Creative Commons: Non-Proprietary Innovation Triangles in International Agricultural and Rural Development Partnerships

Laxmi Prasad Pant
Lecturer, International Development Program
School of Environment, Enterprise and Development
University of Waterloo
Waterloo, Ontario, Canada

and

Helen Hambly-Odame
Associate Professor, Capacity Development and Extension Program
School of Environmental Design and Rural Development
University of Guelph
Guelph, Ontario, Canada

Creative Commons: Non-Proprietary Innovation Triangles in International Agricultural and Rural Development Partnerships

Laxmi Prasad Pant and Helen Hambly-Odame

ABSTRACT

There has been a new paradigm shift towards the innovation systems approach in agricultural and rural development in low-income countries. In the past, agricultural research and technology development (R&D) interventions were conventionally implemented under the notion of the 'technology triangle' - the tripartite linkages of public sector research, government orchestrated extension, and rural farming communities. Using the exemplary practices of open science vis-à-vis intellectual property rights regulation, this paper argues that the commons have been increasingly creative for innovation generation through public private partnerships in specific areas of agriculture. Metaphorically, there has been a transformation from the notion of public 'technology triangles' into pluralistic 'innovation triangles' in international agricultural research and development partnerships at the time the when scientific commons has been increasingly privatized through the use of stringent intellectual property rights, such as patents and licenses often compromising customary rights of local and indigenous communities. Therefore, such an emphasis on extending linkages beyond R&D should ensure that open science practices are promoted at the local level unless stringent intellectual property rights are specifically required to protect regional and national interests in science, technology, innovation and development.

Keywords: innovation systems; agriculture; creative commons; low-income countries; public sector

Introduction

The term innovation is widely used and often misused. When the concept of innovation systems is introduced in practical fields of work such as agriculture and rural development, it risks ambiguity because it is a conceptual abstraction. One would anticipate questions such as: what makes the innovation systems unique among several other systems approaches to agricultural research and technology development (R&D) in public and private sector and why? In policy arenas new facts, figures or metaphors would draw on the increasing interest among stakeholders in this concept, and motivate subsequent policy changes (Hall et al. 2000). Since empirical evidence to test and support the concept of the innovation systems is still emerging, a metaphoric and illustrative use of the term 'innovation triangles' can help grasp the conceptual underpinnings of the new paradigm.

This paper specifically investigates how the concept of the innovation systems has evolved in agriculture and why it is currently viewed as more important, ethical and influential than the conventional agricultural R&D systems particularly in terms of institutional pluralism. The key thrust of this paper is about what policies would foster the promise of creative commons for technological and social innovation generation in agricultural and rural development in low-income countries? Thus the authors propose the metaphor of 'innovation triangles' to inform policies, arguing that this is a step that is appropriate to policymaking arenas in developing countries where the notion of 'the technology triangle' is entrenched in public sector predominance, and a transition towards a more dynamic model of innovation triangles would need to be incremental, possibly a smart and ethical mix of non-proprietary and proprietary innovation triangles without compromising the creativity and innovation of the scientific commons (Nelson 2004). Depending on the nature of the social goals and the type of tasks required to achieve those goals, varying degrees of openness in scientific practices can coexist and stakeholders should learn when a proprietary, non-proprietary or a mix strategy produce the greatest economic, social and environmental values (Maxwell 2006; von Hippel 2001).

Innovation systems framework in agriculture involves collaboration among the public, non-profit private, for-profit private and informal sectors producing technological, organizational and institutional innovations: new products, new processes and new forms of organizational structures and institutional set ups (Hall et al. 2001; Pant and Hambly-Odame 2006). Innovation systems in agriculture emphasize partnerships in knowledge production, transfer, regulation and use pertaining to a particular economic activity, and recognize production, processing, marketing, consumption and rural financing for innovations as sub-systems (Lundvall 1992). Although it emphasizes all possible multi-stakeholder linkages, recent literature emphasizes the linkages of the R&D systems with entrepreneurial firms and farms (World Bank 2007). Linkages should go beyond R&D involving intellectual property right (IPR) linkages, such as patenting and licensing, as well as relatively open science linkages, such as publication, media influence and formal as well as informal inter-personal interactions. Commons usually operate through the second type of linkages where knowledge and information remains in the public domain, but does not necessarily rule out the possibility of protecting national and regional interests through the use of softer intellectual property rights.

The next section of this paper introduces the philosophical bases of systems thinking in international agricultural and rural development. Then the paper discusses a chronology of various agricultural R&D systems and highlights key conceptual, institutional and operational shifts since the mid-20th century. In moving towards the metaphor of 'innovation triangles', the paper subsequently discusses multi-stakeholder linkages beyond R&D using empirical evidence from published literature from around the world and interviews and direct observation in India and Nepal. Then we turn to the discussion of the linkages beyond R&D with specific reference to promoting the notion of non-proprietary innovation triangles in high-income and low-income countries. Finally, the paper concludes that the promise of creative common lies on the policies that foster open science practices – the creativity and innovation of the commons - through multi-stakeholder collaboration but without necessarily eliminating the possibility of protecting national and regional interest through softer forms of intellectual property rights.

Philosophical Shifts in Science, Technology and Innovation

There is a basic difference between transition and transformation that determines the move from one theoretical paradigm to another. Thomas Kuhn (1962) states that transition is an adjustment to conceptual tools of a given paradigm, such as public sector driven R&D, while transformation is a significant change in response to contemporary problems, such as the challenge of working with multiple stakeholders. Transformation of a paradigm is important particularly when an entirely new set of tools is necessary to deal with contemporary problems, such as poverty, hunger, social exclusion, environmental pollution, and natural resource degradation.

Scientific and technological paradigms

A scientific paradigm is broadly defined as an outlook which defines the relevant problems, a model and a pattern of inquiry (Kuhn 1962). Kuhn mentions three types of scientific puzzles: discovery of facts, articulation of theory through empirical work or induction, and prediction of facts from theory or deduction. Karl Popper (1963), however, proposes the theory of falsification (deduction) as he asserts that it is never possible to arrive at a single theory given a coherent set of facts.

In a broad analogy with the Kuhnian definition of a scientific paradigm, a technological paradigm is a model and pattern of solving selected technological problems, based on selected principles derived from natural sciences and on selected material technologies or clusters of technologies, such as information and communication technology (ICT), biotechnology, genetic engineering and nanotechnology (Dosi 1982).

Paradigm shift in agricultural research and rural development

Kuhn's work provides insights into the notion of paradigm shifts in international agricultural R&D as well. This shift is often characterized by ontological and epistemological bases of interpreting social phenomena as ethical and unethical. Ontology is the study of the nature of reality, such as an ultimate reality or multiple realities, while epistemology is the study of the nature of knowledge about the reality. Ontology has provided for distinct ways of knowing the world or epistemologies to emerge, such as positivism, post-positivism, critical theory and related ideological positions, and constructivism (Guba and Lincoln 1994). The metaphysical assumptions underlying the conventional paradigm, the received view of science (positivism transformed into post-positivism), has been questioned. The received view focuses on efforts to verify (positivism) and to falsify (post-positivism) a priori hypotheses. The critical theory and related positions, such as interpretivism and post-structuralism, represent the value-determined nature of inquiry, the intricate ethical relationships between investigator and those being investigated. The findings are thus value mediated. The constructivism refers to an alternative paradigm that assumes the move from ontological realism and reductionism to ontological relativism and holism. In other words, it is a move from the notion of objectively verifiable reality to the assumption that reality is socially constructed under specific contexts.

Although he does not consider the wider range of alternative epistemologies mentioned above, Niels Röling (2000) intersects reductionist and holistic ontologies, and positivist and constructivist epistemologies to construct a typology of scientific research, technology development and innovation (RD&I) paradigms. First, the positivist/reductionist paradigm relies on the notion of 'the technology triangle'; also called the technology-push theory of innovation. This paradigm assumes that public research produces knowledge; extension disseminates the information; and farmers and entrepreneurs implement as if they are passive recipients of information from a single central source, predominantly the public sector (Biggs 1990). Second, the positivist/holistic paradigm, although still relies upon positivism, recognizes the world as systemic; also called hard systems thinking as this paradigm provides conceptual tools more appropriate to examine linkages and feedback loops between biophysical components. However, this paradigm does not completely rule out the possibility of linkages beyond the biophysical components of a system that are at least minimally modified by humans. The system goals, boundaries, feedback loops and goal seeking mechanisms are all human constructions (Bawden 2002).

Third, the constructivist/holistic paradigm views the process of inquiry as systemic. Checkland (2000) describe this as the soft systems thinking. In addition to Checkland's notion of the soft systems, which are appropriate to human interactions, Bawden (2002) suggests critical systems thinking that is specifically suitable to address ideological differences among stakeholders. As this paradigm provides conceptual tools appropriate to examine linkages beyond the biophysical components of a system, this would be characterized by the demand-pull theory of innovation. Recently innovation systems theorists, who embrace this paradigm, propose to remove the dichotomy between technology-push and demand-pull theories because both of these are potentially important at various stages of innovation (Hall et al. 2003c).

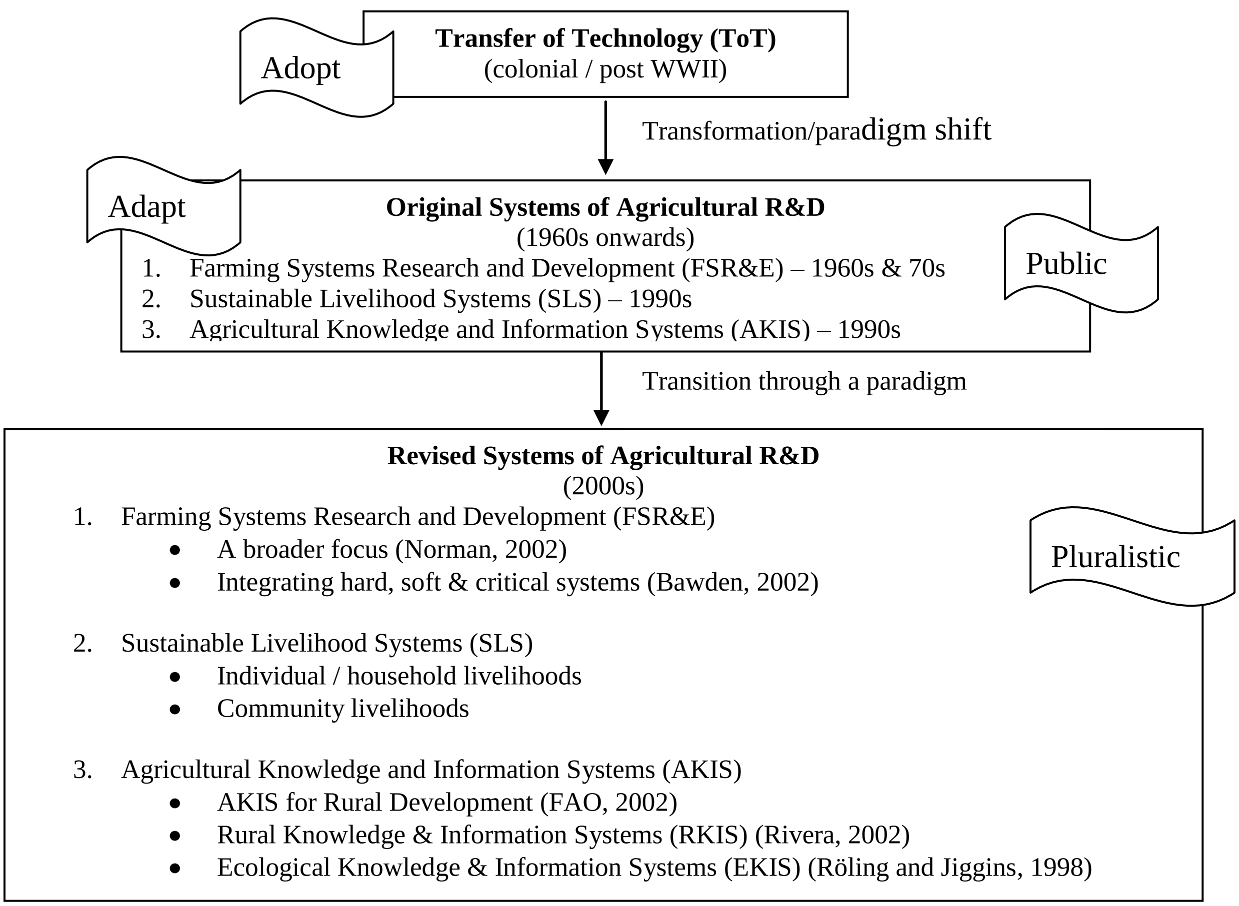
Fourth, the constructivist/reductionist paradigm, which is not yet well developed, views the bounded rationality of humans as influenced by spirituality (adhy-atma in Sanskrit) meaning the soul (atma). Spirituality emphasizes the metaphysical basis of its ontology. The human inability to process information correctly all the time and limitations in foresight and judgment is partly influenced by spirituality. To achieve a full potential of collaboration among multiple actors, language-mediated interactions that are common in the soft systems must be complemented by consciousness-mediated interactions of the spiritual systems (van Eijk 2000). As attempted by the local administration in Maharashtra state of India in their effort to check indebted cotton farmers' suicide through yoga and meditation (BBC 2006), consciousness development through practices like meditation and contemplation would help combine science and spirituality and thus facilitate creativity and innovation for overall well-being of humans.

All in all, paradigm shifts in science, technology, innovation and development are evident at three levels: firstly, conceptual move from the transfer of technology (ToT) to various systems approaches, secondly, institutional move from public sector singularism to institutional pluralism, often threatening the scientific commons, and finally, pragmatic move from adoption of technology to interactive learning and innovations.

Conceptual Shifts in Agricultural Research, Development and Innovation

Systems of agricultural research and development

During the 1960s and 70s, there had been a paradigm shift in agricultural R&D from the linear to systems approaches. The ToT paradigm presumes that diffusion of technological innovation is a linear process - researcher as the producer of knowledge, extension workers as the carriers, and the farmer as the ultimate object of adoption (Rogers 2003). Although the ToT approach is still in vogue often complemented by the intellectual property rights management practices, theorists have acknowledged that RD&I processes are embedded within historical, social, political, cultural and other institutional contexts (Biggs 1990), and proposed various systems frameworks to R&D (Figure 1).



Source: Authors

Figure 1. Transition through the systems of agricultural R&D

The systems of R&D that had been originally developed when the public sector organizations were the dominant actors in agricultural R&D has been under scrutiny. With the economic liberalization in low-income countries during the late 1990s, the public sector monopoly in agricultural R&D associated with perceived or realized inefficiency has been challenged by the private sector development interventions. In response to this scenario, the systems approaches to agricultural R&D went through several transitions.

Since its beginning in the 1960s, the Farming Systems Research and Extension (FSR&E) has substantially evolved in terms of scale, performance criteria and target beneficiaries (Hart 2000). In terms of scale, FSR&E has moved from a predetermined focus on selected commodities, a whole farm focus, a natural resource systems focus including on-farm and off-farm activities, and a livelihood systems focus which includes on-farm, off-farm and non-farm activities (Norman 2002). Moreover, Richard Bawden (2002) explains that the first generation of FSR&E as the research into farming systems (hard systems) , the second as systems research into farming (soft systems), and the third as critical farming systems (critical systems), in which he places his own analysis. Likewise, the original focus of productivity (ton/ha) as a performance indicator had been modified to include stability (a minimum level of productivity over time) in the 1980s, and then further included sustainability in the 1990s. The focus on sustainability emphasizes a triple bottom line – increased production, environmental protection, and intra- and inter-generational equity. The original focus on small farmers as target beneficiaries has been changed to include gender and generational equity – a relatively inclusive approach. The contemporary focus is on livelihood systems.

The sustainable livelihood system (SLS) recognizes multi-occupational nature of the rural livelihoods while reiterating the small-farm focus of FSR&E. This is why the latest focus of FSR&E is on sustainable livelihood systems. Since its beginning in 1990s, the SLS basically evolved in terms of scale, a change from focus on individual and household livelihoods to collective actions and community livelihoods. SLS focuses on assets, capabilities and activities required for a means of living (Brock 1999; Chambers and Conway 1992; Scoones 1998). Assets include natural capital, social capital, human capital, and human-made capital while capability is the ability to convert asset endowments to entitlements, i.e., the ability to access goods and services or to capitalize assets. The activities would involve on-farm, off-farm and non-farm diversification of rural livelihoods as mentioned by Norman (2002; 1995) in his explanation of farming systems with livelihood focus. The latest emphasis on livelihood systems is on social capital, such a social networking and multi-stakeholder collaboration.

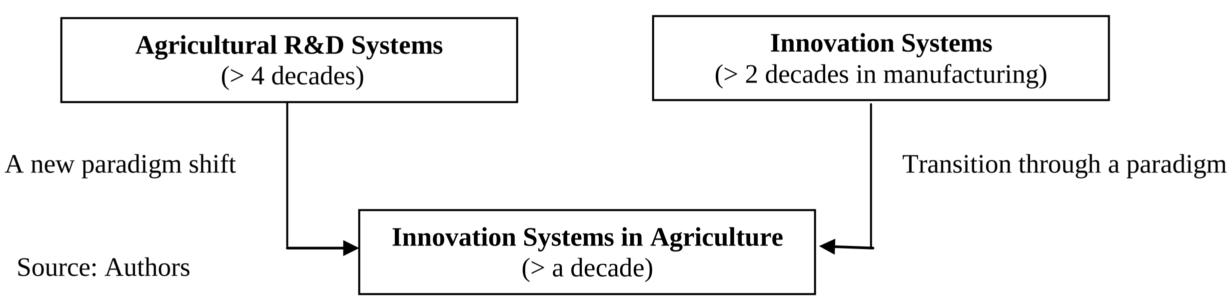
Niels Röling (1990; 1994) proposed a model of Agricultural Knowledge and Information Systems (AKIS) as early as 1990 and emphasized institutional pluralism for knowledge production, diffusion and application. He defines, "AKIS is a set of agricultural organizations and/or persons, and the links and interactions between them, engaged in such processes as the generation,…diffusion and utilization of knowledge and information, with the purpose of working synergistically…" (Röling 1990:1). This definition emphasized that the actors in an AKIS have potential to work synergistically but not necessarily do so. Since its beginning in 1990s, AKIS also went through several transitions. The revised approaches are AKIS for Rural Development (AKIS/RD) (FAO 2000) and Rural Knowledge and Information Systems (RKIS) (Rivera 2004). Still another modification, as proposed by its original theorists, is the Ecological Knowledge and Information Systems (EKIS), which can be agricultural as well as non-agricultural systems (Röling and Jiggins 1998). These conceptual transitions emphasize systems where successful livelihood strategies cross ecological, political, disciplinary and occupational boundaries.

In conclusion, although there have been important transitions in the above R&D systems, this is a long overdue. A complete paradigm shift towards the innovation systems would be desirable. Firstly, full participation of the public, non-profit private, for-profit private and informal sectors and developing their capacity to innovate have been difficult throughout the history of FSR&E (Collinson and Lightfoot 2000; Norman 2002). Secondly, although the SLS recognize the multi-occupational nature of rural livelihoods, its effort to link individual livelihood systems with macro-economic phenomena, such as market and non-market institutional arrangements was always insufficient (Dorward et al. 2003). Thirdly, the focus on critical systems emphasizes that innovations should be socially responsive to diverse actor worldviews including the corporate sector. It would be misleading to expect obvious synergy in a system that consisted of so many actors with possibly diverging worldviews (Leeuwis, Long and Villarreal 1990). The divides between public and private sectors, the revolution in ICTs, and new concepts of interactive learning and innovation provide entirely new challenges and opportunities (FAO 2000). Finally, there is an urgent need to build capacity to innovate, which implies strength of stakeholders with regard to solving unanticipated problems in complex adaptive systems, and exploiting evolving opportunities to solve them through a broad-based collaboration (Hall and Dijkman 2006).

Innovation systems in agriculture

It is argued that a broad concept of innovation systems is situated in contrast to the concept of ToT and would be a useful tool for promoting sustainable economic growth and well-being (Lundvall et al. 2002). The underlying idea is that innovation processes, once treated as linear and static, has become systemic and dynamic (Cooke 2004).

Although the innovation systems framework has been used in manufacturing for the last two decades, its application in rural development and agriculture in low-income countries has emerged only with the advent of the twenty-first century. However, Stephen Biggs (1990) emphasized the multiple source model of agricultural innovation as early as the 1990. Since the beginning of the millennium Hall (2002; 2000; 2001; 2003b), Clark (2001; 2003; 2002), Sulaiman (2002; 2005), Temel (2003) and Sumberg (2005) have embraced this concept in their research and development works in low-income countries. The focus on innovation systems in agriculture suggests a new paradigm shift to integrate the strengths and amend the weaknesses of the R&D systems that have evolved during the last four decades (Figure 2). From the perspective of agricultural R&D, it is characterized as a new paradigm shift although the move is a transition within the framework of the innovation systems and an adjustment to the set of tools that have been developed in manufacturing to adapt to rural development and agriculture.



Source: Authors

Figure 2. Transformation of the agricultural R&D systems

In a nutshell, the R&D systems, although went through several transitions, were originally developed to work with the public sector engaged in producing and diffusing technological innovations while innovation systems encompass all the elements of the networks of private and public sector institutions whose ethical interactions produce, diffuse, regulate and use socially responsible and economically useful knowledge and information (Hall et al. 2001).

The Notion of Innovation Triangles

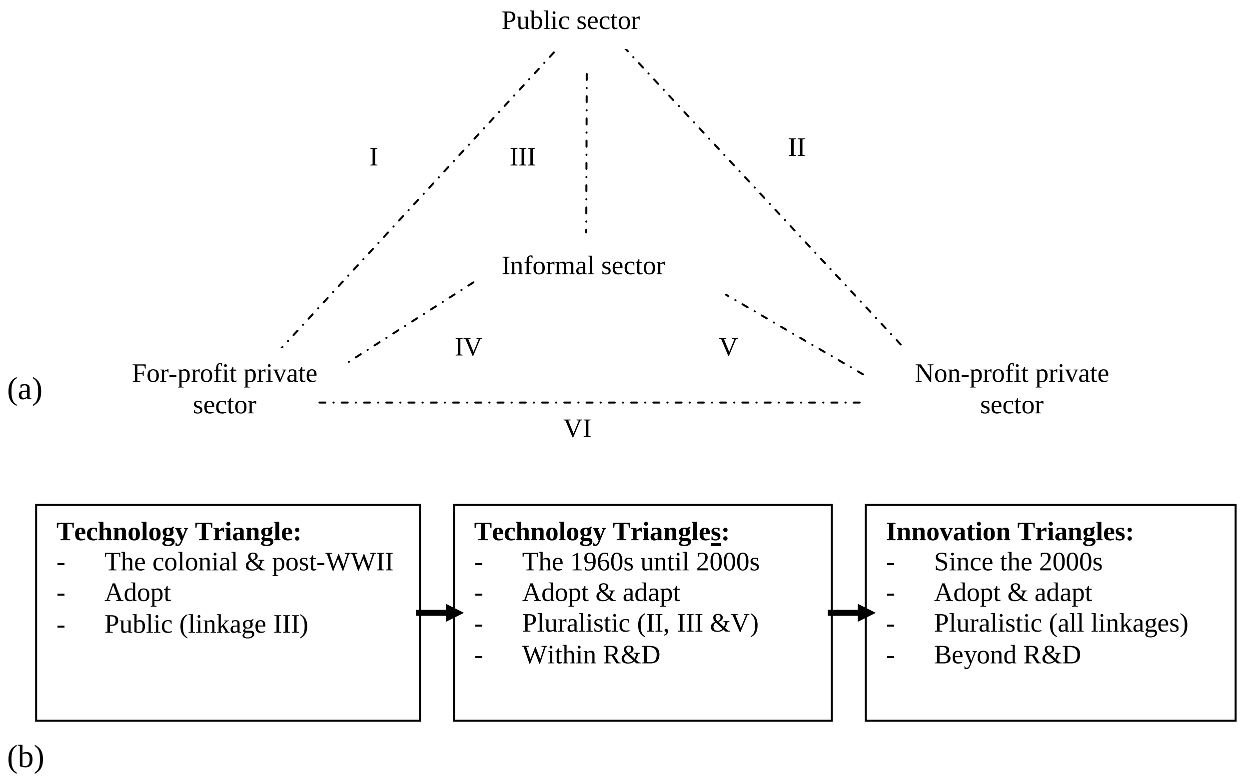
The conceptual foundation of the notion of innovation triangle lies on the use of the framework of 'technology triangle' during the mid-twentieth century. Later in the 1990s, liberalization of economies in many low-income countries promoted pluralistic technology triangles but these triangles hardly transformed into innovation triangles until recently, often providing ambiguity among stakeholders.

Technology triangle(s) or innovation triangles?

Structurally the public, non-profit private, for-profit private and informal sectors are the relevant stakeholders of a particular intervention (Figure 3). Although the framework looks simple, there is diversity within each sector which brings complexity to real-life situations. First, the public sector, for instance, includes international, national, regional and local organizations along the continuum of the pubic to the informal sector (Linkage III).

Second, the non-profit sector also varies from international, national and local NGOs, farmers' cooperatives and growers associations finally down to the informal sector (Linkage V). Third, the for-profit private sector also ranges from multi-national and trans-national life science firms to national and local agribusinesses, thereby presenting a continuum down to the businesses in the informal sector (Linkage IV). A farm may belong to the for-profit private sector although this may not be the case all the time. Unlike the case in developed countries, a majority of small-farms in low-income countries are subsistence because they rarely produce surplus/profit.

As visualized in Figure 3a multi-stakeholder linkages are represented by the embedded triangles. Considering the diversity within all the possible continuums described above (linkages I, II, III, IV, V & VI), one would end up with numerous triangles over time at local, regional, national, pan-regional and local levels. For a specific economic activity, such as seed production, the actual number of triangles would vary over time. One stakeholder would leave while another would join and rejoin.



Source: Adapted from Pant and Hambly-Odame (2006)

Figure 3. Revisiting the notion of technology triangles

Here, one has to understand the difference between 'technology triangles' and 'innovation triangles' (Figure 3b). The basic difference is that multi-stakeholder linkages that limit their activities within the scientific research and technology development are characterized as technology triangles while such linkages that extend its scope beyond R&D, including the technological and social innovations, are described as innovation triangles. While this section introduced the notion of technology triangles vis-à-vis the conventional notion of 'the technology triangle', the next section deals with how one can transform technology triangle(s) into 'innovation triangles', both proprietary and non-proprietary.

Multi-stakeholder linkages within and beyond R&D

As argued in this paper, innovation triangles include multi-stakeholder linkages beyond R&D. With the rise of the private sector, options have increased for farmers to acquire inputs and services from a range of sources, which creates complex web-like linkages of stakeholders (Hambly-Odame 2003). However, the linkages can just be a repetition of the notion of technology triangles or just increasing the number of technology triangles. As Matthews and Johnston (2000) have stated, fundamentally four types of linkages are possible based on the involvement of public and private sectors within and beyond R&D activities (Table 1).

Table 1. Patterns of partnerships and linkages

	Intra-sectoral (public or private)	Inter-sectoral (public and private)
Within R&D	A. Intra-sectoral linkages within R&D process, e.g., public research-extension, NGO-NGO and public university-public university.	B. Inter-sectoral linkages within R&D process, e.g., public R&E-NGO, public university-NGO and public university-private university.
Beyond R&D	C. Intra-sectoral linkages beyond R&D process , e.g., agribusiness-agribusiness consortia for commercialization of innovation.	D. Inter-sectoral linkages beyond R&D process, e.g., NGO-agribusiness, public R&E- agribusiness and university-agribusiness.

Source: Authors with reference to Matthews and Johnston (2000)

Intra-sectoral linkages within the R&D as the technology triangle. These are the linkages within the same sector which do not transcend the R&D process. In rural development and agriculture, these linkages had been predominant until the advent of the public private partnerships during the 1990s with some evidence until recently. Although new types of partnerships are emerging like NGO-NGO linkages, the most common effort during the second half of the 20th century had been to establish linkages within the public sector. As mentioned earlier, partnerships so far were largely limited to maintaining research-extension-farmer linkages, the notion of the 'technology triangle' (Merrill-Sands et al. 1989). However, even within the public sector R&E, various forms of partnerships were possible based on the relative status of institutions, and sources of knowledge and information (Agbamu 2000). For example, research-extension linkages in Indonesia, Nigeria and Tanzania were operating under relatively higher status of research systems and the central source of innovation. Relatively more favorable cases were reported from South Korea and Mexico. In Korea, although R&E operated under equal status, the source of innovation was still top-down. Contrary to this, the latter country adopted multiple sources of innovation despite the lower status of extension systems relative to research systems. However, in the case of Japan, the agricultural research-extension linkages operate under a bottom-up approach with an equal status between the two systems.

Inter-sectoral linkages within the R&D as the technology triangles. Although efforts have been in place in the field of rural and agricultural development towards transforming technology triangles into innovation triangles, it is often hard to move beyond the conventional notion of technology triangle while fostering partnerships with the non-profit private sector. For example, a biotechnology programme funded by the Dutch Government in Andhra Pradesh, India with specific projects on tissue culture propagation of agroforestry species and bio-fertilizer production works under the collaboration of public, non-profit private and informal sectors (Clark et al. 2002). The public sector operated laboratories to produce propagating materials and biofertilizer on a cost-recovery basis in partnerships with the private sector. This nevertheless moved beyond the technology transfer mode of science but the involvement of the for-profit private sector remained largely informal.

Likewise, under the funding from the UK Department of International Development (DFID)'s Plant Science Programme (PSP), the Local Initiatives for Biodiversity Research and Development (LI-BIRD), a Nepalese NGO, and CAZS Natural Resources based at the University of Wales, UK implemented a series of crop improvement projects in southern Nepal in collaboration with various stakeholders from the public and non-profit private sector (Joshi et al. 2005). The public-private collaboration was first with the public sector extension at the local level including the District Agricultural Development Office (DADO), Chitwan and then at the regional and national levels including the National Rice Research Programme (NRRP). Likewise, an Honduran NGO acts as an intermediary to establish linkages between farmer breeders and plant breeders at the national agricultural research systems (Humphries et al. 2005). Again the for-profit private sector operated indirectly and informally.

A similar attempt was under DFID's Crop Post-Harvest Programme (CPHP) in India and specifically the development of controlled atmosphere storage technology to sent sea freight of Indian mangoes to London. On behalf of the Vijaya Fruit and Vegetagle Growers Association (hereafter Vijaya) in Krishna district of Andhra Pradesh, Agricultural Processed Products Export Development Authority (APEDA) in the Ministry of Commerce and UK based Natural Resources Institute (NRI) involved in facilitating a series of contracts with relevant organizations from the Indian Council of Agricultural Research (ICAR), the Council for Scientific and Industrial Research (CSIR) and the Horticultural Department of the local State agricultural university (Hall 2003; Hall et al. 2001; Hall et al. 2003a). This was a unique case of one public sector institution contracting experts from other public sector institutions on behalf of the farmers' cooperative association. Initially perceived to be a technological problem under the notion of technology triangle, the problem of the unacceptable quality of mango arriving in London was realized only after three years as the social innovation failure to manage mango quality, specifically due to a disease called anthracnose. Moreover, the project stakeholders failed to collaborate with the powerful but informally operated mango marketing sector. In short, in all of the above cases efforts to transform technology triangles into innovation triangles were partially achieved.

Intra-sectoral linkages beyond the R&D as the high-profile innovation triangles. This refers to the linkages between institutions in the same sector which transcend the R&D process. Unlike the previous two types of linkages, this type of linkages is less common in developing countries where the regulatory mechanisms are not well developed, consumer clubs are not influential, and majority of farmers are subsistence, practice tacit ways of learning and innovation, and save their own seeds for replanting. (Matthews and Johnston 2000). Partnerships like the one recently emerged between DuPont (Pioneer Hi-Bred as a subsidiary) and Syngenta to license both conventional and genetically modified seed of soybean and corn in Canada and United States, which is parallel to the Monsanto's Roundup Ready genetically modified seeds, represents this kind of linkages (Pollack 2006). This is a kind of high profile proprietary innovation triangle – the triangle of two corporate firms and the intended beneficiaries and managed through intellectual property rights.

Inter-sectoral linkages beyond the R&D as the low-profile innovation triangles. This refers to the linkages between organizations in different sectors which transcend the R&D process. These types of linkages - the notion of innovation triangles - provide an opportunity for diverse kinds of collaborative efforts like NGO-business partnerships, public R&E-business partnerships and university-business partnerships. This type of linkages would provide incentive for R&D organizations to collaborate in activities like production, processing, marketing and systems of finance. However, replicating a high profile innovation triangle as is popular in the developed countries would be less relevant in low-income countries where oral traditions and cultural expectations predominates stakeholder interactions.

To sum up, with the rise of the non-profit private sector in low-income countries, the public-private partnerships is largely characterized by the public and NGO partnerships. This option is attractive where there is no market incentive for an innovation to occur or transaction costs are too prohibitive to develop partnerships with the for-profit sector or for-profit sector operates informally. There no immediate threats to the scientific commons. The current challenge is, however, to transform technology triangle(s) into innovation triangles, where multiple stakeholders including the for-profit private sector organizations and individuals work together for an extended period of time under the philosophy of creative commons. Specifically in low-income countries, transforming technology triangles into innovation triangles would need to consider the issue of intellectual property rights in a different way. In other worlds, a distinction should be made between proprietary and non-proprietary innovation triangles. Unlike the purely proprietary innovation triangles, a low profile joint/cooperative venture and small agri-businesses that build on non-proprietary innovation triangles are likely to be successful in developing countries as a result of the customary social and cultural ties that motivate stakeholders to involve in open science practices (United Nations Millennium Project 2005). Therefore, the biggest challenge to promote open innovation triangles in low-income countries is to learn from the predominant practice of open technology triangles that are already operational and to transform them into non-proprietary innovation triangles.

Coexistence of Proprietary and Non-Proprietary Innovation Triangles

The linkages within the web of innovation triangles can be proprietary as well as non-proprietary, and ethical as well as unethical. While stakeholders in industrial countries are deeply divided around the argument for and against the effectiveness of the proprietary sector for socially responsible and economically effective innovation, low-income countries where technological and social innovations are much needed have grappled with introducing stringent intellectual property rights on local innovations.

Innovation triangles in industrial countries

In developed countries where many stakeholders are entrenched in proprietary innovation triangles or stringent intellectual property rights (IPRs), theorists argue that it would be possible to maintain at least part of their learning interaction into open science practices. In other words, it is not necessary that all linkages beyond R&D should be managed through stringent IPRs, such as patenting and licensing that prevents the scientific commons to do further scientific inquiry, because not all research outputs would be possible to commercialize in the market (Nelson 2004). For example, as illustrated in the Table 2, a survey of the U. S. food industry R&D managers revealed that open science linkages are more commonly practiced than the IPR related linkages in this particular sector (Cohen, Nelson and Walsh 2002)1.

Table 2. Linkages between public research R&D and food industries in the US

IPR related and open science linkage mechanisms	Percentage of respondents indicating at least moderate importance of the mechanism (N = 93)
Patent related practices	
Market mechanisms to transfer codified knowledge	
Patents	9.7
Licences	10.8
Softer forms of linkages	
Mass communication of codified knowledge	
Publications and reports	51.6
Public meetings and conferences	37.6
Interpersonal/ small group communication of both tacit and codified knowledge	
Consulting	46.2
Informal information exchange	44.1
Contract research	30.1
Joint or cooperative ventures (open among the partners)	22.6
Recently hired graduates	21.5
Temporary personal exchanges	7.5

Source: Adapted from Cohen et al. (2002)

With an objective of addressing perceived sluggishness to commercialize inventions, the Bayh-Dole Act (1980) was enacted in the US. This act transferred ownership rights to universities on all inventions arising from research projects funded by federal agencies, including those co-funded by industry partners. Before this act came into effect, federal laboratories had granted only nonexclusive or open licenses to research institutions, but the new act allowed them to grant exclusive licenses to non-federal institutions, such as universities (Day-Rubenstein and Fuglie 2000). Although the Bayh-Dole Act provided US universities with the right to commercialize employees' invention through federally funded research, Kenney and Patton (2009) argue that this model of commercialization –'university ownership model' – has been proved economically and socially suboptimal because non-federal institutions behaved as revenue maximizers, using public funds, rather than the generators of public goods and facilitators of technology transfer for the benefit of society. They warned that countries like the UK and Japan hurried to implement the US model without learning much from the US experience, and recommended two alternatives to avoid this arguably dangerous trend that can potentially kill the creativity and innovation of commons. Firstly, it would be desirable to grant ownership to the inventor, who could choose the path of commercialization. This model legitimizes researchers' involvement in 'gray zone' for ethical and effective transfer of tacit knowledge among relevant stakeholders, such as the one implemented by the University of Waterloo in Canada (Bramwell and Wolfe 2008). The University of Cambridge in the UK implemented the inventor ownership model until 2001 when they took ownership of all faculty inventions embracing the university ownership model (Kenney and Patton 2009).

Secondly, it would be desirable to make inventions publicly available through a relatively weaker form of ownership rights – 'weaker ownership rights model' – either through granting non-exclusive licenses that operate as tax on users or making inventions freely available in the public domain (Kenney and Patton 2009). The basic rationale of this reconsideration of the Bayh-Dole Act like models – university ownership models – that are being implemented in various industrial countries is one way to reclaim the scientific commons (Nelson 2004).

Specifically in collaborative ventures, lack of clarity over the ownership of inventions makes IPR negotiations cumbersome, time consuming and expensive, often resulting in partners' walk out without completing a deal (Lambert 2003). To this end, joint or cooperative ventures have emerged as a relatively open model to foster broad-basd collaboration. Such a venture, in addition to its focus on IPR related negotiations with stakeholders at large, considers open science practices within the core stakeholders of a venture. For example, in the US the National Technology Transfer and Advancement Act (1995), a follow-up of the Federal Technology Transfer Act (1986) to clarify IPR related regulations, grants the private sector cooperators of a federal-private Cooperative Research and Development Agreement (CRADA) the first right of negotiation for exclusive licensing of one of any invention created through a CRADA (Knudson 2000; Day-Rubenstein and Fuglie 2000). Similarly, the Australian Cooperative Research Centre (CRC) implemented a cooperative joint venture in cotton (CRC 2005), out of which, the AgBiotech Australia commercialized a kind of bait, Magnet®, to lure cotton borers, and the patent is owned by grain and cotton farmers and pest management scientists who were part of the joint venture.

In all of the above examples of patenting and licensing, there were every opportunity for stakeholders to learn from each other without necessarily limiting learning and innovations through an stringent IPR regulation, often through illegitimate involvement in 'grey zones', but when it came linkages with stakeholders at large the licensing and patenting were commonly practiced. The R&D managers in the pharmaceutical industry in the USA report that patenting and licensing are important to provide incentives for private sector innovation (Cohen, Nelson and Walsh 2002). However, this is not true among all actors, sectors and situations. The demand side estimation (interviews with the industry personnel) of Cohen et al. (2002) across 35 industries revealed patents and licenses as being minor linkage mechanisms, which is also supported by the supply side estimation with the MIT professors that less than 10 per cent of knowledge transfer from their labs is through IPR regulations (Agrawal and Henderson 2002). Since only 4 % of the total number of biological patents were held by low-income countries as of 2005 (UNDP 2005), it is safe to infer that the role of the IPR regime to facilitate knowledge transfer from lab to land in developing countries is very limited.

Innovation triangles in low-income countries

Now the discussion on proprietary and non-proprietary innovation turns to low-income countries. In the past, the Nepal Agricultural Research Council (NARC) used to be the principal public stakeholder engaged in the formalized systems of agricultural research in Nepal with its own network of commodity specific research programs throughout the country. Often with the discretion of plant breeders, a lot of potential crop varieties have been discarded through the NARC's on-station research without the knowledge of farmers. The second order problem of this centralized public sector plant breeding was non-adoption of officially released crop varieties.

With the economic liberalization and subsequent development of the private sector, and specifically the non-profit private sector, NARC has no more monopoly (often associated with public sector inefficiency) for agricultural research in the country. Since the for-profit private sector collaboration was limited by size of the economy, NGOs and farmers' organizations have been the private sector actors involved in research and development interventions transforming technology triangles into innovation triangles, facilitating informal interaction with seed entrepreneurs, fertilizer dealers and rice grain merchants.

The Vijaya, mango growers' association, in Andhra Pradesh worked in collaboration with the Agricultural and Processed Food Products Development Authority (APEDA), a federal export promotion authority in the Ministry of Commerce, setting up a series of contracts with relevant organizations from the Indian Council of Agricultural Research (ICAR), the Council for Scientific and Industrial Research (CSIR) and the Horticultural Department of the local State agricultural university. This was basically a technology transfer intervention. The for-profit private sector involved in mango marketing was largely informal and could not be engaged in generating socially responsible innovation in the mango sector. It was evident that it is necessary to bring the for-profit private sector, albeit informal, into broad-based stakeholder collaboration, work under creative commons philosophy and allow stringent property rights only when the stakeholders feel necessary to protect regional and national interest.

Unlike in the industrial countries, the stringent IPR regulations are relatively new to public and private stakeholders in low- and medium-income countries, and thus the transformation of technology triangles should be first towards non-proprietary innovation triangles. Only in specific cases when international life science firms are involved, proprietary innovation triangles will be required to protect the national interest. An extreme example of open science practice was revealed in the crop improvement project in Chitwan district of Nepal as one of the farmers who participated in crop improvement project selected two rice varieties of his own from scientific trials initially without the knowledge of concerned scientists. After a decade of selection of his own, one of the rice varieties has been subjected to disease screening in public research stations. Although there was contractual agreement with farmers to participate in rice variety selection and testing, this open science practice was not within the scope of the agreement. Often to the surprise of most scientists from the corporate sector in developed countries, scientists from the Nepalese non-profit and public sectors encouraged the farmer to select a rice variety of his wish list using the seeds from scientific trials2. Similarly, in a tomato packaging technology development project in Himachal Pradesh of India, stakeholders came across a publication by a professor of the Indian Institute of Management (IIM), Alamahabad working on cardboard box design, and involved him as a collaborative partner (Clark et al. 2003). Again to the surprise of the scientists from the West, the professor did not bother patenting the cardboard box design, thereby providing an open access to experiment with his prototype. Moreover, the Vijaya, the mango exporters' organization in India's Krishna in Andhra Pradesh, has been using the Vijaya Sun Gold as a brand for their mangoes without any legal protection. The mango stakeholders would be happy that anyone who procures mangoes from this region uses this brand to promote regional geographic identification of their mangoes. Likewise, certain aromatic rice varieties from the Kaski district of Nepal are market in local and national markets with a geographic indication attached to their name (Pant and Ramisch Forthcoming). In all these examples, creativity and innovations are motivated by the social value and recognition than economic profits than stringent IPR regulations.

All in all, the purpose of patenting and licensing is nothing but to encourage the for-profit sector actors to invest in R&D, thereby providing them monopoly over their inventions for an extended period of time (17 years in the U. S.). The for-profit sector in low-income countries is largely informal and public-private collaboration through open science practices would benefit all relevant stakeholders as long as they ethically work under the notion of creative commons. There can be softer form of incentives for diverse public and private stakeholders to work in collaboration, such as awards and recognition than stringent intellectual property rights. As claimed by the initiators of the rice improvement projects in Nepal, one of the significant achievements of this project over a decade was its influence on the recent amendment of the variety release policy in Nepal, which has provisions to approve crop varieties developed through private sectors, specifically the non-profit private sector (Joshi et al. 2005). However, unlike the attempts to test and release crop varieties developed out of the community-based participatory research through Nepal's national systems, the Honduran stakeholders established a tradition of acknowledgement of farmers' involvement in crop varieties development at the local level (Humphries et al. 2005). Nevertheless, innovation awards and other forms of softer intellectual property rights at the local and national levels have been effective to acknowledge the efforts of creative commons in socially responsible learning and innovation in Nepal, Honduras and India. Even when relatively stringent IPR regulations are desirable, stakeholders should neither compromise opportunities to use the patented materials for further scientific inquiry nor limit customary intellectual property rights held by a particular community.

Conclusions

The conceptual transformation of the ToT approach into agricultural R&D systems during the second half of the twentieth century was in response to the economic liberalization and the rise of the private sector, both non-profit and for-profit. However, the transformation and the subsequent transitions within each framework were insufficient to transform technology triangle (s) into innovation triangles. Moreover, each of the R&D systems – farming systems, livelihoods systems, knowledge and information systems – moved through several transitions to address institutional pluralism and multi-occupational nature of rural livelihoods, often influenced by market and non-market institutional arrangements at local, regional, national, pan-regional and global levels.

As defined in this paper 'innovation triangles' are the tripartite linkages of the public, non-profit private, for-profit private and informal sector stakeholders that transcend beyond R&D to complement the new paradigm shift toward the innovation systems in recent years. The operational linkages beyond R&D, such as intellectual property rights, for effective functioning of this system in agriculture, and specifically in the context of developing countries are becoming clearer as this paper argues for coexistence of proprietary and non-proprietary innovation triangles depending on the goal and functions of scientific interventions. When the type of knowledge being transferred is tacit as found in the context of the smallholder agriculture in developing countries where local innovations are important, multi-stakeholder linkages through non-proprietary innovation triangles are preferred over proprietary ones the former is based on social norms and values than stringent legal measures to guide ethical research and innovation practices. However, when negotiation with international life science firms is necessary to protect national interest, a more stringent intellectual property rights should coexist, of course, quite possibly under a range of options, including creative commons.

Notes

1. The Carnegie Mellon Survey of R&D managers in the U.S. involved 35 industries including the food industry. Respondents were asked to rank the importance of ten linkage mechanisms on a four-point Likert scale concerning a recently completed major R&D project.
2. Nepal as a signatory of the WTO agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) is required to protect inventions, such as new plant varieties, either by patents, an effective sui generis legislation (a unique form of intellectual property protection suitable for national sovereignty), or a combination of the two.

Acknowledgements

This research was funded by the International Development Research Centre (IDRC) of Canada, and implemented by the Rural Studies PhD Programme at the University of Guelph, Canada. The authors are thankful to organizations and individuals in Nepal, India and Canada who directly or indirectly contributed to this research, either as respondents or as intellectual discussants in informal and formal meetings including related projects, workshops and conferences. This paper represents the views of the contributing authors and the authors kindly acknowledge that the usual disclaimers apply.

About the authors

Laxmi Prasad Pant is Adjunct Assistant Professor and Sessional Lecturer of Problem Solving for International Development at the School of Environment, Enterprise and Development, Faculty of Environment, University of Waterloo, Waterloo, Canada. He also teaches at the University of Guelph's undergraduate and graduate courses on international development and capacity building. He holds a PhD from the University of Guelph, and has a wide range of international research and development experience in agriculture, environment and development. His research focuses on human creativity and innovation to enhance renewable natural resource-based livelihoods, such as agriculture and agri-business, specifically analyzing the agency of individual actors within the broader framework of innovation systems. Laxmi has published in the field of knowledge management, learning networks, innovation assessment of development projects and programmes. Dr. Pant can be reached at: lpant@uoguelph.ca

Helen Hambly Odame is Associate Professor in Capacity Development and Extension, in the School of Environmental Design and Rural Development, University of Guelph. She has worked in international research and development programs in Africa, North Africa and Latin America with the Consultative Group on International Agricultural Research (CGIAR) and the International Development Research Centre (IDRC). Dr. Odame's research area is widely defined as science-society linkages with specific attention to media, communication and change processes in rural societies. Her recent publications have included attention to systems of innovation in agriculture, media for agricultural and rural development in Africa and rural broadband in Ontario, Canada.

References

Agbamu, J.U. 2000. "Agricultural research-extension linkage systems: an international perspective." AgREN Network Paper 106a:1-8.
Agrawal, Ajay, and Rebecca Henderson. 2002. "Putting Patents in Context: Exploring Knowledge Transfer from MIT." Management Science 48:44-60.
Bawden, R. 2002. "On the Systems Dimension in FSR." Journal of Farming Systems Research and Extension 5:1-18.
BBC. 2006. "India farm suicide hit new high." London: British Broadcasting Corporation (BBC). Accessed April 7. 2008 http://news.bbc.co.uk/2/hi/business/5312600.stm
Biggs, Stephen D. 1990. "A Multiple Source of Innovation Model of Agricultural Research and Technology Promotion." World Development 18:1481-1499.
Bramwell, A. and D. A. Wolfe. 2008. "Universities and regional economic development: The entrepreneurial University of Waterloo." Research Policy 37 (8):1175-1187.
Brock, K. 1999. "Implementing a Sustainable Livelihoods Framework for Policy-Directed Research: Reflections form Practice in Mali." IDS working paper 90.
Chambers, R., and G. Conway. 1992. "Sustainable rural livelihoods: practical concepts for the 21st Century." IDS Discussion Paper 296.
Checkland, P. 2000. "Soft Systems Methodology: A Thirty Year Retrospective." Systems Research and Behavioral Sciences 17:S11-S58.
Clark, N. 2001. "Innovation system, Institutional Change and the New Knowledge Market: Implications for Third world Agriculture Development." UNU/INTECH Discussion Paper 10.
Clark, Norman, Andy Hall, R. V. Sulaiman, and G. Naik. 2003. "Research as Capacity Building: The Case of an NGO Facilitated Post-Harvest Innovation System for the Himalayan Hills." World Development 31:1845-1863.
Clark, Norman, B. Yoganand, and Andy Hall. 2002. "New science, capacity development and institutional change: the case of the Andra Pradesh-Netherlands Biotechnology Programme (APNLBP)." The International Journal of Technology Management and Sustainable Development 1:196-212.
Cohen, Wesley M., R. R. Nelson, and John P. Walsh. 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D." Management Science 48:1-23.
Collinson, M. E., and Clive Lightfoot. 2000. "The Future of Farming Systems Research." Pp. 391-419 in A History of Farming Systems Research, edited by M. E. Collinson. Oxon, UK/ Rome, Italy: CABI Publishing/FAO.
Cooke, Philip. 2004. "Introduction. Regional innovation system-an evolutionary approach." in Regional Innovation Systems: the role of governance in a globalized world. Second Edition, edited by Philip Cooke, Martin Heidenreich, and Hans-Joachim Braczyk. London: Routledge.
CRC. 2005. "Reaping the benefits: innovation through collaboration." in Highlights of the Cooperative Research Centres Programme. Australia: CRC Association.
Day-Rubenstein, K. and K. O. Fuglie. 2000. "The CRADA Model for Public-Private Research and Technology Transfer in Agriculture." pp. 155-174 in Public-Private Collaboration in Agricultural Research: New Institutional Arrangements and Economic Implications, edited by Keith O. Guglie and David. E. Schimmelpfennig. Ames: Iowa State University Press.
Dorward, Andrew, Nigel Poole, Jamie Morrison, Jonathan Kydd, and Ian Urey. 2003. "Markets, Institutions and Technology: Missing Links in Livelihood Analysis." Development Policy Review 21:319-332.

Dosi, G. 1982. "Technological paradigms and technological trajectories." Research Policy 11:147-162.
FAO. 2000. "Agricultural Knowledge and Information Systems for Rural Development (AKIS/RD): Strategic Vision and Guiding Principles." Rome: FAO/The World Bank.
Guba, E. C., and Y. S. Lincoln. 1994. "Competing Paradigm in Qualitative Research." Pp. 105 - 117 in Handbook of Qualitative Research, edited by N. K. Denzin and Y. S. Lincoln. London: Sage Publications.
Hall, Andy. 2003. "Post-harvest innovation systems in South Asia: Research as capacity development and its prospects for impact on the poor in developing countries." Outlook on Agriculture . 32:97-104.
Hall, Andy, Norman Clark, R. V. Sulaiman, and S. Taylor. 2002. "Institutional learning through technical projects: Horticultural technology R&D systems in India." The International Journal of Technology Management and Sustainable Development 1:25-39.
Hall, Andy, Norman Clark, R.V. Sulaiman, M. V. K. Sivamohan, and B. Yogandnd. 2000. "New Agendas for Agricultural Research in Developing Countries: Policy Analysis and Institutional Implications." Knowledge, Technology, & Policy 13:70-91.
Hall, Andy, Norman Clark, S. Taylor, and R. V. Sulaiman. 2001. "Institutional learning through technical projects: Horticultural technology R&D systems In India." AgREN Network Paper 111.
Hall, Andy, and J. Dijkman. 2006. "Capacity development for agricultural biotechnology in developing countries: Concepts, contexts, case studies and operational challenges of a systems perspective." in Working Paper Series #2006-003. Maastricht: United Nations University-Maastrict Economic and Social Research and Training Centre on Innovation and Technology (UNU-MERIT).
Hall, Andy, R. V. Sulaiman, B. Yoganand, and Norman Clark. 2003a. "Post-harvest innovation systems in South Asia: key features and implications for capacity development." Pp. 78-93 in Post-harvest innovations in innovation: reflection on partnership and learning, edited by Andy Hall, B. Yoganand, R. V. Sulaiman, and Norman Clark. UK/India: Natural Resources International Ltd/ Crop Post-Harvest Programme, South Asia.
Hall, Andy, R.V. Sulaiman, Norman Clark, and B. Yoganand. 2003b. "From measuring impact to learning institutional lessons: an innovation systems perspective on improving the management of international agricultural research." Agricultural Systems 78:213-241.
Hall, Andy, B. Yoganand, R. V. Sulaiman, and Norman Clark. 2003c. "Innovations in innovation: partnership, learning and diversity in the generation, diffusion ad use of new knowledge." Pp. 1-15 in Post Harvest Innovations in Innovation: reflections on partnership and learning, edited by Andy Hall, B. Yoganand, R. V. Sulaiman, and Norman Clark. UK/India: Natural Resources International Ltd/ Crop Post-Harvest Programme, South Asia.
Hambly Odame, Helen. 2003. "Connecting the Two Stations of Agricultural Research and Rural Radio." Journal of Development Communications 23:1-14.
Hart, Robert. 2000. "FSR - Understanding Farming Systems." Pp. 41-51 in A History of Farming Systems Research, edited by M. E. Collinson. Oxon, UK/ Rome, Italy: CABI Publishing/FAO.
Humphries, S., O. Gallardo, J. Jimenez, F. Sierra, and et al. 2005. "Linking small farmers to the formal research sector: lessons from a participatory bean breeding programmed in Honduras." AgREN Network Paper 142.
Joshi, K. D., Stephen D. Biggs, D. Gauchan, K. P. Devkota, C. K. Devkota, P. K. Shrestha, and B. R. Sthapit. 2005. "The evolution and spread of socially responsible technical and institutional innovations in a rice improvement system in Nepal." in Discussion Paper 8. Bangor,Wales, UK: CAZS Natural Resources, University of Wales.

Kenney, M. and D. Patton. 2009. "Reconsidering the Bayh-Dole Act and the Current University Invention Ownership Model." Research Policy 38 (9):1407-1422.
Knudson, Mary K. 2000. "The Research Consortium Model for Agricultural Research." Pp. 175-198 in Public-Private Collaboration in Agricultural Research: New Institutional Arrangements and Economic Implications, edited by Keith O. Guglie and David. E. Schimmelpfennig. Ames: Iowa State University Press.
Kuhn, T. H. 1962. The Structure of Scientific Revolutions. Chicago: The University of Chicago Press.
Lambert, R., 2003. Lambert Review of Business-University Collaboration. London, UK: HMSO
Leeuwis, Cees, Norman Long, and M. Villarreal. 1990. "Equivocations on knowledge systems theory: An actor oriented critique." Knowledge in Society: The International Journal of Knowledge Transfer 3:19-27.
Lundvall, Bengt-Åke., R. Johnston, E.S. Andersen, and B. Dalum. 2002. "National systems of production, innovation and competence building." Research Policy 31:213-231.
Matthews, M. , and R. Johnston. 2000. "International Trend in Public Sector Support for Research and Experimental Development: A Preliminary Analysis. Australia: ." in Technical Report 99/8: Commonwealth of Australia.
Maxwell, Elliot. 2006. "Open standards, open source, and open innovation: Harnessing the benefits of openness." Innovations 1:119-176.
Merrill-Sands, Deborah, David Kaimowitz, Kay Sayce, and Simon Chater. 1989. "The Technology Triangle. Linking Farmers, Technology Transfer Agents and Agricultural Researchers." in Researchers Report of the International Conference. The Hague: ISNAR.
Nelson, R. R. 2004. "The market economy and the scientific commons." Research Policy 33 (3): 455-471.
Norman, D. W. 2002. "The Farming Systems Approach: A Historical Perspective." in Paper presented at the 17th IFSA Symposium. Lake Buena Vista, Florida.
Norman, D., F. D. Worman, J. D. Siebert, and E. Modiakgotia. 1995. "The Farming Systems Approach to Development and Appropriate Technology Generation." in FAO Farming Systems Management Series 10. Rome: FAO.
Pant, L. P., and Helen Hambly-Odame. 2006. "Multi-stakeholder deliberation on dialectical divides: an operational principle of the Systems of Innovation." Knowledge Management for Development 2:60-74.
Pant, L P., and Ramisch, J. (forthcoming) ‘Beyond Biodiversity: Culture in Agricultural Biodiversity Conservation in the Himalayan Foothills’ in Beyond the Biophysical: Knowledge, Culture and Politics in Agriculture and Natural Resource Management, edited by L. German, J. Ramisch, and R. Verma. New York: Springer.
Pollack, Andrew. 2006. "DuPont and Syngenta Join in Modified-Seed Venture." in The New York Times. New York.
Popper, Karl R. 1963. Conjectures and refutations: The Growth of Scientific Knowledge. New York: Basic Books Inc.
Rivera, W. 2004. "Communication for Rural Development: Challenge to Diffuse Development Information on Non-agricultural Rural Needs." in Paper presented in the ninth United Nations Roundtable on Communication for Development. Rome: FAO.
Rogers, E. M. 2003. Diffusion of Innovation, Fifth Edition. New York: Free Press.
Röling, Niels G. 1990. "The Agricultural Research-Technology Transfer Interface: A Knowledge Systems Perspective." Pp. 1- 42. in Making the Link: Agricultural Research and Technology Transfer in Developing Countries, edited by D. Kaimowitz. London: Westview Press.

—. 1994. "Agricultural Knowledge and Information Systems." in Extension Handbook: process and practices, edited by D.J. Blackburn. Toronto: Thompson Educational Publications.
—. 2000. "Gateway to the Global Garden: Beta/Gamma Science for Dealing with Ecological Rationality." in Eighth Annual Hopper Lecture. Guelph: University of Guelph.
Röling, Niels G., and J. Jiggins. 1998. "The ecological knowledge system." Pp. 283-311 in Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty, edited by Niels G. Röling and M. Wagemakers. Cambridge, UK: Cambridge University Press.
Scoones, I. 1998. "Sustainable rural livelihoods: a framework for analysis." IDS Working Paper 72.
Sulaiman, V.R., and A. Hall. 2002. "Beyond technology dissemination: reinventing agricultural extension." Outlook on Agriculture . 31:225-233.
Sulaiman, V.R., A. Hall, and N. S. Bharathi. 2005. "Effectiveness of Private Sector Extension In India and Lesson for the New Extension Policy Agenda." AgREN Network Paper 141.
Sumberg, J. 2005. "Systems of Innovation theory and the changing architecture of agricultural research in Africa." Food Policy . 30:21-41.
Temel, T., W. Janssen, and F. Karimov. 2003. "Systems analysis by graph theoretical techniques: assessment of the agricultural innovation system of Azerbaijan." Agricultural Systems 77:91-116.
United Nations Millennium Project. 2005. Innovation: applying knowledge in development. Task Force on Science, Technology and Innovation. New York: United Nations Development Programme (UNDP).
UNDP. 2005. Human Development Report 2005. New York: United Nations Development Programme (UNDP).
van Eijk, Toon. 2000. "Holism and FSR." pp. 323-334 in A History of Farming Systems Research, edited by M. E. Collinson. Oxford, UK/Rome, Italy: CABI Publishing/FAO.
von Hippel, Eric. 2001. "Open source shows the way - Innovation by and for users - no manufacturer required!" Sloan Management Review 42:82-86.
World Bank. 2007. Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems. Washington, D. C.: The World Bank.