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Shaping agricultural innovation systems responsive to food insecurity and climate change[1]

Sally Brooks and Michael Loevinsohn

Abstract

Climate change and variability present new challenges for agriculture, particularly for smallholder farmers who continue to be the mainstay of food production in developing countries. Recent global food crises have exposed the structural vulnerability of globalized agri-food systems, highlighting climate change as just one of a complex set of environmental, demographic, social and economic drivers generating instability and food insecurity, the impacts of which disproportionately effect poorer groups in marginal environments. Rather than search for single causes, there is a need to understand these changes at a systemic level. Improved understanding of and engagement with the adaptive strategies and innovations of communities living in conditions of rapid change provides an appropriate starting point for those seeking to shape agricultural innovation systems responsive to food insecurity and climate change. This paper draws lessons from selected country experiences of adaptation and innovation in pursuit of food security goals. It reviews three cases of systems of innovation operating in contrasting regional, socio-economic and agro-ecological contexts, in terms of four features of innovation systems more likely to build, sustain or enhance food security in situations of rapid change: (i) recognition of the multifunctionality of agriculture and opportunities to realize multiple benefits; (ii) access to diversity as the basis for flexibility and resilience; (iii) concern for enhancing capacity of decision makers at all levels; and (iv) continuity of effort aimed at securing the well-being of those who depend on agriculture. Finally, implications for policymakers and other stakeholders in agricultural innovation systems are presented.

Keywords: Agricultural innovation systems, climate change, food security

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1. Introduction

Food security remains an elusive goal in many parts of the world despite the concerted efforts of Governments and non-governmental and international agencies over the last fifty years. In its State of the Food Insecurity in the World Report (SOFI), the Food and Agriculture Organization of the United Nations (FAO) announced that the number of hungry people in the world had exceeded one billion (FAO, 2009).

The food price surges of 2007-8 and 2010-11 exposed the complexity and vulnerability of today's global food system. Notably the FAO (2009) report attributed the 2007-8 global food crisis not to poor harvests attributable to climatic changes but to a global economic crisis which had disproportionately affected the ability of the poor to access food (cf. Sen, 1981). Recent analyses highlight an emerging market in biofuels (Borras *et al*., 2010) and financial speculation in food futures (Ghosh, 2010) as factors further destabilizing global food markets. In considering the links between climate change, food insecurity and agricultural innovation, therefore, the starting point for this paper is to consider climate change as one element within a complex set of drivers generating unprecedented levels of instability and food insecurity. Rather than search for a single cause, we argue, there is a need to understand these changes at a more systemic level.

It is in this context that climate change and variability present new challenges for agriculture in low and middle income countries, in ways that compound existing vulnerabilities. Of particular concern are the implications for smallholder farmers, since they remain the mainstay of food production in developing countries and therefore key to economic growth (FAO, 2009; Pingali, 2007; Juma, 2010). Gains secured since the Green Revolution (GR) (Hazell, 2009), while uneven and not without costs (Glaeser, 1987), have been diminished by a proliferation of new challenges in a rapidly changing world. Thornton *et al*. (2011:118), for example, predict escalating pressures on global food systems driven by climate change, population growth, urbanization, income growth (stimulating greater demand for animal products) and the globalization of diets. The effects, while widespread, will be locally specific and socially differentiated, since the effects of climate change "merely unveil an already precarious and vulnerable situation" (Vogel, 2005:33). In such situations, multiple drivers of change — environmental, demographic, political and socio-economic — interact to produce patterns of "differential vulnerability" (Kasperson and Kasperson, 2001; Adger 2006).

This paper addresses the question of how to shape innovation systems that enhance community capacities in ways that build flexibility and resilience as a basis for sustained food security. In this context, we argue that the study of community-level adaptive strategies that build resilience to shocks and robustness to stresses in conditions of rapid change may be more instructive than that of formal interventions designed to re-establish stability (Scoones *et al*., 2007). However, while an understanding of local adaptive strategies is necessary, it is by no means sufficient. As noted by Thornton *et al*. (2011:118) "rural communities and households continue to demonstrate tremendous adaptive capacity in the face of economic and social change but this capacity needs appropriate social, institutional and political support". Furthermore, as temperature increases edge towards 4°C, incremental adaptations will no longer be effective, forcing communities into "system flips", for example from mixed cropping to rangeland systems (Thornton *et al*., 2010; Jones and Thornton, 2009). In this situation "farmers need support to switch strategies" (Thornton *et al*., 2011:128). The question is what constitutes appropriate support — for incremental adaptation as well as transformation of livelihood systems — and from whom, and what kind of institutional arrangements are needed to facilitate this. These are the questions that this paper attempts to address.

1.1. Innovation systems for food security in situations of rapid change

This paper adopts a 'systems of innovation' approach which "views innovation as a cumulative process that is path dependent, but open to change" (Mugwagwa *et al*., 2010). This approach emerged from historical analyses of "national systems of innovation" that generated rapid industrialization in Japan and South Korea (Freeman, 1995; Edquist, 1997). Key features of this approach are the de-centring of formal R&D in favour of a more holistic framework which comprises a range of actors, institutions and policies, on the demand as well as the supply side (Berdegue, 2005, World Bank, 2006). The application of this approach to agricultural innovation has been relatively recent, however, due to the dominance of conventional, neoclassical theories of induced innovation and linear diffusion models (Rogers, 2005; Ruttan, 2005).[2] An agricultural innovation system (AIS) can be defined as the set of agents (individuals, organizations and institutions) that contribute to the development, diffusion and use of new agricultural technologies, and that directly or indirectly influence the process of change in agriculture (Temel *et al*., 2003). Innovation arises from the actions of and interactions between agents, so the boundaries of innovation systems are not prescribed but evolve over time. As such, they can be characterized in terms of scale (international, national, sub-national), inclusiveness (who is in and who is out?) and the density of interactions and knowledge flows (between agents in the system and with those outside it).

Hall (in World Bank, 2006) identifies two types of trajectory though which innovation systems can evolve, which he calls the "orchestrated trajectory" and the "opportunity-driven trajectory". The factor differentiating them concerns whether they are triggered by policy measures or market signals. Typically, an orchestrated trajectory emerges as a result of a governmental intervention, while in the case of an opportunity-driven trajectory the private and non-governmental sectors are key. Orchestrated systems therefore benefit from clear goals and centralized coordination but can be closed to a wider circle of actors

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[2] The AIS approach builds on earlier system-based formulations such as the national agricultural research system (NARS) and the agricultural knowledge and information system (AKIS). However, these models emphasized the roles of public sector research, extension and education. The AIS is a more inclusive, flexible framework that 'highlights the complex relationships between new and old actors, the nature of organisational learning processes, and the socio-economic institutions that influence these relationships and processes' (Juma 2010: 53)

that do not meet its membership "rules" (prescribed in terms of sector, discipline, institutional base etc.). Opportunity-driven systems, on the other hand, are more responsive to market and (extending Hall's logic) environmental changes and more open to new actors, institutions, types of knowledge and forms of interaction that allow the system to evolve. However, without some degree of orchestration, such systems can lack the strategic vision and coordination necessary for scaling up and out, and, in particular, mechanisms for resolving power asymmetries and conflicts of interest between actors operating at different scales. Ultimately, these are ideal types and agricultural innovation systems in reality include elements of both types. The critical issue, we argue, is the extent to which characteristics of the resulting system foster learning and continuous improvement in response to ever changing contexts.

This balance between orchestration and responsiveness to opportunity (as well as threats) is especially pertinent in an era of unprecedented levels of environmental and socio-economic change. As discussed in the introduction, the input of new ideas and technologies is needed to support communities in building on existing adaptive capacities to respond to unforeseen and unpredictable agro-ecological changes. Our concern, therefore, is not only the internal functioning of individual innovation systems, but also the interface between systems operating in different sectors and at different scales, and the extent to which learning and evolution takes place between as well as within innovation systems. In the next section of this paper we present three case studies — from South Asia, Southeast Asia and Sub Saharan Africa — which highlight clear contrasts in the way in which particular innovation systems have evolved in the respective regions, and assess the extent to which these systems equip communities with the capacity and resources to respond to the challenges of the present and those they may encounter in the future. Listed below are four elements which, we argue, are key features of innovation systems more likely to build, sustain or enhance food security in situations of rapid change and uncertainty. We focus on these features in our analysis of the cases that follow since they are of increasing importance in this context, even though they are so often excluded from conventional analyses of innovation systems.

Capitalizes on the multi-functionality of agriculture: It is critical to see innovation in agriculture within a wider context. Agriculture produces more than merely food for producers and consumers. It underpins the livelihoods of a large number of people throughout the length of its production chains. While consuming natural and financial resources, it also provides a range of ecosystem and other services. These include recycling and purifying inputs such as water, conserving local biodiversity, regulating disease and offering important cultural and amenity values. If this multi-functionality of agriculture is not recognized and valued, it can easily be lost by ill-considered policy and action; however, its visibility tends to be impeded by sectoral divides. A consciously multifunctional view of agriculture (IAASTD, 2009) is therefore needed, which provides a comprehensive framework for valuing interventions and orienting policy across sectoral divides. If such an approach is taken, in many instances different functions can be advanced through a single intervention. For example, improving access to food through an action that extends crop production into the dry season by capturing water can yield multiple benefits in terms of maternal and child nutrition, reduced maternal mortality and enhanced child development.

Facilitates access to diversity: Maintaining access to sources of material and institutional diversity is particularly important in conditions of rapid change. Diversity refers to more than mere variety (simply a numerical category count) in that it reflects the many dimensions of difference inherent in the heterogeneity (of all aspects of farming and livelihood systems, from crop-soil-livestock combinations to institutions and practices) as it exists in particular places (Stirling, 2007, 2008) and provides the basis for experimentation, adaptation and "reinvention" (Rogers, 2005). Institutional diversity is critical to the processes of learning that enable an AIS to evolve in response to a changing context. For example, local knowledge and "place-based innovation in governance" is an important source of this institutional diversity (Juma, 2010: 75). NGOs are often in a position to draw on this local knowledge and provide intensive support at a local level, providing valuable lessons that can be shared with governmental and intergovernmental institutions operating at national or international scales, "scaled out" through processes of dialogue and collaboration.

Builds capacity from the bottom up: The capacity to innovate is as central to adaptation to climate change; as it always has been tofarmers adapting to ever-changing circumstances. It is this underlying, quintessentially local capacity that underlies the diversity of agricultural systems and their constituents — a diversity that predates the emergence of formal agricultural research and on which agricultural research has drawn for inspiration and raw materials, notably genetic diversity. Local innovation continues to operate in parallel to formal research efforts and governmental extension services and makes free use of its outputs to the extent they are found useful. How to create constructive alliances between the informal systems and formal systems operating at different scales has over the years been a major challenge to researchers in areas like varietal breeding and selection and natural resource management. There is increasing recognition that accelerating climate change and price and production volatility increases the importance of that local capacity and the urgency of sustaining and allying with it. Such alliances require constant capacity development at all levels of the system, facilitated through the "orchestration" of new configurations of actors and interactions and institutional innovations.

Maintains continuity of effort and attention: The development of farming systems that can provide food security in fragile, risk-prone environments requires repeated cycles of innovation, trial and assessment. This demands sustained attention from all actors who support innovation at the farm level and further down commodity chains, as well as effective coordination, to create and maintain a policy environment that fosters that continuity. Institutions that have effective accountability downwards, to farmers and others whose livelihoods depend on agriculture and its products, are more likely to sustain that attention. That accountability should be reflected in monitoring and evaluation systems that assess the progress of programmes and make possible corrections. This kind of sustained attention is undermined when, as in many cases where key institutions are weak, a succession of external "fixes" have inordinate influence (Scoones *et al*., 2005).

2. Review of policy and programme responses

The case studies presented in this section trace the evolution of systems of innovation operating in particular contexts and facing particular challenges. In Southeast Asian post-Green Revolution rice cultivation, we trace innovations responding to the unintended consequences of rapid technological change. In India, we focus on attempts to recover degraded semi-arid lands and the degraded livelihoods, lands and lives bypassed by the Green Revolution in a rapidly developing now middle income economy and a functioning democracy. In Southern Africa, we explore responses to similar social and environmental challenges to those in the Indian context but in low income economies with less developed institutions and democratic practice. In each case, we analyse the evolution of these innovation systems, and highlight the extent to which the features described above have been present, in what form and to what effect.

2.1. Case study 1: Managing rice crops and rice fields in Southeast Asia

Over a span of little more than a decade, large numbers of Asian rice farmers changed their cultivation methods radically. Vast areas of lowland rice cultivation were planted with new varieties responsive to nitrogen fertilizers and treated with synthetic pesticides. The new varieties were also insensitive to photoperiod, making possible, together with expanded irrigation, more extensive double cropping. These were the elements of the Green Revolution packages that were conceived and tested by research organizations, disseminated by extension programmes and often promoted by subsidized credit schemes. Farmers taking up the new seeds and chemical inputs generally realized large production increases and as a consequence contributed to a marked decline in the price of rice — providing an important benefit to both urban and rural consumers.

There is wide evidence, however, that farmers used the elements of the packages but employed them in ways often at variance with the recommendations. This was observed in easily accessible areas, not just remote ones. The divergence appears to have been substantial, consistent among farmers and stable over time. Notably, it involved some elements with which farmers had only limited previous experience. In Central Luzon, Philippines, less than 10 years after farmers began using nitrogen fertilizer extensively, more than 90% were applying it in one or two doses after transplanting, contrary to the recommendation to begin applying it before transplanting. Much research sought to measure and explain this "technical inefficiency" yet when trials compared researcher and farmer practice, under farmers' conditions, the latter were found to out-yield the former and to make more efficient use of nitrogen. Subsequent research confirmed several of the reasons farmers gave for their practices (Kaiser, 1984; Fujisaka, 1993). Farmers in the region also maintained plant densities and employed pesticide concentrations that varied substantially from the recommendations (Loevinsohn and Kaiser, 1982).

The persistent dissonance provides evidence of significant farmer-led, informal experimentation and communication that informed farmers' practice, giving them confidence to resist the pressure from formal extension agents. This capacity was not widely appreciated by agricultural research or policy and it was not enlisted in the official response to two pest-related crises that rocked Asian rice economies and affected those whose livelihoods depended on rice farming.

The first was a series of outbreaks, beginning in the 1970's, of hitherto minor pests and diseases which devastated rice crops across many countries, chief among them the brown planthopper and rice tungro virus. The principal methods promoted in response were genetic resistance wrapped in the seed and expanded use of pesticides. Farmers were generally not aware of this resistance and often sprayed pesticides even when this was not necessary. Many of these applications caused the pests to resurge by decimating their natural enemies, such as spiders.

The second crisis, widespread environmental pollution and occupational poisoning, was a consequence of that poorly regulated expansion of pesticide use. It was only slowly recognized that substantial morbidity and mortality were occurring (Loevinsohn, 1986; Rola and Pingali, 1993). Regulation of the most hazardous pesticides followed but lagged behind the research that had demonstrated their consequences. In the Philippines, advocacy by civil society actors played a major role in securing the change in policy, but only after the end of the Marcos dictatorship, in a political climate in which rural interests had somewhat greater weight (Loevinsohn and Rola, 1998). Regulation was also insufficient on its own to prevent misuse.

Research institutions responded to the pest and pesticide crisis by developing integrated pest management (IPM) approaches. These aimed to give farmers a number of other control options with pesticides seen as a last resort — to be judiciously and safely employed only when justified. New pedagogical approaches were found to be necessary to impart the skills and understanding needed to effectively use IPM. Over a 10-year period in the Philippines and Indonesia, the Farmer Field School was developed, privileging experiential learning (Pontius *et al*., 2002). In weekly sessions over a season, some 25 farmers closely followed the development of a rice crop. Typically, they would observe spiders, to which few had previously paid much attention, and hunt brown planthoppers and other insects. They saw both pests and predators dead in the water after the crop was sprayed. And they found that when rice leaves were cut back by 50% early in the crop's development, simulating the damage caused by defoliating pests, there was often no discernable impact on the final yield. Follow-up evaluations commonly found large reductions in pesticide use and often a small but significant increase in yield (Kenmore, 1996). Through similar methods, the Farmer Field

School enabled farmers to understand better the role of the different plant nutrients and to make more effective use of fertility-enhancing measures.

The Farmer Field School approach has been used in other developing regions and has been adapted to farming systems other than intensive rice cultivation. The range of management skills addressed has also been extended beyond pest and crop management to include, for example, the linkages between agricultural practices and the breeding of insect vectors of human diseases. Community IPM is a further evolution of the approach that aims at securing a self-sustaining institutional base for continued farmer learning about the complex systems of which they are a part.

A number of significant features of the innovation system that has underlain the evolution of rice crop management can be discerned. Critical innovations have been contributed by actors at different levels. For instance, entomological and agro-ecological studies conducted by national and international researchers in the Philippines and Indonesia informed the curriculum of the Farmer Field School, while adult education approaches contributed by NGOs in Indonesia shaped its pedagogical process. The innovation system is generally quite "thin" in terms of formal, national institutions: in few places is there a concentration of researchers and development practitioners, and international actors have played a large role. National champions have been important in propelling IPM implementation and farmer education approaches such as the Farmer Field School but, in many countries where these are being implemented, it is difficult to find the kind of sustained political commitment that has characterized watershed development in India.

Contentious issues have persisted without resolution. The most substantial one concerns the capacity of farmers: should the priority be to educate farmers, to enhance their ability to assess and decide, or should they be served with messages relating to specific practices? Gershon Feder *et al*. (2004 and 2004a) drawing on Indonesian data, have questioned the extent of learning in Farmer Field Schools, its impact on practice in the field and the prevalence of farmer-to-farmer communication of that learning. Heong *et al* (1998) carried out trials in Vietnam in which a simple "heuristic" was extended to farmers through a number of media. "Don't spray in the first 40 days" encapsulated the experience farmers typically gained from their observations in the Farmer Field School. The authors found that both measures resulted in marked reductions in pesticide use but that this could be achieved more widely and at lower cost through the dissemination of the heuristic.

Rejesus *et al* (2009), in a re-evaluation of the heuristic and farmer Field School approaches in Vietnam, found that only the latter resulted in significant decrease in pesticide use. Van den Berg and Jiggins (2007) took issue with Feder *et al*.'s analyses. They questioned both the data they selected and the interpretations they drew from them. More substantially, they critiqued the conclusion that the Farmer Field School is an expensive extension method: it aims at wider impacts, as does education more generally. How these conflicting perspectives will be resolved remains an open question. There is likely room for finding common ground around the need for quality control in the learning processes that occur in large programmes and the role that simple messages may sometimes play. The prospects for a constructive and considered outcome are more likely where political commitment and research focus are persistent. It is significant that even in Indonesia, which suffered most from the pest/pesticide crises and where the most persistent efforts have been made to institute rice IPM, the FFS/Community IPM programme continues to be pursued in parallel with conventional extension approaches (Matteson, 2000).

However this contestation evolves, enhanced farmer capacity and access to information, in whatever way it is achieved, is essential to the development of more effective, local adapted responses to changed circumstances. In Indonesia, farmers who had graduated from FFS responded more calmly to the re-emergence and outbreak of the white stem borer in the late 1980's, observing and implementing non-chemical measures in contrast to farmers who had not attended the FFS (Winarto, 2004). That capacity to respond to changed conditions is critical in the context of climate change and market volatility.

Beyond the immediate fruits of better management, there are multiple benefits at stake. At the personal level, farmers using pesticides only as a last resort, sparingly and aware of their risks, have been shown to suffer less from pesticide poisoning (Smit *et al*., in press). More widely, networks of FFS graduates have emerged, undertaking research on issues of local concern. They have gained confidence, in Indonesia convening and demanding more responsive, farmer- and environment-friendly policies including on environmental regulation and credit.

The issues at stake extend beyond pest and crop management to ones of citizenship — taking up the demand side in innovation systems and creating a constituency for accountability.

Epilogue: The System of Rice Intensification (SRI) emerged in Madagascar in the early 1990's and by the mid-2000's had spread to all major rice growing countries. Farmers who have followed its principles — transplanting younger seedlings widely spaced to permit robust plant development; keeping the soil moist, not flooded, to enable roots to breathe; and mechanically incorporating weeds to enhance soil aeration — have often reported substantially increased yield (50% is not uncommon) and reduced irrigation water use (50% is again fairly typical). Fewer agrochemicals are employed, as well; organic fertilizers are promoted where available and pesticides are found to be less necessary with the stronger vegetative plant growth and wider spacing. Greater resistance to extreme weather events — droughts, floods, storms — have also been reported. SRI thus represents a very different perspective of "intensification" than that embodied in the

Green Revolution of three decades earlier and one with potentially huge significance in the context of climate change and food insecurity.

Yet much still remains uncertain. For example, evaluations have so far been limited in scope and in rigour such that it is difficult to make out to what extent the yield improvements are due to the selective uptake of SRI by the most skilled farmers and its use on the most favoured landholdings (Berkhout and Glover, 2011). Evidence of resistance to extreme weather appears to be limited so far to a few striking photographs. Potential negative consequences have not been seriously considered. There is reason to be concerned that the reduced labour requirements that farmers taking up SRI report may have negative consequences for landless labourers where employment in transplanting the rice crop is an important income source.

SRI differs strikingly from the Green Revolution in terms of the innovation system that has shaped its development and spread. It emerged from the observations of an agronomist-missionary in the paddies of Madagascar. Its introduction to Asia and then Latin America and Africa has been due to the efforts of a few dedicated "champions" and networks of civil society organizations and researchers. In India, which appears to have the largest area under SRI, "learning alliances" have been formed that exchange experiences and take the lead in interactions with government. Federal institutions in that country have been slower to engage with SRI than have state ones, notably in Andhra Pradesh, Tamil Nadu and Tripura. The involvement of formal research has so far been limited primarily to a few state universities and institutes. A number of Chinese and Indonesian research centres have engaged strongly with SRI (Prasad, 2009; Uphoff, 2009). In a recent desk study, Dutch researchers identified some 60 articles on SRI in Chinese language journals; translating the abstracts, they found a potentially wide interest, including recent articles reporting complex multi-factorial trials (Berkhout and Glover, 2011).

Conspicuous by its absence from research on SRI has been the International Rice Research Institute (IRRI), which took the lead in the Green Revolution. Beyond IRRI's own research capacity, other functions that it is uniquely placed to play are not being brought to bear on SRI, including facilitating the international flow of information — ensuring that national literatures such as the Chinese are widely accessible — and stimulating reflection and action in the research and policy communities on priority issues. One sees here, as in the earlier situations described above, the perpetuation of "parallel systems of innovation", between which there is limited and asymmetrical flows of information. This tends to slow the pace of agricultural evolution, reducing interactions among important actors and restricting their access to vital information. We take up this point again below.

2.2. Case study 2: Watershed development in India: learning and changing over decades

A watershed is an area of land that is drained by a common watercourse. In India over the past three decades, watersheds of from fifty to a few thousand hectares have been the focus of increasingly intensive development efforts, particularly in the semi-arid zones. Many are characterized by eroded slopes, degraded pastures and forests in their upper reaches and falling water tables. These are areas of intense poverty and food insecurity that were largely overlooked by the Green Revolution which transformed agriculture in more favoured areas.

The first, large-scale watershed projects were led by a narrow disciplinary focus on soils and hydrology and a concern for correcting the physical symptoms of degradation. The dominant intervention was the construction of infrastructure to retain water and slow erosion, such as: check dams, gully plugs and land levelling. Typically this was accompanied by a ban on grazing and harvesting of forest products on the ridges, in order to slow run-off and permit the groundwater to recharge. The visual impact of these actions was often striking. Within a few seasons, once bare hillsides were covered in grass, shrubs, and young trees; wells that had run dry not long after the rains now provided drinking water all or most of the year. However, the benefits were badly skewed: farmers in the lower reaches whose crops had withered when the rains faltered could now harvest once and often twice a year with irrigation. People dependent on fodder and forest products from the upper parts — women, the landless, tribal people and those of lower castes — were hurt by the restrictions. These groups typically also had little voice in village councils.

A number of pioneering village-level projects initiated in the 1970's sought innovative ways to avoid this structural inequality. Two initiatives, Sukhomajri and the Pani Panchayats granted rights to the landless in the additional surface water that was generated in exchange for their collaboration in conserving soil and vegetation in the upper watershed. They were able to capitalize on these rights by selling the water to farmers or using it on rented land. Substantial benefits were realized in environmental terms and in broad-based social and economic impacts (Kerr *et al*., 2002; Prasad, 2011).

These projects were extremely influential and inspired a range of efforts by both government and NGOs. While the specific social innovations often prove difficult to replicate in other contexts, other approaches emerged, including expanding employment opportunities based on natural resources and local opportunities outside agriculture. Fostering the development of institutions that can give voice to the interests of women, the landless and tribal groups has been central, among them the self-help affinity-based groups and federations of these groups pioneered by NGOs, notably MYRADA in Karnataka (Fernandez, 2003). These groups are represented in the watershed committees that are established to oversee implementation and which ensure that local concerns and ideas guide the work. This broadened, more inclusive approach is often referred to as "watershed plus" (Turton, 2000)

Government-led efforts that drew on the successes of Sukhomajri and the Pani Panchayats tended to borrow from their technological innovations rather than their social ones. Rigid implementation guidelines and schedules were imposed that contributed to limited local ownership and benefits that in many cases were not sustained beyond the project period (Farrington *et al*., 1990). In response, several European bilateral agencies in the 1990's sponsored programmes that promoted collaboration between state and central government agencies and NGOs and attempted to support their social approach on a large scale. An evaluation of watershed development programmes in Maharashtra and Andhra Pradesh found that government-NGO partnerships and NGO-led projects achieved higher levels of satisfaction, both among farmers with the largest landholdings and among the landless, than those mounted by government alone (Kerr *et al*., 2002).

In these well-conceived and executed programmes, substantial gains in farm output have been achieved, extending cultivation into the dry season and securing benefits for the landless as well through increased employment. Out-migration has significantly declined (World Resources, 2005).

Stepping back slightly, one can discern a system of innovation operating with respect to watershed development in India that has several significant features. States and especially the central government have evinced a longstanding interest in improving the practice of watershed development. They have established a series of guidelines on the planning, implementation and evaluation of watershed initiatives (GOI, 1994b; 2001; 2003; 2008). Taken as a whole, their thrust has been to enlarge the concern of watershed programmes to resources from ridge to valley, including forest, pastures and livestock and to promote the broadening of the social objectives described above. A succession of evaluations and reviews of watershed development programmes has been carried out in recent years. Many have documented, as did Kerr *et al*., highly variable performance in economic, environmental and social terms and an often limited capacity of implementing agencies to meet the standards required by the evolving guidelines (GOI, 2004a; Shah, 2001a,b; Joy *et al*., 2006; Wani *et al*., 2008; GOI, 2006). Their reports have in turn informed the revision and reorientation of guidelines and public investment.

NGOs respected for the quality of their watershed initiatives have played an important role in enhancing capabilities and raising standards. MYRADA, WOTR, BAIF and others have overseen and trained other NGOs implementing projects, trained personnel in line ministries, support agencies and district and local government and have seconded their own staff to these institutions. The NGO network WASSAN has for nearly a decade engaged in advocacy and dialogue at state and federal levels.

Watershed development programmes and the local institutions they foster provide an attractive context in which to refine and communicate agricultural and natural resource management technologies. Many organizations routinely introduce and promote the assessment of new farming options, including those issuing from local innovation. A recent review highlights the scope for furthering such efforts (participatory plant breeding and selection (see below) is specifically mentioned) and the fact that farmers in many watersheds still have severely limited access to useful information (Wani *et al*., 2008).

Watershed development faces a number of critical challenges. On one side is the growing appreciation that when it is done well, with attention to equity and local participation, multiple benefits can be expected. Though still inadequately assessed, there is evidence that where production and employment have increased and extended through the year, nutrition and access to drinking water have improved and distress-linked migration curtailed (Kakade, 2001; WOTR, 2005). These effects may be contributing to enhanced child development, women's empowerment and a broad range of health benefits, including reduced HIV risk (D'Souza and Lobo, 2004; BAIF, 2006; Loevinsohn, 2006). These plausible benefits raise the incentive to get watershed development "right" and to further ratchet up practice.

On the other side, watershed development must confront the consequences of its own success. Where significant areas are managed to capture and use water, the volume available to critical wetlands and downstream consumers in rural areas — for both domestic and agricultural purposes — and outside is reduced. "Basin closure" is likely to be an increasing source of conflict to which the growing aridity expected under some climate change scenarios will only contribute (Kakade *et al*., 2001; Batchelor *et al*., 2002; 2003). Excessive, poorly regulated groundwater extraction exacerbates these threats and is a major challenge to policy (Joy *et al*., 2006; Kulkarni and Shankar, 2009; Shankar, Kulkarni *et al*., 2011; Shankar *et al*., 2011). Significantly, it is a challenge that is evoking innovation, technical and social, at village level (Prasad, 2011)

The wider relevance of watershed development in India bears consideration. Without losing sight of the extreme poverty and food insecurity that persist in many dryland areas, it is evident that the understanding of what constitutes good watershed development has changed markedly over the past three decades. The importance of participation and attention to equity are now widely accepted. That partial success provides hope that the system of innovation that underlies it can rise to the serious challenges outlined above. Critical to that system are a consistent political commitment (some US$ 1.8 billion are budgeted for watershed development annually in India), a community of Indian researchers and development practitioners who have contributed important innovations and sequences of evaluation, and review and standard setting that can propel improvement.

2.3. Case study 3: Maize-centred mixed farming in Sub Saharan Africa

Maize is the world's most widely grown cereal, grown on large and small farms around the world (Smale and Jayne, 2009). Initially a "new world crop", its inherent versatility has enabled maize to find its way into diverse farming systems and agro-ecologies (McCann, 2005). Introduced in Africa as a cash crop by European settlers, maize became the staple of choice for several post-independence African states in East and Southern Africa, notably, Kenya, Malawi, Zambia and Zimbabwe (Smale and Jayne, 2009). In the immediate post-independence era there was considerable optimism about the potential for a maize-based "Green Revolution" in Sub Saharan Africa (SSA). High yielding, hybrid maize varieties originally developed for European settler-farmers during the colonial era formed part of a package of technologies and policy measures designed to promote maize farming as a basis for "modern" agricultural development, national food security and economic growth. In the early years, results were encouraging (Smale and Jayne, 2009), but by the mid 1980s early optimism gave way to concerns about "patchy" results and stagnation (de Groote *et al*., 2005; Byerlee and Heisey, 1996). A key problem was that the existing agricultural innovation system had evolved in response to the needs of (white settler, then African) commercial farmers, and not the smallholders that, in terms of acreage, now dominated maize cultivation in the region (McCann *et al*., 2007).

In the 1990s this emphasis began to shift, with the spread of alternative, participatory research methodologies focused on the needs and conditions of small scale, maize-centred, mixed farming systems. These were based on recognition of the value of farmers' knowledge based on their adaptations to complex, diverse and risk-prone environments (Chambers *et al*., 1989; Scoones and Thompson, 1994). Participatory plant breeding (PPB) is one such methodology. While formal breeding programmes were geared to farmers located in high potential environments and/or able to modify their environments to suit new cultivars, PPB is a decentralized approach through which varieties are developed to suit local conditions in less favourable agro-ecological environments. Over the last 10-15 years a range of methodologies have developed under the rubric of PPB, though these differ widely in terms of "the institutional context, the bio-social environment, the goals set, and the kind of 'participation' achieved" (Sperling *et al*., 2001:439). PPB methods give a voice to those often excluded from crop research, particularly women and poorer farmers (Ceccarelli and Grando, 2007) and can also foster intra crop specific (varietal) biodiversity, though this is not guaranteed (Joshi *et al*., 2001; Bellon, 1996). Notably PPB appears to have been more successful with subsistence crops overseen by women farmers, for example pearl barley and phaseolus bean, than maize (Sperling *et al*., 1993; see also CIAT, 2010; GTZ, 2004). This may be due to the subsistence or gender focus, the nature of the crop itself (these are self- rather than cross-pollinating, as is the case with maize) or differences in the cultures of the lead institutions, or most likely a combination of these factors.

Within formal maize breeding programmes, notably in the CGIAR, a more limited form of PPB known as participatory varietal selection (PVS) has been incorporated to varying degrees. In the 1990s, the International Centre for Improvement of Maize and Wheat (CIMMYT) launched the Southern Africa Drought and Low Fertility programme (SADLF), operationalizing what McCann *et al*. (2007) call the "smallholder paradigm". This paradigm combined the following elements: a shift from breeding for "optimal" to breeding for "managed stress" conditions; a switch from hybrids to open-pollinated varieties (OPVs) in recognition of smallholder farmer practices of saving seed from one season to the next; and a shift from conventional plant breeding to a participatory varietal selection (PVS) methodology known as the "mother-baby" model (McCann *et al*., 2007; Banziger and Cooper, 2001). They key difference between PPB and PVS is that in the case of PVS, farmers are invited to evaluate already stabilized materials, so they are not actually involved in setting goals for plant breeding, though they do have a say in which cultivars are ultimately released as varieties (GTZ, 2004). The SADLF was the first formal maize breeding programme to implement the smallholder paradigm and evaluations were encouraging (McCann *et al*., 2007). Even concerns that private seed companies would shun OPV markets since they would not be guaranteed repeat sales proved to be unfounded (McCann *et al*., 2007:105-106). As a result, the model was scaled up in a joint CIMMYT-IITA (International Institute for Tropical Agriculture) initiative, launched in 1998 and entitled, "Developing and Disseminating Stress-Tolerant Maize for Food Security in East, West and Central Africa", though better known as the Africa Maize Stress (AMS) project (Banziger and Diallo, 2000).

Meanwhile, a recent example of a Green Revolution-style maize seed plus fertilizer "package" can be found in the response of the Government of Malawi to national food crises in 2004/5 and 2008/9. While building on input subsidy schemes implemented from the late 1990s onwards, the controversial Fertiliser Subsidy Programme (FSP) was introduced with massive popular support following a general election dominated by memories of the 2001/2 famine. While the stated aim was to kick-start farmers into using higher yielding hybrid seeds and inorganic fertilizers as a way to break the ''low equilibrium poverty cycle' of unproductive, subsistence maize cultivation (Dorward and Chirwa, 2011; Levy, 2005), it has continued as a social protection mechanism which reduces the need for food aid (Future Agricultures Consortium, 2009). Despite strong opposition at the outset, the "smart subsidy" is now regarded by international donors as a legitimate policy instrument (Chinsinga, 2007). Most importantly, it worked. Food security, at least in the short term, was achieved through a "significant increase in national maize production and productivity" leading to "increased food availability, higher real wages, wider economic growth and poverty reduction" (Dorward and Chirwa, 2011:1).

Questions remain about the longer term sustainability of subsidised inorganic fertilizer use, in economic and ecological terms, although the prospects of a transition to more sustainable (but also more demanding) integrated soil fertility management (ISFM) regimes seem doubtful if subsidies continue indefinitely

(Dorward and Chirwa, 2011). Of more fundamental concern is the way in which the immediate success of the FSP may have obscured the underlying causes of the famine. Maize-dependence has been identified as one of the causal factors underpinning the 2001/2 famine, which was essentially a severe case of a seasonal hunger crisis (Devereux and Tiba, 2007). In this context, despite its effectiveness in relieving its symptoms, the introduction of maize fertilizer subsidies did not address the underlying structural causes of the famine (Loevinsohn, 2011). Meanwhile, distress migration patterns during the famine show people gravitating towards cassava growing areas, highlighting its role as a famine crop. These strategies yielded multiple benefits, not least of which was a greater resilience to HIV infection (Loevinsohn, 2011:9). Cassava is "a perennial crop, with a 2-4 year productive life span, farmers harvest cassava year round, over a period of years, in small quantities, mainly for household consumption. Farmers rely on this safety valve, adjusting their cassava harvest upwards in years when the maize crop fails and downwards when the maize crop does well" (Haggblade *et al*., 2009:12). Researchers on the CATISA (Cassava Transformation in Southern Africa) project have demonstrated the suitability of cassava as a buffer crop that could be incorporated into regional food security planning; as well as the potential for further diversification through value addition. Together, these alternatives have the potential to provide more genuine diversity (across crops, livelihood options and seasons) than further investment in maize (Haggblade *et al*., 2009).

Nevertheless, the dominant response of the international donor and crop research community to concerns about the effects of climate change on agriculture, especially in Africa, continues to focus on centralized hybrid maize development programmes. Since 2008, two large scale maize breeding programmes have been launched: a public sector, CIMMYT-led programme called Drought Tolerant Maize for Africa and an AATF-brokered public-private partnership called Water-Efficient Maize for Africa with substantial support from the Bill and Melinda Gates Foundation. In both cases, lessons from PPB/PVS and earlier implementation of the "smallholder paradigm" appear to have been missed (Brooks *et al*., 2009). Rather, these programmes are based on a technology "pipeline" model that leaves little scope for meaningful farmer participation (Ashby, 2007), adaptation and "re-invention" (Rogers, 2003).

These new hybrid varieties are to be made available, together with other commercial inputs such as inorganic fertilizers, through a network of private providers who promise variety (in terms of the number of products on sale), and which may ultimately displace the rich diversity of material adapted over generations to specific agro-ecological and seasonal conditions. This commercial model reflects a convergence of interests of public sector institutions oriented towards Green Revolution-style interventions and private sector partners favouring centralized breeding programmes and technologies that embed intellectual property protection. This model is reflected in the UPOV 1991-derived seed regulatory systems, in place or under development across the region, that reflect private sector concerns for varietal uniformity (not diversity) and discourage farmer-to-farmer seed exchange.

These developments highlight an innovation system that is largely supply driven, shaped by research agendas set by international actors and donors. A key problem is the lack of organized farmer demand for innovation (Wiggins, 2005; Jones, 2005). In this case, Malawi's Fertiliser Subsidy Programme is a rare exception, arising from popular demand expressed in a National election. Ultimately, however, the outcome is a standardized package which provides a short term solution but does not address structural causes and longer term challenges.

Thus far, farmers' organizations and other intermediaries have played a limited role. Participatory plant breeding (PPB) is a case in point. While in South and Southeast Asia farmer-led PPB and community seed banking initiatives have emerged in response to vibrant civil society activism (Southeast Asia Regional Initiatives for Community Empowerment, 2007; Sahai *et al*., 2005), in Sub Saharan Africa civil society mobilization around this issue remains limited and the "voices" in favour of alternatives are as much from external sources (international scientists and donors) as from conventional breeding programmes.

National agricultural research systems are increasingly diverted from local needs and priorities by international collaborative programmes that offer much needed resources (Sumberg, 2005). The growth of public-private partnerships is further narrowing research agendas, with technology pathways "increasingly … fashioned by elite science, corporate funding and interests, resulting in a lack of involvement with wider stakeholders" (Scoones, 2005: 113; see also Ashby, 2009). As a result, a top down, technology "pipeline" model continues to dominate international agricultural research; this is reinforced by the preference of transnational private sector partners for centralized breeding and seed production models. Contestation does occur, but this is largely among external actors, rather than emerging from locally accountable organizations cognisant of local innovation capabilities, constraints and possibilities.

Nevertheless, lessons have been learned from community responses to food crises in recent years, which highlight the potential to realize multiple benefits with respect to food security, nutrition and health (cf. IAASTD, 2009). CATISA is an example of an initiative that is building on these lessons to develop regional strategies to complement national policies and programmes.

3. Lessons from the case studies

In this section, we return to the four features of innovation systems most likely to build food security in situations of rapid change that were outlined in the first section and use these to draw lessons across the three case studies. As mentioned in the introduction, this is not an exhaustive list of desirable characteristics to be found in effective, functioning systems of innovation per se, but features that are particularly pertinent to situations characterized by rapid change and uncertainty. We focus on these features in our analysis of the cases since they are of increasing importance and yet are often excluded from conventional analyses of innovation systems.

3.1. Capitalizes on the multi-functionality of agriculture

The three case studies illustrate in different ways the multifunctional nature of agriculture and the potential (achieved to varying extents) to realize multiple benefits. The case of pest management in post-Green Revolution Southeast Asia highlights the efforts of farmers to manage to their advantage novel technical options. Some of these options had deleterious effects on their health and the natural environment within and beyond their fields, the effects of which they were only partially aware. Farmers' emerging practices often varied substantially from those recommended by extension, based on formal research. Poorly regulated pesticide impacts are now fairly widely understood: negative human health implications and downstream effects, e.g. on stream fauna important to human food security and nutrition. The simplest multiple benefit from IPM (stop spraying toxic products and prevent the consequent damage to health) has been demonstrated in a few instances (Winarto, 2004). The wider benefits from an educated and organized farming population are still an area of contestation.

In the case of watershed development in India, the multiple consequences of degradation in highly seasonal areas on health, child and social development have only been partially assessed and not yet convincingly linked to the common cause of watershed degradation. Important multiple benefits from effective, equitable Watershed Development (WSD) are often apparent to local actors but have yet to be credibly demonstrated to a wider audience and to political decision-makers; they have yet to influence policy and programmes. The implications for inter-sector coordination and collaboration, at different levels, have yet to be substantially addressed. In the case of maize-centred mixed farming in Sub Saharan Africa, there are pathways that beckon, but so far have not been taken. The various responses to the Malawi famine highlight the interconnectedness of agriculture, food and health. These insights point to the limits of maize-based strategies but also to the potential for realizing food security and health benefits by building on elements of people's adaptive strategies. The case of cassava as a counter seasonal complement to maize is such an example.

3.2. Facilitates access to diversity

Each case highlights different dimensions of diversity. The case of pest management in Southeast Asia highlighted the transition from the Green Revolution to Integrated Pest Management as one in which an intervention framed as a single source innovation was translated into a diverse range of interpretations and practices in different contexts. In the process, a plurality of actors and institutions are participating in a system characterized by multiple sources of innovation (cf. Biggs, 1990) including intensive farmer-led experimentation. IPM brings together a range of options (of which pesticide use is just one option; and the option of last resort) that has its roots in these processes of experimentation and learning that evolved, at least initially, from the challenges presented by the unintended effects of the Green Revolution package. Similarly, WSD in India is also a story of multiple sources of innovation, across multiple scales, evolving over time from an initial, technical, problem definition to a multidimensional socio-technical change process.

Watershed areas are characterized by high socio-economic and agro-ecological heterogeneity. A key strength of some of the WSD examples described here is the way in which systems of innovation were allowed to evolve over time in ways that reflect this heterogeneity, creating the space for a range of social, institutional and technical innovations. A key feature of this innovation trajectory has been, not only the participation of heterogeneous institutions operating at different scales, but the interactions between them, leading to a productive cross-fertilization of ideas, methods and expertise. Lessons learned from small-scale, experimental NGO projects, for example, while not "scalable" in themselves; have informed the design and implementation of larger scale, governmental programmes thus contributed to improved practice more generally. A similar dynamic has been observed with farmer field schools, though this has not really taken hold at the national level and remains patchy, dependent on a loose network of committed researchers and the endorsement of high profile "champions".

The case of maize-centred mixed farming in SSA highlighted various kinds of diversity that are present within people's everyday adaptive strategies but downplayed in maize-dependent economies. The case of diversification into (and/or migration to areas of) cassava cultivation as a spontaneous famine relief strategy in Malawi in 2001/2 is illustrative. Interestingly, these adaptive strategies reflect findings of region-wide analysis that point to the potential for cassava as a regional buffer crop as a counter-balance to fluctuations in maize price and availability and provide a basis for the development of food processing industries (Haggblade *et al*., 2009). In this case "useful diversity" relevant to food security is diversity that bridges seasonal fluctuations. Meanwhile, participatory plant breeding remains a marginal activity within research programmes in which the CGIAR plays a major role (Ashby, 2009). While science institutions value local materials for use in formal breeding programmes (which can be conserved ex situ, in gene banks) there is less appreciation of the institutional diversity that informal seed systems adapted to diverse agro-ecologies represent. The question then, is how to effectively decentralize breeding programmes and facilitate productive exchange between these parallel formal and informal systems (cf. Sperling *et al*., 2001; McGuire, 2008).

3.3. Builds capacity from the bottom up

The cases here highlight the importance of investing in the capacity to manage and adapt. Management cannot be treated as an add-on to already "finished" technologies (cf. Douthwaite *et al*., 2001) although large-scale, Green Revolution-style breeding initiatives now under way in SSA perpetuate such assumptions. In contrast, the experiential, adult education-based approaches that emerged in Southeast Asia in the 1980-90's supported farmers' informal learning and experimentation in pest management. Through season-long observation and joint experimentation, they learned, among other things, about the reality of food webs and natural enemies, as well as the effects of insecticides on pests and predators alike. The result was typically a much reduced use of insecticides and a skeptical response to those who promoted them. Effective regulation of toxic pesticides was a further element of support to farmers, ensuring its effective implementation remains a challenge in Southeast Asia and other regions. Where watershed development approaches have succeeded is in enabling farm households and communities to better secure livelihoods and access to food, taking on board local understandings of constraints and opportunities. In semi-arid lands, identifying opportunities to harvest and store water is at the heart of the benefits watershed development can offer. Success, to the extent it has been achieved, in ensuring equitable access to water and other resources, has also been built on local ideas and nascent efforts.

Both cases highlight the potential for capacity improvements through cross-fertilization of ideas, methods and expertise between institutions of different sectors, operating at different scales. In the case of the FFS approach, however, there remains unresolved contestation over the cost-effectiveness of these approaches, at least in part due to disagreement over what costs and what effects should be considered. There seems to be some agreement that the quality of learning in large programmes is often poor, though there is less agreement on what conclusions should be drawn. Thus far, the approach has yet to become established at the national level and remains dependent on individual researchers and "champions".

Experience to date with participatory approaches to plant breeding and varietal selection shows that barriers to their effectiveness and spread are, to a great extent, institutional ones. With the historical evolution of the CGIAR system, and its relations with national breeding programmes, a centralized, hierarchical model has become entrenched; reinforced through incentive structures and disciplinary career trajectories; and now further reinforced by the preferences of private sector partners (Scoones, 2005). In this context, initiatives that focus on varietal selection criteria and emphasize building capacity of individual scientists can only have a limited impact (McGuire, 2008). More attention needs to be directed towards the cultures of science institutions and the structures, systems and practices that would need to be transformed for a more decentralized approach to varietal development to emerge (cf. Brooks, 2010).

3.4. Maintains continuity of effort and attention

The cases presented in this paper have highlighted contrasting accountability dynamics which reflect broader differences between the respective regions. India is a middle income country with a long history of civil society organization, as are several countries in Southeast Asia. As a result, in both WSD and IPM, organized rural people have been able to more clearly and consistently articulate demands both for supportive research and policy. In the Philippines, it was only in a changed political environment in the post-Marcos era that regulatory changes responding to evidence from research were made; it was also only in that changed political space that advocacy for farmer education in IPM, through Farmer Field Schools, was effective (Loevinsohn and Rola, 1998). How to ensure consistent involvement of those poorly funded civil society actors, e.g. in signalling emerging hazards and threats (pest, diseases; unsuspected human and environmental toxicity), remains a challenge.

In low income countries in SSA, lack of civil society organization has implications for the demand side of innovation systems and ultimately their accountability to "users" and citizens. In this case, monitoring and evaluation (M&E), an essential element in any innovation system, becomes all the more important. In particular, M&E systems need to be answerable to all stakeholders, not just donors, and especially to the clients and co-creators of innovations as citizen-voters to whom public institutions are ultimately answerable. Haddad *et al* (2010) have drawn attention to the "sorry state" of M&E in agriculture as well as the potential to address food insecurity if it is improved.

In the long term, civil society actors, including organized farmers, play an important role in advocating for changes to policy and programmes. In the case of pest management in Southeast Asia, the evidence suggests that it was only through investing in local capacity that crises provoked by ill-prepared and unregulated use of chemical inputs and pest and disease resistant germplasm could be overcome. Efficient use of natural resources and non-toxic inputs was also enhanced through these approaches. Encouraging experimentation and farmer-to-farmer exchange has been central, though, as mentioned earlier, there remains unresolved contestation over the cost-effectiveness of these approaches.

WSD emerged in areas bypassed by the Green Revolution where a crop-centred approach, targeted to individual farmers was inappropriate, or of extremely limited applicability to a small minority of the wealthiest land users. WSD was an area-based approach that evolved into a community and area-based approach that (in contrast to technology-first GR approaches) addressed the structural constraints to enhanced production first. These were areas of substantial heterogeneity, both agro-ecologically and socially. Arguably this is a far better analogue for much of SSA than the favoured and more socially homogenous lowlands where GR rice technologies were taken up.

Future challenges concern wider regulation and governance structures. In the case of maize varietal diversity in SSA, advocating alternative frameworks for seed regulation based on principles of diversity rather than uniformity is a difficult task, particularly where civil society organization is limited. Today, trends are towards regulatory harmonization around international conventions that reflect a prioritization of trade over food security. Similarly, watershed development as currently practiced faces a policy obstacle. Existing legislation grants landowners unlimited access to the groundwater they can access, while electricity tariffs encourage pumping even as water tables drop. In these circumstances, developing community-based common property solutions is extremely difficult (Joy *et al*., 2006). NGOs and research organizations have separately and jointly advocated for changes to legislation but the political terrain is complicated.

4. Implications: Shaping innovation systems responsive to food insecurity and climate change

We draw a number of implications from the three cases. They are relevant to public policy, which plays a critical coordinating role even in opportunistic systems of innovation, but also to other actors and stakeholders in these systems.

Maintaining the essential continuity of focus on the well-being of those who depend on agriculture requires efforts by more than just the formal institutions of R&D and their ministries and governing bodies. Ensuring the consistent engagement of these public sector organizations demands political will which, in functioning democracies, can only be sustained by an aware citizenry, able to express it itself through autonomous organizations and prepared to call elected officials to account. A free and responsible press remains a critical source of information on the health of innovation. A striking example is the tireless investigation and reporting by P. Sainath over many years of the continuing farmer suicides in central India; his work has been essential to bringing the issue to public attention and keeping it there[3].

Farmer organizations and NGOs play important roles in innovation systems. Maintaining a consistent focus on the well-being of those dependent on agriculture is difficult when an organization controls limited parts of its budget and is reliant on donors whose priorities are liable to shift. A recent study of Indian NGOs that have remained influential over a considerable period found that one of the processes that enabled them to maintain focus was harnessing their values as compasses and “litmus tests” to guide everyday and more

[3] See for example a series of his articles from 2004 http://www.indiatogether.org/opinions/psainath/suiseries.htm

strategic decision-making. “Will this choice strengthen the institutions of the poor?” was one test applied by MYRADA; an important actor in the evolution of watershed development (Ho, 2007).

Financial resources are no doubt easier to come by in a rapidly growing, now middle income country like India than in a low income African country. But the pledge made by African governments to devote 10% of their budgets to agriculture and the fact that some have achieved that level[4] (among them Malawi, one of the poorest, but committed to its input subsidy scheme) indicate what is possible where political will is maintained.

Of course, more is required than money to sustain focus. The weakness of national R&D institutions may to an extent be mitigated by regional collaboration (Juma, 2010). One notable example is the Comprehensive Africa Agriculture Development Programme (CAADP) which supports a number of potentially significant efforts, among them the Cassava Transformation in Southern Africa (CATISA) project referred to earlier.

The case of maize in southern Africa described the obstacles to the development of even limited involvement of farmers in the process of maize breeding and selection. The evidence that, for example, in this and other crops, farmers can make good judgments about the likely performance in the field of breeding material has counted for little and led to few practical developments on any appreciable scale. This illustrates the continued strength of a supply-driven, orchestrated system of innovation in which actors’ roles are largely fixed. In this context, “participation” is restricted to allowing farmers to choose among largely finished cultivars or other technical options, few of which embody what they are really looking for. This is a formula for generating variety rather than diversity.

Similar dissonance can be seen in the response of formal R&D institutions to the wide discrepancy between research and recommendations on the one side and farmers’ practices on the other, with respect to management of the Green Revolution elements and again in the dominant response to the System of Rice Intensification. The risk is that actors find themselves in parallel systems of innovation between which there is limited communication. The practical consequence is that major national and international institutions are still not engaging with SRI and that important technical and social issues are not receiving the sustained research attention they merit. Opportunities to improve SRI’s benefits and to identify and curtail possible negative consequences, such as the displacement of landless labourers, are being missed. Dispassionate assessments of the agro-ecological contexts to which it is suited, or in which modifications are required, are still lacking. Fewer farmers are hearing about and getting a chance to try SRI than would be the case were these systems of innovation better integrated. The water savings and the enhanced resistance to extreme weather events that are claimed as benefits of SRI are of potential significance for

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[4] http://www.resakss.org

many farmers today. They will be all the more so as access to water becomes more problematic and climate more variable and uncertain.

It was suggested that in India a more facilitating environment was created around watershed development than in the other cases. Communication between different approaches and perspectives was enabled by, for instance, joint NGO-government implementation, training by NGOs of staff from other NGOs and government agencies and staff secondments. Evaluations assessed achievement on a broad range of criteria: social, environmental and economic. Governmental institutions drew on those evaluations to set and revise standards for implementation. Much remains to be achieved and the challenges are large but it is pertinent to ask: what was different in this case?

No definitive answer is possible but we suggest that failure had much to do with it. Green Revolution approaches and soil and water management prescriptions were widely acknowledged not to be working in the heterogeneous and drought-prone uplands. Not working meant that too many of the poorest and marginalized were being excluded or indeed harmed by these approaches. Different voices called attention to that exclusion, voices that carried some political weight, sometimes, in some places, those of the poor themselves. Importantly, the principal R&D institutions were national. The lack of accountability to farmers of some of the key, especially international, R&D institutions in the maize and rice cases has earlier been highlighted.

We suggest that it is an important role of researchers, journalists and others to call attention to the failures or impending failures of innovation and innovation systems. Access to diversity, to choices, is essential to agility in the face of change. The persistence of parallel innovation systems between which there is limited communication reduces the diversity that people can access and assess in terms both of alternative approaches and models and of material options. Unresolved contestation over fundamental issues such as the priority to be given to farmer education and autonomous farmer organizations leads to stasis and wasted opportunities. An important feature in the evolution of watershed development in India was the gradual recognition that functioning local institutions, including farmer and women's organizations, are critical to the achievement of social inclusion and land management approaches adapted to local conditions and opportunities. They are of even greater worth when, as is generally the case, environmental and economic changes threaten the livelihoods of the poorest disproportionately and local conditions mutate rapidly.

We emphasize again that persistence of focus does not entail unflinching promotion of particular options, whether specific crops or methods of farmer education. It is important that different approaches be tried and assessed. This need not require choosing one over others: complementary or hybrid approaches may facilitate greater reach and impact, for example interactive rural radio (Tripp, 2009) alongside a Farmer Field School programme.

Beyond highlighting the risk of failure, focusing attention on what is at stake may help induce needed evolution in systems of innovation. Here research can play an important role: describing the multiple functions played by agricultural systems, focusing on ones that are under threat from rapid change and neglect, clarifying the implications of loss and the potential to achieve multiple benefits from improved policy and management. This implies inter-disciplinary research, which often proves difficult to organize and fund. However, such research should be recognized as of strategic importance, deserving of investment by national and international donors. Its complexity should not be exaggerated, however; some of the underlying linkages are obvious to people at the grass roots level, such as the links between health and livelihood; it is at the level of formal institutional research, with its sectoral focus, that they have been obscured.

We have concentrated in this concluding section on some of the factors that may motivate evolution in agricultural innovation systems that would better equip them to assure food security in a context of accelerating climate change and variability. We do not mean to underestimate the forces that resist such evolution. These include the habits of R&D professionals, the incentive structures of their organizations and the interests of private companies, such as those involved in centralized breeding and seed supply. We recognize the importance of, for example, reform in the curriculum of professional schools and universities. We would also draw attention to the fact that interests have shifted as new opportunities have been revealed, for example in the area of micro-finance and micro-retail. Policy has an important role here in inducing and, where necessary, regulating innovation at this level.

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