actor event timeline exercises often bring out the important role that a key individual played in past innovation processes. In the ALM key individuals can be given a cell of their own.

4. Actor linkage maps versus ALMs

Judgment has to be used about when to use one or another of these tools. In the Nepal situation, the actor linkage maps were the most useful way to get people to think about ways to strengthen linkages with new actors and to develop new mechanisms to facilitate these linkages. In a number of meetings where ALMs were discussed, the tool did not appear to be of use. In the Bangladesh case the situation was different. Here a small, stable group uses the ALM frequently. As the group now understands and feels comfortable with the ALM, it has become a useful thinking tool: a way to visualize the institutional context, to monitor the impact of activities, and to plan future activities. To some extent, all the tools discussed here are time- and location-specific. Professionals with experience in the use of these tools have to take opportunities as they arise to use tools as and when appropriate. In a development situation the context determines what is useful to be used when. In a more academic context one might attempt to be more 'rigorous' in the pre-planned research design. However, this is not too different from any creative research process. As those who are experienced in creative research processes (rather than repetitious technical/social science research) know, analytical frameworks and tools are generally adapted and changed as the work proceeds.

5. A role for quantification?

In some cases a more critical use of the matrix, or quantifying linkages might be appropriate, for example, where a team are setting themselves linkage goals and monitoring their performance. Here they might find it useful to set criteria for ranking the strength of a linkage. Methods for assessing the strength of a linkage will be highly location- and time-specific because of the institutional culture in different settings. For example, in one setting, having a meeting of some actors who normally never meet could be a major positive achievement. In another situation, having a meeting of those actors might be just a continuation of mechanical or ritualistic meetings and be more an indictor of 'business as usual', rather than an indicator of significant change.[16] Similarly, quantification might be useful for a baseline assessment of an innovation system. However, even here one has to avoid pitfalls of old approaches where people thought 'baselines' could be established against which progress could be 'impartially' monitored and evaluated. The case study of the NARC clearly showed that the project 'benchmark' assertions that there was little PTD research taking place and that NARC had few non-government R&D partners was a misleading representation of the situation. In this case it was partly due to the fact that no social science professionals with institutional analytical skills had been included in the project preparation team, although almost all the project was about restructuring and institutional change. It was not until the mid-term review that these issues were addressed in a more substantial way and the overall culture of the project changed (Biggs and Smith 2003).

6. Cultural dimensions of transaction costs

One of advocacies of many of today's aid projects is to reduce transactions costs. Often this has come in response to the fact that some government procedures are inordinately slow and involve files being moved and signed many times. The actor tools presented here help to address transaction cost issues in two ways. Firstly they provide a framework in which transactions between actors can be conceptualized and systematically analyzed. Secondly they provide a framework in which new types of transactions mechanisms can be explored. Thirdly, and probably the most important contribution, is that it keeps issues such as perceptions and culture to the forefront of the analysis. For example, in the Nepal agricultural research restructuring example, no amount of training in new stakeholder collaboration methods and accounting procedures to reduce formal transaction costs would have produced results while there was a culture of confrontation and little trust between the World Bank and the AREP project. In the Bangladesh case, the culture of the Extension Ministry (and perceptions by its staff) was that it worked in all areas of the country. Until this culture was challenged, and a different reality acknowledged, there would have been little use in talking about minimizing transactions costs in the context of any of the actors involved, let alone talking about ways to develop new long-lasting partnership relationships. The use of the actor linkage maps, and the actor timelines in the historical analysis of PTs in Nepal has helped change the inward-looking 'special project' culture that is so prevalent in Nepal. What in the past was seen as a negative transitions cost (ie, the negative costs of having to go and contact and work with extension and other development agencies) is now being seen as a worthwhile investment to keep the research focused and have partners who run with the new technology.

The actor-oriented tools also help to remind us that the term 'transaction cost' can never be discussed outside of the social and political context in which it is used. For example, people who subscribe to more autocratic and hierarchical social systems would see many of the meetings, consultations, and voting procedures of more democratic social systems as unnecessary and as giving rise to high transaction costs.

7. Keep it simple

It is tempting to be complex. But in order to use these tools productively, ie, interactively, they must be kept simple and specific to the political and socioeconomic cultures in which they are used. Its better to have several maps, several matrices, and several timelines rather than trying to describe too much in one place. Membership of meetings to use the tools needs to be thought out very carefully. Trying to use the ALM with a wide range of actors can result in difficulties in convincing some people present of its usefulness.

The actor-oriented approach to innovation systems encourages the user to look at the whole range of actors involved in an innovation system, including the role of the users of these techniques. In the Bangladeshi case our key research actors and potential future coalition members include farmers, Bangla-speaking government field staff, businessmen, and BASC. Some of these actors are unfamiliar with research and have difficulty understanding the point of these techniques. We found that non-researchers, and even some technical researchers, tend to take relationships as 'obvious' and are eager to move onto the action stage immediately! In the case of public-sector researchers they often underestimate the challenges that are involved when working with the private sector and NGOs. While public-sector personnel have rules and procedures about the way invitations for meetings are made and transferred, some of these mechanisms (some of the substance of linkages) do not work when working with the private and NGO sectors.

Involving people in mapping and analysis seems to help build some awareness of the usefulness of the technique. This is another reason to keep the tools simple and for striving to make them user-friendly.

8. Elusiveness of pro-poor activities and effective monitoring of socially responsible behavior in NR innovation systems

All the projects discussed in this paper were funded as part of pro-poor development activities. However, even with this overriding goal, and with the use of actor-oriented tools in analyzing the respective innovation system, it was very hard to keep activities focused on such poverty-reduction issues as the improvement of rural livelihoods, gender relationships, social inclusion, and the empowerment of socially marginalized groups. In fact, the innovation systems framework runs the risk of being captured by those who are interested only in the spread of innovations per se, and not in the social responsibility dimensions of these activities. In this sense the approach has little to add to conventional market chain analysis or the commercialization of agriculture and NR. In addition, there are a whole range of methods by which mainstream or powerful groups can co-opt and use new language and new frameworks, and leave in place a business-as-usual' behavior.[17] We have no easy answers as to how to address these issues. However, explicitly adopting socially responsible criteria from the start of the project is one way forward. In other situations, a project might decide to introduce social responsible criteria, as the project proceeds, as was the case of the PT project in Nepal. It will be interesting to see how this coalition of interested parties evolves in the future. There are plans to search out socially responsible partners and form a socially responsible network of business entrepreneurs, bankers, researchers, etc. in the rural mechanization industry. An example of a socially responsible business development organization (BDO) in Nepal is the Nepal Handmade Paper Association (HANDPASS) which had been developed by actors in the handmade paper industry (Biggs and Messerschmidt 2004). What distinguishes a socially responsible BDO from an ordinary BDO is that the members are concerned, not only with issues of business entrepreneurship, market development, etc., but also with social entrepreneurship. This entails explicit concern with the livelihoods of poor people, social inclusions, gender relationships, and fair trade issues.

9. Strengthening effective social science analysis within innovation systems

The tools and techniques we have discussed here come from a wide range of disciplines and development practice situations. These methods are not just another set of tools to be added to the PRA tool bag, or as additional chapters to manuals on how to facilitate and organize stakeholder workshops. While such manuals and guidelines have their place, they have, by the way they have been promoted and used been partially responsible for the 'dumbing down' of strong social science analysis about the nature of innovation systems and how strongly based disciplinary economists, anthropologists, political scientists, etc. can effectively work within innovation systems and influence their direction and outcomes. If innovation systems are to be directed in socially responsible directions, we suggest it is time for strongly disciplinary based social science skills to be strengthened within NR innovation systems. New mechanisms will need to be developed to do this. Some of the frameworks, methods, and tools of this paper illustrate how some of this might be done. The references we have given in the endnotes and references on new types of ethnography illustrate that some disciplinary developments in, for example, anthropology are directly relevant to the day-to-day decision making within applied NR R&D and technology promotion programs.[15]

Conclusions

We hope we have shown that the actor-oriented approach and the tools presented here can be useful in understanding innovation systems and as a basis for planned action and change. We feel that the techniques are relevant to addressing many of the issues that actors in contemporary innovation systems are now facing. The techniques are complimentary to other research and planning methods. They have their strengths and weaknesses. Like all theories, methods, and tools they have to be handled with care, with experience, and in a responsible way.

Endnotes

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1. We would like to thank Don Messerschmidt, Scott Justice, Devendra Gauchan and Rob Tripp for helpful comments on an earlier draft of this paper that has recently been published in the AgREN Network Series (Biggs and Matsaert 2004).
2. For an example of where actor linkage maps were used to highlight the need to bring 'research funders' into the analysis of innovation systems see Gauchan et al. (2003).
3. This follows the framework for analyzing institutions from Bromley (1989). In his framework institutional transactions are the activities of different actors that give rise to changes in the institutional context in which economic transactions take place. For an actor-oriented analysis of the total interdependency of conventional economic choice of technique analysis and choice of institution analysis in agricultural and rural mechanization policy see Ashford and Biggs (1992). For recent similar types of analysis that focus on the role of actors, and the need for institutional change in major aid agencies see Bennett (2003) and Eyben (2003).
4. Ellis and Biggs (2001) used a timeline to map major changes in the mainstream agricultural and rural development discourse from 1950 –2000. The article was written from an agricultural economist's perspective. To some extent that article documented the product of using this tool of analysis in rural development postgraduate teaching for many years in the School of Development Studies, University of East Anglia, UK. It is interesting to note that David Mosse uses a similar tool to encourage reflection and learning in a university teaching context in London (Mosse 2001).
5. For some early attempts to systematically use ALMs see the publications of the ISNAR study on the On-Farm Client-Oriented Research (OFCOR) project (for example, Kayastha et al. 1989). However in that study they were used in an external, ex-post evaluation mode. In this paper we are looking at the way these tools can be used within the activities of planned policy and development activities. A very useful new addition to the literature on how how to go about such work is by Gellner and Hirsch (2001). This was one of the main themes of a of a workshop on "Order and Disjuncture: The Organisation of Aid and Development" organized by David Lewis and David Mosse held 26–27 September 2003, at the School of Oriental and Asian Studies (SOAS), University of London, London, UK. (papers available at: www.soas.ac.uk/departments/departmentinfo.cfm?navid=459)
6. Of course, if institutional strengthening of innovation systems is a goal of projects/programs these topics can be systematically addressed and brought into log frames, and indicators developed to monitor the strengthening (or weakening) of different institutions and the relationships between them (Gasper 2000)
7. In a recent discussion of social science research methods that have largely evolved from within development situations Mosse (2001) defines two main streams of methods: 1. participatory learning, also known as participatory rural appraisal (PRA), and 2. Process documentation research or process monitoring. In the first set it is unusual for the 'researcher or development team' to place themselves in the actor linkage map and systematically analyze their relationships with different actors. In process monitoring it is more usual for the researcher or development team to be reflective and to consciously analyze their own behavior and its effects on other actors. Therefore they are more likely to include themselves in the actor linkage map. In the actor approach we are investigating here the researchers (or team) are always included in the actor linkage map, because much of the analysis concerns their motives, roles, and behavior with respect to other partners, as it does looking at the relationships between other actors in that specific context. As part of the present research activity the first author is following another type of insider/outsider research methodology. In this work the 'outsider' (SB) is working very closely with 'insiders' to write up actor-oriented contemporary ethnographies of the innovation systems of which they are a part. For example see Westendorp and Biggs (2003); and Biggs et al. (2003); and Pandey et al. (2002). While there are predictable problems regarding 'the objectivity' of the analysis, there are great advantages in that the documents carry with them a degree of 'insider' authenticity and in-depth analysis and insights that studies by 'outsiders' do not carry. Tendler's (1997) perceptive studies of rural development 'successes' in Brazil were conducted by an 'outsider'. The autobiographical studies of successes in

Krishna et al. (1998) are totally written by the 'insiders' themselves. Messerschmidt's book (1981) takes up the theme of looking at the problems faced by anthropologists who work as 'outsiders' but study their own home cultures.

8. There was also a great deal more PTD taking place in NARC if one took into account the informal personal contacts scientists had with farmers, NGOs, farmers' associations, consultancy companies, etc. In addition some NARC researchers were farmers themselves and some, in their private capacity, had seed multiplication farms. However, these very prevalent informal linkages, which had a major effect on the behavior of NARC staff and the organization's functioning were not investigated in the formal public discourse at the time. Also many of the formal human resources development plans did not, at the time address these issues in any depth.

9. Gauchan (personal communication) observes that the actor approach has helped NARC staff to envision the new NARC mandate and thrust areas in the recently developed and published NARC long-term vision for 2021.

10. The NARC OR Division published the papers describing these different major innovation systems in the agricultural sector. They were all written for planning workshops attended by major actors in each of the innovation systems. The papers covered crops and soil fertility (Gauchan et al. 2000a); livestock (Gauchan et al. 2000b); and horticultural crops (Gauchan et al. 2000c). An excellent paper by Subedi at an outreach workshop in July 2000 showed how actor linkage maps could be used to represent the ways a major local NGO the Local Initiative for Biodiversity, Research and Development (LIBIRD) made different types of partnerships linkages in different projects with government, private and NDO actors (Subedi 2000).

11. For a more detailed analysis of the Nepal case and the importance of addressing in a substantial, analytical way cultural issues within projects, programs, development coalitions, etc., see Biggs and Smith (2003)

12. For readers interested in how to define, record and measure changes in 'social capital' this paper makes good reading. It uses similar indicators to those used in Lewis (1998) and Westendorp and Biggs (2003).

13. In our earlier paper we illustrate how these tools can be used in an ex-post project evaluation of a farming systems research and extension project in Namibia (Biggs and Matsaert 1999). A similar ex-post analysis was carried out on a micro enterprise project in Namibia (Biggs and Matsaert 2000).

14. For an ethnography of aid that has a strong orientation towards NR innovation systems see Crew and Harrison (1998). For ethnographically oriented studies of international/national NR and agricultural research systems see Squires (1999) and Hogg (2000).

15. Although, of course, we recognize there will be reflective, open-minded people who might be exposed briefly to the tools and integrate them appropriately into their personal and professional life.

16. Because of the diversity of political, cultural, and institutional contexts in which actor approaches are used it would be unwise to try to devise international or global indicators to assess changes in linkages and other institutional characteristics of innovations systems.

17. The culture of different situations determines how language, methods and frameworks are used and whether they are co-opted by dominant groups for their own purposes. For a discussion of these issues see Biggs et al. 2003.

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8. Institutional learning and change: towards a capacity-building agenda for research. A review of recent research on post-harvest innovation systems in South Asia

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Abstract

Reviewing recent research on partnerships in the post-harvest sector this paper explains the way the innovation systems framework was developed and used to gain insights into the institutional context of R&D with a view to promoting good practice. Emerging from this research is the recognition of the central importance of institutional learning and change as a way of creating the constantly shifting links, partnerships, and approaches that underpin innovation. Based on what is now known about the process of innovation and institutional change, it is suggested that the next task for research is to explore institutional learning and capacity building in greater detail. The recommended approach is an interactive policy research methodology that ensures an action research orientation, placing the work in real life (and real time) innovation contexts. This needs to be linked to the development of a community of practice that will promote consensus on the need for and direction of institutional change.

Introduction

This paper reviews recent innovation policy research in the post-harvest sector and outlines future plans for research in this area. A joint Indian and British research team undertook the work reviewed with support from the Crop Post-Harvest Programme (CPHP) of the UK Department for International Development (DFID). The significance of the research was that it examined the importance of partnership in research at a time when partnership approaches were starting to be recognized as useful, but when little was known about promoting such an approach in ways that strengthened pro-poor innovation. The research focus on innovation was also significant because innovation was explored in the broad sense of the activities and processes associated with the generation, distribution, adaptation, and use of new technical, institutional, and managerial knowledge. This distinction is made to emphasize that the research was not

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about innovation in the narrow sense of the invention of new technology in research and development (R&D) laboratories – although R&D is clearly important. Rather the research was about how R&D needs to be viewed as part of a larger process that brings about technical and economic change.

Among the many findings of this work has been the growing realization that innovation happens when arrangements are in place that support learning and institutional change among groups of partners and stakeholders. This means arrangements whereby those involved in research and rural development reflect with their partners on their successes and failures and adapt approaches and procedures in order to achieve success. This process is referred to in a number of ways – 'learning-by-doing', 'failing forward', 'participatory learning and action'. The term 'institutional change' is used here as shorthand for this concept and by this we simply mean changing the norms, routines, and conventions associated with the way post-harvest innovation is approached. This might mean reconsidering who is involved in research or implementation activities; who decides priorities and approaches; or how successes are judged, and by whom.

During the 3 years over which the research was conducted it was observed that this combination of cycles of learning and institutional change is a powerful way of bringing about innovation.While we have realized the importance of institutional learning and change, we know far less about how to encourage and promote this process in organizations and clusters of partners. The purpose of this paper is to provide a synthesis of the past work that has led us to these conclusions. We then go on to discuss further avenues of research that could build on this work.

We begin with a brief discussion of the emerging importance of these types of policy study.

The need for policy research on innovation and institutional issues

The need for this type of policy research in a technology domain such as post-harvest stems from widespread recognition that the institutional environment or context of R&D plays a major role in the outcome of such efforts, governing their success not just in terms of technical performance, but also in terms of relevance and impact on the livelihoods of poor people (Biggs 1990; Rajeswari 1995; Hall et al. 2001a). Blaikie et al. (1997) make similar comments in the context of efforts to incorporate the knowledge and values of poor people into rural innovation processes (Box 1 defines the institutional context of R&D).

By way of introducing the interrelatedness of technology, policy, and socio-economic outcomes, Box 2 presents an example of how the institutional context of post-harvest research affects project progress and impact. The case described highlights the nature of partnerships, as well as the rules governing partners and their relationship with each other, as a critical area of policy that is integral to post-harvest innovation. What is notable in the case in Box 2 is that failure to engage with critical institutional and policy contexts of the project not only led to failure in establishing improved post-harvest management systems (the main technical focus of the research), but also allowed the project to proceed for a number of years with little hope of helping the groups of poor people that it assumed were its key stakeholders.

Box 1. Institutional context of R&D.

The institutional context of R&D concerns the rules, norms, and conventions that govern research. In practice this means the rules and norms governing:

- How research priorities emerge, are promoted and executed
- The role of various actors involved in the production, transfer, and use of knowledge
- The relationship between these different actors and the factors that affect their relationships
- How research performance is evaluated and rewarded (incentives), and by whom
- How R&D is held accountable to different interest groups and society as a whole
- How knowledge is built up, shared, and used
- How organizations reflect and learn.

Other aspects of the institutional context concern the wider institutional environment. For example, it concerns the way national culture embeds in the norms of individuals and organizations and the way this affects how they operate, interact, and relate to each other, and how they learn and use knowledge. Therefore there can be different national cultures of science, with norms of acceptable behavior, review, and validation. There are also different organizational cultures and traditions in different sectors. For example, government agencies (sometimes unfairly) are thought of as top-down bureaucracies, whereas NGOs are usually (sometimes incorrectly) presumed to have flatter management structures. These are all illustrations of institutional contexts that impact on the way decisions are made, whose voice is heard, and the dynamics of relationships between partners – all factors that impinge on the direction and outcome of R&D.

In fact, it was the experiences of working on the projects described in Box 2 that laid the foundations for the research discussed in this paper. The original proposition of this work was that often the institutional context of R&D was a major restriction to innovation and thus socio-economic impact. However, it was postulated that the emergence of a series of new types of relationship between the public and private sectors in India was starting to alter the institutional context of innovation. Furthermore, there was some hope that this would bring about institutional changes that were pro-poor, the hypothesis being that these developments would build links between the poor, sources of technology, and markets. At the time, this pro-poor hypothesis was starting to become particularly critical because the donor, DFID, was seeking ways to improve the poverty relevance of its programs.

A critical novelty of the research was that it conjectured (probably prematurely) that a new non-linear paradigm of innovation was starting to emerge as a result of these partnerships. By this it was meant that the research–extension–farmer model of technology development and transfer was starting to be supplemented by networks of organizations and individuals with two-way flows of information and technology. The research proposed that the national systems of innovation conceptual framework could provide a way to understand these developments and to explore ways in which they could be capitalized on and promoted.

The main attraction of the innovation systems framework was that it brought into the analysis of R&D project performance the broad range of actors and institutional contexts that shape research and techno-economic change. It also recognized that learning was important in dynamic systems and thus introduced this as an issue to be investigated. These were all clearly important dimensions for post-harvest research as it spans the

Box 2. Interaction among multiple agencies in the horticultural supply chain in India.

Between 1996 and 2001 CPHP supported the development of mango exports by Vijaya, a fruit growers association, and the Agricultural Processed Products Export Development Authority (APEDA). The main focus was on the development of controlled atmosphere (CA) container sea-shipment protocols. APEDA set up a series of contract arrangements with relevant organizations from both the Indian Council of Agricultural Research (ICAR) and the Council for Scientific and Industrial Research (CSIR) as well as with the Horticultural Department of the local State Agricultural University. These organizations then worked with Vijaya to develop and test the CA protocol. The ICAR institute dealt mainly with pre-harvest pest management issues; the CSIR institute undertook experimentation on CA storage regimes; and the university department advised on packhouse management.

Trial shipments took place over a period of 3 years. However, consistent problems with the quality of fruit exported led to an evaluation of the export protocol and technical backstopping provided. Individually the quality management recommendations were technically robust. However it was observed that there was limited interaction with farmers in the development of recommendations and this was part of a broader concern over the client focus of the contracted agencies. Typical of their organizations, the scientists involved had little experience in working with farmers or in a commercial environment, and were usually not encouraged to do so. It was also observed that quality management measures were not devised and implemented in an integrated way across the supply chain. This resulted from relevant technical expertise being located in organizations governed by two different research councils, with scientists contracted independently to work on components of the quality management problem. Vijaya was then left (unsuccessfully) to ensure that these component technologies and practices operated effectively together. This was particularly apparent with attempts to deal with anthracnose, a quality-related disease that needs to be tackled with an integrated pre- and post-harvest approach.

The notable feature of the Vijaya case is that even where interactions with the public sector can be developed through contracting arrangements, the ability of individual research institutes to assist is limited by current institutional arrangements. Not only is there strong disciplinary segregation, but different research council affiliation also tends make integration difficult. The nature and rigidity of organizational culture – a key institutional arena – also makes the development of more integrated and responsive working practices amongst scientists difficult.

But if innovation in a general sense was restricted, what were the prospects for pro-poor innovation? In this case even though mango growers were (rather euphemistically) referred to as poor farmers, the reality was that those involved in the export shipment trials were inevitably large-scale, non-poor producers. It was this group that dominated the farmers' association involved, even though the majority of members were genuinely poor households whose livelihoods depended on mango production. The key stakeholders in this intervention were willing to continue the rhetoric of pro-poor focus, as this was a stipulation of the donor supporting the work. Dominant (and perfectly legitimate) stakeholder agendas included: mango export promotion; accessing high-value export markets; accessing technical expertise; developing (and having ownership) of new post-harvest technology and other research products. Stakeholder agendas were not investigated until much later in the research process, by which time it was probably too late to make any difference. By ignoring this important institutional context, not only was innovation in a general sense impeded (different agendas and roles were never negotiated and resolved), but more importantly it was almost a forgone conclusion that pro-poor innovation would not take place.

Source: Hall et al. 2003b.

interests of many research, development, marketing, and production actors. In addition, it is an arena where the poverty focus is always going to be contested by a large number of stakeholders with diverse and competing interests and hence institutional issues and contexts are of central importance. When this policy research approach was proposed (see Hall et al. 1998) and adopted in 1999 it was the first application of the national systems of innovation framework in the agricultural sector of developing countries.

The origins and features of the innovation systems framework

The attraction of the innovation systems framework stems from the way it engages with the institutional, political, economic, and social dimensions of knowledge production and its use at a time when these concerns are occupying a central position in development practice. Thus current debate is broader than concerns about research as a basis for scholarship and the development of new technologies – although both ultimately remain important. The term innovation – used in the sense of new creations of wider socio-economic significance – helps us to break away from the confines of a debate focused on research and allows a more inclusive and nuanced discussion of the process of development and change.

The origin of innovation systems thinking can be traced to the idea of a 'national system of innovation' proposed by Freeman (1987) and Lundvall (1992). At its simplest, this concept states that innovations emerge from evolving systems of actors involved in knowledge production and use. Lundvall identifies learning and the role of institutions as the critical components of these systems. He considers learning to be an interactive and thus socially embedded process, which cannot be understood without reference to its institutional and cultural context, usually in a national setting. The innovation systems concept is now widely used in the policy process in developed countries, but has only recently started to be employed in relation to research policy in the South (see, for example, Hall et al. 2001a; 2001b).

Another way of making a similar point is proposed by Gibbons et al. (1994) in their much-cited discussion of 'mode one' and 'mode two' production of knowledge. In mode one, knowledge is generated, often with government assistance, by a research community accountable to its disciplinary peers. The Gibbons' thesis is that institutional changes in western societies (particularly where the market has started to eclipse the state as the primary decision-maker) have forced science to become more socially embedded and less hierarchical, thus defining the mode two type. The important point is that as societies and economic systems become ever more complex, the mode one type of production of knowledge becomes less able to respond to rapidly changing user contexts. Only by assuming the features of mode two production of knowledge can systems be designed to cope with complexity and rapid change.

Six principles of the innovation systems framework

1. It focuses on innovation (rather than research) as its organizing principle. The concept of innovation is used in its broad sense of the activities and processes associated

with the generation, production, distribution, adaptation, and use of new technical, institutional, and organizational or managerial knowledge
2. By conceptualizing research as part of the wider process of innovation it helps identify the scope of the actors (including public, private, research, enterprise, and technology-users sectors) involved and the wider set of relationships in which research is embedded
3. Because it recognizes the importance of both technology producers and technology users and that their roles are both context- specific and dynamic, it breaks out of the polarized debates of 'technology-push' versus 'demand-pull' theories. Instead it recognizes that both processes are potentially important at different stages in the innovation process
4. It recognizes that the institutional context of the organizations involved and particularly the wider institutional environment governs the nature of relationships, promotes dominant interests, and shapes the outcome of the system as a whole. This aspect is enormously important for introducing a poverty focus. The framework provides a lens to examine and reveal which agendas are being promoted, highlighting the arena in which the voice of the poor can be promoted
5. It recognizes this as a social system. In other words, it does not just focus on the degree of connectivity between the different elements, but also the learning and adaptive process that makes this a dynamic, evolutionary system
6. It is only a framework for analysis and planning, and as such it can draw on a large body of existing tools from economics, anthropology, evaluation, management and organizational sciences, and so forth.

Overview of work to date

Where have the last 3 years led us, and what have been the outcomes? The research conducted under the project has firstly given us confidence that the innovation systems framework is a valuable way of conceptualizing the institutional context of research and innovation. A great deal of time has been spent in thinking about what the concept means in terms of its application to agricultural innovation in a developing-country context and how it might be used.

The research has also used the innovation systems framework to analyze a series of case studies of partnerships initiatives related to agricultural innovation, including some of the CPHP's portfolio of projects in South Asia (Box 3 lists the case studies that have been conducted). Part of the work has concerned general analysis of the nature of Indian agricultural innovation systems (see Box 4). This empirical work has lead to a number of broad conclusions.

Firstly, our initial announcement of the death of the old linear, technology transfer paradigm was exaggerated! Our case-study work has certainly given us examples of instances where institutional change is starting to take place as a result of new forms of partnership. But, time and time again we found that in many areas, particularly (but not exclusively) in the public-sector research system, much institutional change is required before systems approaches to innovation can be adopted. Often this is an issue of integrating and linking research organizations into the wider context of other sector stakeholders including the private sector, non-governmental, and community-based

Box 3. Case studies of partnership and post-harvest innovation.

CPHP projects

- Developing a quality assurance system for mango export in India. (Experiences of trying to develop export protocols through the collaboration of the export development authority, public research organizations, and a farmers' association)
- The sustainable retailing of post-harvest technology in India. (Experiences of developing and supplying a new packaging technology for tomatoes using a partnership-based approach)

Others

- Contrasting research arrangements in the public, private, and co-operative sectors using the illustration of the sugar sector in India
- Kerala Horticultural Development Programme, India, an example of a learning-based approach to developing research partnerships and linking farmers to markets
- Public–private sector partnership in the Indian seed industry
- Partnership-based approaches to commercialization of sorghum and pearl millet in southern Africa
- New institutional arrangements for developing pro-poor biotechnology capability in Andhra Pradesh, India
- Agro-processing and local markets through People's Technology Initiatives In India
- Mango processing by tribal communities in Gujarat, India
- The pomegranate innovation system in Maharashtra, India
- Building local capacities for traditional agro-processing: the case of indigo in Andhra Pradesh, India
- Food system innovations and the role of civil society organizations: the case of *Spirulina* technology in India.

organizations (Boxes 4 and 5). With this task in mind, our research has led to a number of lessons on the nature of the partnership process and ways partnerships and linkages could be promoted (see Box 6).

While the creation of new partnerships will be needed if innovation systems are to be strengthened, the institutional change required also concerns changing the 'rules of engagement' that would govern this integration and the relationships that stem from it. In particular, conventions and arrangements that put poverty-reduction criteria firmly on the agenda of innovation efforts are still an area that needs much greater attention in many parts of the innovation system. Similarly, the need to break down many of the hierarchies that currently characterize agricultural research and rural development interventions need to be replaced by more consensual approaches with broad-based (and genuine) participation of the diverse range of stakeholders involved in the sector.

Our research suggests that partnerships, while making an important contribution towards this goal, need to be accompanied by the recognition that institutional change is needed in some of the fundamental areas that relate to the governance of agricultural science and technology. Our research has also shown that without institutional change the relevance of formal research organizations reduces over time as they have no way to adapt their focus and activities to match the constraints and opportunities faced by technology users and society as a whole. It is for this reason that institutional learning assumes such importance in strengthening innovation systems performance (see Box 7 for definition of institutional learning). Table 1 provides a comparison between old and

Box 4. India's agricultural innovation system and challenges it faces.

In India it is apparent that many of the elements of an effective agricultural innovation system are emerging. There is a strong and extensive public research system. There is a vibrant private sector. There are large numbers of skilled and committed rural development agencies in both the public and non-governmental sectors and increasing efforts have been made to foster linkages between different sectors. However the system is challenged, particularly with regard to the way that scientific organizations relate both to each other and to user sectors including the poor. The result is that scientific expertise remains locked up in research organizations. This will not be resolved until all the elements of the innovation system are able to work effectively together. This will require significant institutional reform.

Some of the issues to be addressed:

- Disciplinary segregation between different research areas relating to cross-cutting economic themes such as post-harvest
- Administrative segregation of research relating to agriculture and research relating to industrial development, including food science
- Hierarchical cultures within science, between science and social science, between research and knowledge transfer and use, leading to linear or uni-directional flows of information and technology, restricting joint learning and consensus building
- Organizational cultures in research establishments that discourage learning and only encourage the reporting of 'successes'
- Co-opting of participatory methods to camouflage existing behaviors and roles of scientists and poor technology users
- Research priority setting and evaluation by scientists and economists using principles of excellence in science and economic efficiency criteria. Weak accountability to society
- Lack of wide stakeholder participation in the agricultural research planning and implementation process
- A disconnect (underpinned by professional hierarchies) between the learning from science and development initiatives in the civil society sector on the one hand and the priorities and practices in the formal research establishment on the other.
- A disconnect between research and policy, including a disconcert between policy advocacy for poverty reduction and policy advocacy for agricultural research, but also weak linkages between science, society, and policy in such regulatory areas as food safety, IPR, and biotechnology.

new, system-friendly institutional arrangements for research using an example from ICRISAT's partnership-driven approach in southern Africa. Table 2 contrasts technology transfer and innovation systems models of innovations, illustrating the institutional issues that need to be analyzed when assessing the nature and effectiveness of innovation systems.

The task at hand is therefore two-fold, concerning: 1. the need to link up parts of the innovation system; and 2. ensuring that institutional arrangements allow the different parts to work in a systems fashion that is simultaneously pro-poor, provides incentives for broad-based participation from diverse stakeholders and is responsive to evolving development priorities and opportunities.

In terms of enhancing post-harvest innovation and its poverty relevance, a number of generic points emerge from our work over the last 3 years.

Box 5. Public–private interaction in India's agricultural innovation system.

Private distribution of public technologies. The seed industry benefited from early policy liberalization and a successful private seed industry has emerged. Strong and positive interaction exists between the public sector and small-scale private seed distribution companies. However larger-scale seed companies, now an important source of new varieties and hybrids, feel that they suffer from a more competitive relationship with the public sector.

Private purchase of research services. In the horticultural sector contract research is starting to increase interaction between public and private sectors. However there are still significant institutional constraints that need to be addressed before such arrangements can become more widespread. These constraints concern contractual accountability, bureaucratic procedural norms, and institutional segregation among public agencies. Case studies of the sugar industry demonstrate how such concerns not only act as a disincentive for the private sector to engage with the public sector, but also how they greatly reduce the relevance of the technology and related services that the pubic sector can provide.

Public–private research partnerships. Collaborative research partnerships between the public and private sectors are still uncommon. The reasons why such arrangements have yet to become widespread include a long history of separation and mutual mistrust between the sectors. Underpinning this problem are sharply contrasting views on the role of science and the way to apply it in a problem-solving context. This is made worse by a public administration system designed for a centrally planned State where delays are frequent and the possibility of sudden policy changes can cause much uncertainty. This institutional environment is poorly suited to commercial working styles. Case studies also suggest a basic misunderstanding on the part of the public sector about the demand of the private sector. Whereas the public sector feels that its 'shelves' of un-adopted technologies are its greatest asset, the private sector is equally interested in public research expertise and infrastructure. This suggests that the nature of partnerships to exploit this synergy needs to involve knowledge sharing and developing technologies jointly, rather than simply transferring public products to the private sector

Source: Hall et al. 2002a.

On the nature of post-harvest innovation

- Innovation in the post-harvest sector involves dealing with issues in complex systems that have both technical and socio-economic parts and often involve producers, market chain actors, and consumers (Hall et al. 2003b)
- Both technical and institutional innovations are important (Hall et al. 2002b)
- Formal R&D is only one of a series of related tasks required to bring about innovation. It requires collaboration between different scientific disciplines, between researchers and technology users and between public and private sectors. It is sometimes useful to involve an organization to act as a catalyst facilitating this pattern of broad-based collaboration. (Hall et al. 2001a; Rasheed Sulaiman and Hall 2002; Clark and Mugabe Paper 6, this volume.)
- The institutional context of these collaborations or partnerships is a key determinate of their direction and outcome (Hall et al. 2001a)

Box 6. A dozen things we know about partnerships.

1. Partnering is a pragmatic response to the need to accomplish complex tasks that cut across disciplinary, organizational, and sectoral mandates. Joint task identification and definition builds partnership. Forced partnerships and ritualistic partnerships have no value and will not be sustained
2. Partnerships should only last as long as there is a shared task to be accomplished and should not be viewed as a permanent linkage
3. Not all organizations have the appropriate skill to be good partners
4. While the clear definition of roles for all partners is important, it also needs to be recognized that the roles of partners change during the innovation process, with different partners assuming greater importance at certain times
5. Partnering helps sharing of resources, skills, and knowledge and thus is critical to learning and innovation. Not all organizations have a culture of learning. This restricts both their ability to partner and generate institutional innovations
6. Rigid institutional and organizational structures, particularly those with hierarchical designs tend to stifle learning and the development of iterative relationships with broader sets of partners
7. While it is easy to stereotype public, private and NGO organizations, and the organizational culture that goes with them, there is a need to examine these more closely in the analysis of project partnership viability
8. Successful partners have intuitive ways of identifying each other that relate to shared values, trust, and complementarity. Shared history built up over previous partnerships obviously contributes to this. To promote partnership it is necessary to provide opportunities for this trust to develop
9. Partnership skills are part of a range of capabilities that help organizations innovate, and that are learned through interaction with partners and networks
10. How organizations learn and build up these skills is not yet entirely clear
11. The strengthening of learning processes in project partners appears to be a key area of capacity development
12. Activities that widen the interaction of organizations with other partners and networks are likely to be an important way of building up innovation capabilities, both in individual organizations and in wider national systems.

Box 7. Institutional learning.

The concept of institutional learning concerns the process through which new ways of working emerges. It concerns learning how to do things in new ways. It asks the question 'what rules and norms have to be changed to do a new task or to do an old one better?' (eg, how has our research approach changed in response to the need to improve the poverty relevance of our work and what else needs to change? What can we learn from activities that did not have expected outcomes?). A key aspect of this learning may involve learning how to learn better, a concept that the management and organizational theory literature refers to as 'double-loop' learning. The learning process is very context-specific and consequently institutional learning can lead to great diversity in approaches, partnerships, and strategies. Institutional learning is an inevitable and intuitive process, a fundamental property of all social systems. Where programs have explicit, systematic learning objectives and procedures, research management strategies can evolve and progress rapidly.

Source: Hall et al. 2003a.

Table 1. Key features of the research management and technology promotion in contrasting institutional settings: SMIP[1] task networks and conventional agricultural research arrangements.

	Conventional agricultural research arrangements	SMIP task network
Guiding agenda	Scientific	Developmental
Relationships involved	Narrow, hierarchical	Diverse, consultative
Partners	Scientists in other public agencies	Scientist, entrepreneurs, and development workers, from the public and private sectors
Selection	Predetermined by institutional roles defined by the arrangement of the research system	Coalitions of interest. Determined by the nature of task, national institutional context and skills and resources available
Role	Fixed. Predetermined by institutional roles defined by the arrangement of the research system	Flexible. Determined by the nature of task, national institutional context and skills and resources available
Research priority setting	Fixed. By scientists	Consensual. By regional stakeholders and by needs of task network
Work plans and activities	Fixed at beginning of project	Flexible, iterative
Mandate for research/task approach adopted	Fixed by institutional norms of the research system	Negotiated through coalitions of interest
Technology development and transfer approach	By scientists and extension staff	Participatory technology testing with farmers and agro-processing enterprises. Use of farmer groups for technology promotion
Knowledge produced	Technical/ scientific	Technical/scientific and institutional
Performance indicators	In scientific terms to other scientist	In development terms to donors. In terms of fulfilling role in task network to other partners
Responsibility for achieving impact	Other agencies dedicated to extension and technology promotion	SMIP scientists and their partners in task networks
Capacity building	Trained scientists and research infrastructure	Collective capacity of task networks, social capital, partnership skills

1. SMIP is the SADC/ICRISAT Sorghum and Millet Improvement Program. This 20-year program has aimed to develop sorghum and pearl millet improvement capabilities in southern Africa and to promote the uptake of research products.

Table 2. Opposite end of the continuum: a comparison of models of agricultural innovation.

Features	Transfer of technology	Agricultural innovation system
1 System features		
1.1 Actors involved	Mainly public research and extension organizations	Diverse combinations of actors from public, enterprise, NGO and community-based organizations (CBO) sectors
1.2 Patterns of relationship	Hierarchical arrangements with linear flows of information	Flatter more consultative relationships to exploit complementary resources and joint learning Partnerships and alliances important
1.3 Sources of institutional innovation and learning	Centrally generated, blueprint model Static	Through experimentation by partners Evolving and dynamic
2 Role of different actors		
2.1 Technology users/ farmers	Technology adoption	Source agro-ecological and socio-economic knowledge Undertaking research and adaptive testing Technology adoption Identifying research priorities and evaluating research performance
2.2 Private enterprise	Technology transfer	Technology transfer Knowledge of inputs and output markets and demands of technology users Source of research funding In-house research expertise Advocacy for policy change Evaluating research performance
2.3 NGOs	Technology transfer	Technology transfer Implementing research and development initiatives Market studies, enterprise development Facilitating linkages between farmers and other agencies Facilitating the development of farmer organizations Advocacy for policy change Evaluating research performance Identifying research priorities
2.4 CBO	Technology transfer	Technology transfer Community based research and development initiatives Agro-ecological and socio-economic knowledge Evaluating research performance Identifying research priorities
2.5 Public research organizations	Conducting research. Identifying research priorities and evaluating research performance Passing technologies to specialist technology transfer organizations	Partner providing research services, technology and technical backstopping Creating regulatory framework Linkage with international scientific community

Table 2. continued....

2.6 Policy bodies	Resource allocation Passive recipient of policy research recommendations	Strengthening the enabling environment of innovation systems Active partner in the research process
2.7 Donors	Sources of funds	Clients and partners in the research process
2.8 International agencies	Promote blue prints (?)	Program management and oversight Linkage to source of funds Technology supply Research services Linkage facilitation
3 Governance of R&D		
3.1 Scope of participation	Limited	Consultative with many partners, including farmers and technology users
3.2 Accountability	Limited to peer review	Collective and to society and technology users directly
3.3 Scope of vision and goals	Scientific	Developmental
4 Wider context		
4.1 Relationship with wide institutional and political context	Disconnected	Embedded
5 Capacity building		
5.1 Focus	Research capacity of the existing research organization	Evolutionary capacity of entire agricultural innovation system
5.2 Composition of capacity	Research personnel and their scientific skills, research infrastructure, level of research funding	Individual capacities of different organizations collective capacity of temporary coalitions and alliances Longer term capacity arising from development of partnering skills and joint learning
6 System performance impact		
6.1 Criteria	Scientific and economic outcomes	Developmental outcomes and institutional or behavioral changes in the system
6.2 Method of evaluation	Peer review by scientists and economists	Expert review by public and private sectors, science and non-science stakeholders
6.3 Indicators	Citation analysis, technology adoption rates Economic rates of return to research investments	Changes in livelihoods and other socio-economic outcomes Evidence of new partnerships, consensual approaches and other processes that promote pro-poor innovation

On institutional change

- There is a generic concern relating to the need to build stronger and more consultative linkages between public-sector science and other actors in the innovation system. This implies a need to address a broad range of institutional features of the current agricultural innovation systems that prevent these linkages developing. Static and compartmentalized roles, combined with a poorly developed learning culture are institutional issues that need specific attention (Hall et al. 2000; 2001a; 2002a)
- Supporting institutional change requires long-term commitment on the part of donors and policy agencies. This is particularly so because successful institutional change is observed to emerge indigenously, through trial and error in response to local circumstances (Clark et al. 2002; Hall and Yoganand 2003)
- Transferred institutional models or blueprints rarely succeed (Hall et al. 2000; Rasheed Sulaiman and Hall 2002).

On partnerships

- Successful projects have been those that have focused specifically on establishing coalitions of local actors around a particular problem area or task. These actors include scientific ones, but not exclusively so and not necessarily as the leading actors. Similarly, roles may evolve over time (Reddy et al. 2001; Clark et al. 2003; Hall 2004; 2002)
- The selection of the most appropriate grouping of partners is very often an empirical question that cannot realistically be answered at the outset of a project. Projects should allow for this with inception phases and mechanisms that allow the introduction of new partners or replacement of old ones (Rasheed Sulaiman and Hall 2002; Hall 2002; 2004; Clark et al. 2003).

On institutional learning

- There is a tendency, reinforced by the output-oriented, problem-solving framework of the conventional project cycle, to under-report process or institutional innovations and lessons associated with technological success (or failure.) These lessons are often complementary innovations to the new technical knowledge and its application. This institutional learning should be part and parcel of technical projects and their outputs (Hall et al. 2002b; 2003a)
- If institutional or process lessons and innovations are to be fostered as a research output, an action research approach should be used. To implement this approach self-reflection and process monitoring and documentation skills will need to be developed in project teams. This is particularly so where team members come from formal scientific research organizations where the learning culture is poorly developed (Hall et al. 2003a; 2003b).
- Institutional learning and change is often highly contested. It rarely succeeds if it is driven by only one or two individuals, particularly if they are relatively junior in an organization. Institutional change can be prevented or legitimized depending on the support or otherwise of key senior figures, particularly directors of organizations, or

senior bureaucrats in donor and policy bodies (Reddy et al. 2001; Clark et al. 2002; Hall et al. 2003a)

- Organizations that are willing to experiment and learn are the ones that succeed. Often successful approaches develop and evolve along the way. Projects and organizations that encourage continuous institutional learning seem more likely to succeed (Clark et al. 2003; Hall et al. 2003b)
- Research approaches that lead to institutional learning and change (as arguably all do to varying extents) need to be recognized for their contributions to developing the capacity of innovation systems. This needs to be considered when planning monitoring and evaluation procedures as it is behavioral changes within the innovation system that will indicate progress towards such longer-term goals as poverty reduction (Hall 2002; Clark et al. 2003).

On poverty focus

- The relative degree of poverty focus is related to the agendas of different project partners and the dynamic that determines how these agendas are promoted in the project. To succeed projects often have to introduce specific institutional changes or arrangement to achieve this poverty focus; for example, deciding to work only with landless groups or tribal communities (Rasheed Sulaiman and Hall 2002; Hall et al. 2003c; Abrol 2003)
- Needs assessment and farmer participatory approaches, while valuable, have been much less important in ensuring a poverty focus than the agendas of the stakeholders involved in a given project. These stakeholders include both members of the research team as well as external individuals and organizations (Underwood 2002)
- Revisiting during the project key assumptions about, for example, roles of partners and technology users, relevance of project outcomes to livelihoods, and the changing agendas of different stakeholders, helps maintain a poverty focus in projects (Underwood 2002)
- There are still unanswered questions about the way organizations build up skills that allow them to participate in the innovation process in pro-poor ways and how these types of behavior and practices can be introduced into innovation systems (Hall 2002).

Emerging issues

During the course of the research it became apparent that the question of how organizations engage in institutional learning, and how this can be promoted, was central to developing post-harvest innovation systems capacity. Take, for example, the case of the IDE(I) tomato packaging project (see Clark et al. 2003 for detailed discussion). This project had developed an important institutional innovation in technology identification, adaptation, and supply using a market-based total-systems approach that was relatively pro-poor. The project was particularly notable for the way it developed a range of partnerships with different organizations during the course of the project. The roles of the different partners evolved over time (see Table 3), with IDE(I) playing a facilitative role allowing the project and its partnerships to evolve in useful

Table 3. Who does what and when: multiple partners and evolving roles from the case of IDE(I).

Partners/ roles in each phase	Problem definition	Technology and partners search	Technical development and testing	Establishing product and supply system
Lead organization	Consulting, collating, negotiating	Identifying technology and facilitating partnership development	Coordinating activities of different partners and managing relationships	Coordinating activities of different partners and then withdrawing
NGO	Facilitating local consultation		Facilitating farmer participation in adaptive testing	Facilitating farmer groups' access to credit to pre-finance technology production
Scientific research organization		Advising on available knowledge and technology	Researching technology performance	Publishing
Farmers' groups	Advising on problem definition		Testing technology, advising on technology performance	Pre-financing of technology production Adoption of technology
Market actors	Advising on marking systems		Testing technology, advising on technology performance	Distributing new technology
Manufacturers		Advising on available knowledge and technology	Modifying technology	Producing technology

ways. The project was very successful in establishing a pilot commercial system to supply 30,000 cardboard cartons to small-scale tomato producers by the end of the third year of the project.

At best the only way to describe the learning (and implementation) process was as 'intuitive' and it was unclear what practical advice could be given to other organizations or groups of partners who wanted to evolve their own approach through a similar process of institutional learning and change. This does not detract from what IDE(I) achieved, it just highlights that there is obviously much more that needs to be known about how R&D organizations learn through their activities and through the partnering process. Another case examined was the Kerala Horticultural Development Programme (KHDP) and its efforts to link producers with both markets and technology (see Rasheed Sulaiman and Hall 2002 for detailed discussion). Again a learning approach underpinned its success and informed its partnership strategy, but how it actually did this is less clear.

A similar example can be found with the case of the efforts of Dastkar Andhra (DA), a civil- society organization attempting to reintroduce production, processing, and use of indigo to weaving communities in Andhra Pradesh (see Box 8). In the DA's own words, it developed an approach through experimentation, failing and learning, recognizing that there was an important formative role for organizations that were willing to fail. What is less clear is precisely the nature of the process through which the organization learned and built up its learning skills and what practical tips another organization could borrow from this example.

Emerging from this is the conclusion that while institutional learning and change has clearly underpinned the successes of some of our successful examples of innovation, ways of promoting this remains an empirical question. Before we discuss ways of approaching this question it is useful to pause and reflect on what has been the outcome or impact of this work on post-harvest innovation systems and the novel application of the national systems of innovation framework. We reflect on this at this point because our success to date in promoting institutional change through our work holds lessons for future ways of exploring this issue.

What has been achieved

The research reviewed in this paper has led to approximately 30 publications – a significant number. Almost half of these are peer-reviewed articles, the rest being policy briefs, network papers, book chapters, international conference papers, and workshop proceedings. We point out this achievement because it was an important component of our strategy of making innovation systems analysis of post-harvest R&D a credible and visible approach. In addition to publishing this material we have mailed hard copies to Indian and international audiences. But what has been the impact of all of this? Have we actually changed research management strategies? One of our targets was the DFID research programs (of which CPHP is one). While acknowledging the efforts of others we feel that our research on innovation systems played an important role in paving the way for the adoption of innovation systems as a core principle of the coalitions approach of CPHP (this is discussed in detail in Hall et al. 2003b). We also had success with DFID's Livestock Production Programme (LPP) and we were set to use the innovation systems approach to explore the design of LPP's 'dissemination' strategy in India – but this was unfortunately thwarted by the diversion of funds within DFID.

In the Indian agricultural science community, and notably among agricultural economists, the innovation systems term has entered the lexicon of policy debate. For example, a recent conference of the prestigious Indian Academy for Agricultural Science, that convened to discuss agricultural research policy, not only concluded with an expression of the need for institutional change, but it also recognized that the innovation systems approach is a suitable way to proceed. We presented our work on partnerships and innovation systems in the post-harvest context (Hall et al. 2002c) and our participation in this conference had a significant impact on this debate and its outcome (see Raina and Abrol 2002).

Those of us working in the Indian agricultural research system are increasingly receiving requests for information on innovation systems. The concept has been presented at a number of important conferences and workshops and is again attracting attention, particularly among mid-career professionals to whom it is all too clear that a practical way of engaging with institutional issues is the need of the hour. As part of the

Box 8. The re-introduction of indigo: a case of experimentation and learning.

This case involves the reintroduction, over a 10-year period, of indigo production and processing technology. Central to this was the role played by Dastkar Andhra (DA), a civil-society organization providing research and consultancy services to the artisanal sector. The intervention has been through three distinct phases. The first concentrated on introducing the indigo crop. This was generally viewed as unsuccessful. It revealed, however, that information on indigo, indigo processing, and its quality and price, while widely documented in the specialist literature, was almost nil amongst weavers. DA learned that an indigo-growing project needed to be formulated as an experiment as well as a commercial feasibility study. Similarly, the process needed to be driven by an independent interest group emerging around indigo products and that this would require the intervention to be rooted in strong local partnerships.

The next phase took place a number of years latter. Through its role of marketing the handloom products of a number of cooperative societies DA recognized that there was a demand for indigo-dyed cloth. Building on past experience DA realized that growing indigo would need to be supported by other activities. A key intervention was seen as the introduction of indigo dying vats amongst weavers who never dyed their yarn and had become separated from the dyeing process. A dyer with knowledge of the vats was brought to live in a weavers' village in order for him to set up a vat. A series of village-level seminars was subsequently held as a way of disseminating the technology in context. The seminars brought together a number of different groups, among who were indigo growers, indigo traders, weavers, designers, natural dyeing experts, and buyers of the final product – indigo-dyed cloth.

The third and more recent phase approached the tasks in a much more integrated fashion, building on the lessons from the earlier experiment with indigo growing, which was seen as having failed primarily due to the lack of strong partnerships at the field level. The project entitled, 'Action Research in Indigo in Andhra: Growing, Processing and Dyeing' involved three components: 1. to use archival research to reintroduce practices of indigo cultivation, 2. to fuse this with experimentation in the field, which would demonstrate that cultivation, processing, and dyeing of indigo is a viable occupation, and 3. to link these activities with weavers and to establish a market for end products, ie, indigo cakes and indigo fabric. In other words, an interest group for the product was developed simultaneously with activities on indigo production and processing. Re-forging links between growers of indigo, dyers, and weavers was an important aspect of this project.

DA recognizes the following key lessons:

- The first phase while unsuccessful was important because it was an experiment that nobody else was willing to make and the only knowledge that existed resided either in books or amongst a few individuals of communities who were no longer producing indigo. The insights gained and the ideas developed laid the foundation for subsequent steps and placed the private knowledge of a few in the public domain
- In order to take the first steps beyond identification of needs and begin addressing them through experiments or programs, strong partnerships in the field are needed
- While the NGO can initiate the process of knowledge or innovation rooting in local contexts, the success or failure of this seems to depend on the participatory networks that it is able to create and sustain. The same is true for the dissemination phase where networks and partners are seen as key
- There is an apparent value to DA's role of linking various players – farmers, traders, weavers, the market, government agencies, and research organizations.

A generic point is that none of this could take place without DA approaching this task experimentally, undertaking learning jointly with stakeholders, and thus determining what would be the next step. In other words, to make the intervention successful it was necessary for the external agencies to engage in an evolutionary process where the way of approaching the reintroduction of an agro-processing activity was the central empirical question that needed to be pursued over many years.

Source: Seemanthini Niranjana 2003.

Indian science community, with our intimate knowledge of this institutional context, we believe that the institutional edifice is starting to crumble. There are people with alternative perspectives on innovation, but they currently lack a collective voice and mutual support systems to become an effective force for change.

We have also had some impact on the Consultative Group on International Agricultural Research (CGIAR) system. An external review of economics and policy research at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) concluded that the work on innovation systems was one of only three significant methodological developments to have been achieved by ICRISAT in the last 5 years. Our work on innovation systems has created interest at a series of CGIAR international conferences. It is starting to have an impact on the way impact assessment work in the CGIAR is being discussed (for example, see IFPRI 2003) and our research team has been closely involved in a proposal to attract donor support for institutional learning and change backstopping for a number of the CGIAR centers (Watts et al. 2003).

Its also important for us to acknowledge that the emergence of the innovation systems debate in the agricultural research sector has had a number of sources, but we are clearly one of those sources. (Coincidently, DFID has used the innovation systems approach in its recent research policy review.) Similarly, innovation systems are one of the key themes on which the reformed International Service for National Agricultural Research (ISNAR) will focus its work. Our work may not yet be impacting on the conduct of innovation directly in a general sense (nor would it be expected to have done so by this stage), but it has certainly impacted on the debate surrounding agricultural innovation policy.

Where we have failed and what we have learned

We also acknowledge the shortcomings in the work we have conducted so far. In this regard we are grateful to Dr Stephen Biggs [International Centre for Integrated Mountain Development (ICIMOD), Nepal], who pointed out to us that we failed to heed the advice we were promoting as policy researchers, ie, the need to develop our own coalition of partners around the promotion of the innovation systems framework as an alternative approach to post-harvest R&D in India. The idea of developing an informal network or community of practice is an approach that has been used to great effect elsewhere – a good example is the advocacy associated with participatory approaches to development and the subsequent spread of these. A similar case is the way powerfully placed agricultural economists within the CGIAR system have managed to advocate the use of certain types of impact assessment methodology despite the existence of other forms of evaluation preferred by other professional groups.

We now recognize that without the creation of such a network of support and advocacy, a policy research project stands little chance of creating a new consensus that can challenge the normative organizational culture of R&D establishments and the institutional context that this implies. This is particularly true with regard to large public agencies responsible for post-harvest and other areas of agricultural R&D, but the same applies to other organizations and stakeholders in the innovation system who need to be part of the institutional change process. We also now realize how important it is that the coalition or community of practice advocating systems approaches will require the involvement of poor people if the system approach is going to lead to institutional change for pro-poor innovation. Exploring ways of engaging in local knowledge systems is an important element of this task.

A rationale for interactive policy research approach to institutional learning and change

Flowing from the above are three major concerns that further research in this area must address. Firstly, and as already stated, the main thrust of enquiry needs to be on understanding how institutional learning and change takes place, and how it can be strengthened and promoted. Secondly, ways of exploring how learning takes place is an empirical question in itself. Furthermore, a research question of this type would lend itself to an action research approach whereby ways of building learning and change capabilities are investigated in real time and supplemented with case histories from wider experience. Thirdly, the research and capacity-building action research activities need to be embedded in the greater task of developing a community of practice that simultaneously builds consensus and advocacy as well as linking research into the range of stakeholder interests (farmers to policy-makers) associated with how innovation is organized and promoted. To make the same point differently, this suggests an approach whereby research is used to feed training and facilitate institutional learning and change activities which themselves then form the basis for the development of a network or community practice. This is very much a shift in direction away from the formal policy research that we conducted in our earlier work, where the approach was to develop broad principles and recommendations for research managers and planners.

This mixed approach to policy research that we suggest should be referred to as 'interactive' policy research signifying the iterative, systems nature of the approach and distinguishing it from the conventional linear policy approach critiqued by, for example, Sutton (1999). In addition to the conclusions we draw from our earlier research, advocacy for such an approach can also be seen in recently published reviews of the organizational development literature (Ticehurst and Cameron 2000) and the evaluation and capacity development literature (Horton 2002; Horton and Mackay 2002; Stein 1997). These sources stress the need to design, negotiate, and implement change (eg, new policies and institutional arrangements) with the full participation of the stakeholders involved. Beijer and Holtland (2001), for example, provide an example of how this interactive policy approach has been used to develop agricultural extension policy in Albania. Horton (2002) provides a useful definition of capacity development that highlights the reason we give such importance to an interactive policy research perspective: "the process by which individuals, groups, and organizations improve their ability to perform their functions and achieve the desired results over time."

This institutional learning and change agenda also concerns the need for research teams to learn how to operationalize this interactive policy approach. This in itself will be a key source of institutional and methodological lessons. The perspective of removing the (notional) distinction between the researched and the researchers is emerging as central to much of the debate about good practice in development (eg, Abbot and Guijt 1998; IDS 1998; 2001) and there is considerable literature on ways of pursuing such approaches (Lusthaus et al. 1995; Bainbridge et al. 2000; Lawrence et al.

2002). Of course, the innovation systems framework attaches similar importance to these learning mechanisms. Indeed, as this perspective notably recognizes, relationships and interactions between agents have to involve non-price relationships and that while the transaction costs theory of institutions (for example, North 1990) cannot explain the dynamics of such systems, an interactive learning theory of institutions can (Lundvall et al. 2002).

Practical considerations

How could these ideas be operationalized in the practical sense of a research project? The conventional case-study methods will still be important in understanding learning. The novelty of the interactive policy research approach that we are suggesting here, however, is in the use of this case-study material to illustrate in training and capacity development exercises the different ways of supporting pro-poor, post-harvest innovation. This form of capacity development is a well recognized approach. Again we draw on a recent review of several decades of work on capacity development (Horton 2002) that concludes that learning by doing, or experimental learning, lies at the heart of capacity development. Horton suggest that a balanced approach that includes small amounts of formal training should be accompanied by facilitating change processes in pilot-case organizations and using the learning from this pilot work to feed a network generating and applying knowledge on institutional innovation.

Conclusions

By way of conclusion we would like to make three points. Firstly, policy research on institutional change and innovation has to be at the heart of efforts to exploit, in pro-poor ways, such technology domains as post-harvest. The involvement of the poor as part of the social process of learning and innovation requires complementary streams of technical and institutional knowledge that not only tell what can be done, but also how this doing can be achieved.

Secondly, the progress and outcomes of our research to date demonstrate that policy research can make an impact on the praxis of post-harvest innovation, although we acknowledge that there is much work still to be done. A significant task in this regard is to strengthen ways of developing capacity for pro-poor innovation through institutional learning and change.

Thirdly, based on our research findings and what we now know about the process of institutional change, we suggest that the next task for research is to explore institutional learning and capacity development in greater detail. We also suggest that an interactive policy-research methodology should be employed to ensure an action research orientation, placing the work in real life (and real time), interactive, post-harvest innovation contexts. This needs to be linked to greater efforts in developing a community of practice promoting consensus and change.

Endnote

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Appendix 2. Acronyms and Abbreviations

ABI	agribusiness incubator
ACTS	African Centre for Technology Studies (South Africa)
ADB	Asian Development Bank
AgREN	Agricultural Research and Extension Network (ODI)
AICP	All India Coordinated Programme
AICPA	All India Coordinated Programme on Algae
AIVIA	All India Village Industries Association
ALM	Actor Linkage Matrix
AMIT	affordable micro-irrigation technology
APEDA	Agricultural and Processed Products Export Development Authority (India)
APNLBP	Andhra Pradesh–Netherlands Biotechnology Program
APRLP	Andhra Pradesh Rural Livelihoods Project (DFID)
AREP	Agricultural Research and Extension Project (Nepal)
ASP	Agri-Science Park (ICRISAT)
BASC	business advisory services centre (Bangladesh)
BDO	business development organization
BDS	business development services
CA	controlled atmosphere
CAPART	Council for Promotion of Application of Rural Technologies (India)
CBD	Convention on Biological Diversity
CBO	community-based organization
CDP	Capacity Development Programme (ACTS)
CFTRI	Central Food Technology Research Institute (India)
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Mäiz y Trigo
CPHP	Crop Post-Harvest Programme (DFID)
CRDAT	Centre for Rural Development and Appropriate Technology (India)
CRISP	Centre for Research on Innovation and Science Policy
CSIR	Council of Scientific and Industrial Research (India)
CSMCRI	Central Salt and Marine Chemicals Research Institute (India)
CSV	Centre of Science for Villages (India)
CTD	Centre for Technology and Development (India)
DA	Dastkar Andhra (India)
DBT	Department of Biotechnology
DFID	Department for International Development (UK)
DIC	Dainippon Ink Corporation
DLS	Department of Livestock Services (Nepal)
DoA	Department of Agriculture (Nepal)
DoI	Department of Irrigation (Nepal)
DoR	Directorate of Oilseeds Research (ICAR)
DST	Department of Science and Technology (India)
DUS	distinctness, uniformity, and stability
EGS	Employment Guarantee Scheme (India)
ERP	enterprise resource planning
ESSE	European Seminar on Extension Education (The Netherlands)
ETTA	ecology, taxonomy, technology and applications
EU	European Union

FC	field center
FFS	farmer field schools
FSR&E	farming systems research and extension
FYM	farmyard manure
GEF	Global Environmental Facility
GoI	Government of India
GMO	genetically modified organism
GSES	Graduate School of Environmental Studies (UK)
HANDPASS	Nepal Handmade Paper Association
HMG	His Majesty's Government (Nepal)
IARC	international agricultural research center
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICICI	Industrial Credit and Investment Corporation of India
ICIMOD	International Centre for Integrated Mountain Development (Nepal)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre (Canada)
IDE(I)	International Development Enterprises, India
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IIED	International Institute for Environment and Development (UK)
IIMA	Indian Institute Management, Ahmedabad
IJAE	Indian Journal of Agricultural Economics
INGO	international non-governmental organization
INTECH	Institute for New Technology
IP	intellectual property
IPM	integrated pest management
IPR	intellectual property rights
IR	intermediate results
IRRI	International Rice Research Institute
ISI	Bureau of Indian Standards [*formerly* Indian Standards Institution]
ISAAA	International Service for the Acquisition of Agri-biotechnology Applications
ISNAR	International Service for National Agricultural Research
IUCN	International Union for the Conservation of Nature
IVRI	Indian Veterinary Research Institute
KARI	Kenya Agricultural Research Institute
KAU	Kerala Agricultural University (India)
KHDP	Kerala Horticulture Development Programme (India)
KWS	Kenya Wildlife Service
LI-BIRD	Local Initiatives for Biodiversity Research and Development (Nepal)
LPP	Livestock Production Programme (DFID)
LSNS	large scale nutritional supplementation
MAAIF	Ministry of Agriculture, Animal Industries and Fisheries (Uganda)
MAS	marker-assisted selection
MCRC	AMM Murugappa Chettiar Research Centre (India)
MF	master farmer
MoF	Ministry of Finance (Nepal)
MoU	memorandum of understanding
MPKV	Mahatma Phule Krishi Vidyapeeth (India)
MPSSM	Mahatma Phule Samaj Sewa Mandal (India)
MSCF	Maharashtra State Co-operative Federation (India)

MSE	micro and small enterprise
MSEPS	Monograph Series on Engineering of Photosynthetic Systems (India)
NAADS	National Agricultural Advisory Service (Uganda)
NAARM	National Academy of Agricultural Research and Management (India)
NARC	Nepal Agricultural Research Council
NARE	national agricultural research and extension
NARI	Nimbkar Agricultural Research Institute (India)
NARO	National Agricultural Research Organisation (Uganda)
NARS	national agricultural research system
NBRI	National Building Research Institute (India)
NCAP	National Centre for Agricultural Economics and Policy Research (ICAR)
NEERI	National Environmental Engineering Research Institute (India)
NEPAD	New Partnership for Africa's Development (South Africa)
NFI	Nutrition Foundation of India
NGO	non-governmental organization
NIE	new institutional economics
NIN	National Institute of Nutrition (India)
NISTADS	National Institute of Science, Technology and Development Studies (India)
NORAD	Norwegian Agency for Development Co-operation
NOW	nutrition on wheels
NR	natural resources
NRDC	National Research and Development Corporation (India)
ODI	Overseas Development Institute (UK)
OECD	Organization for Economic Co-operation and Development
OFCOR	on-farm client oriented research
OR	outreach
PHI	post-harvest innovation
PMA	Policy for Modernization of Agriculture (Uganda)
PPP	Agricultural Pocket Package Program (Nepal)
PPST	Patriotic and People Oriented Science and Technology (India)
PRA	participatory rural appraisal
PT	power tiller
PTD	participatory technology development
PTI	People's Technology Initiatives (India)
PVP	plant variety protection
R&D	research and development
RCT	resource conservation technologies
RIN	rural innovations network
RORES	Reorganisation of Rural Economy and Society (India)
S&T	science and technology
SACCAR	Southern African Centre for Cooperation in Agricultural and Natural Resources Research and Training
SADC	Southern African Development Community
SAU	state agricultural university
SC	scheduled caste
SERVE	*Spirulina* for Employment Generation and Rehabilitation of Victims of Earthquake (India)
SHG	self-help group
SMIP	SADC/ICRISAT Sorghum and Millet Improvement Program (ICRISAT)
SMS	subject matter specialist
SOAS	School of Oriental and Asian Studies, University of London (UK)

SRISTI	Society for Research and Initiatives for Sustainable Technologies and Institutions (India)
SSA	sub-Saharan Africa
ST	scheduled tribe
T&V	training and visit
TIC	Technology Innovation Center (ICRISAT)
TMOP	Technology Mission on Oilseeds and Pulses (India)
TNC	Trans National Corporation
TTTI	Technical Teachers Training Institute (India)
UNBP	Ugandan National Banana Programme
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNU	United Nations University
USAID	United States Agency for International Development
VFPCK	Vegetable and Fruit Promotion Council, Keralam (India)
WRI	World Resources Institute
ZARS	Zonal Agricultural Research Station (NARP)