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# Shaping Agricultural Innovation Systems Responsive to Food Insecurity and Climate Change

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**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. Its effects, while widespread, will be locally specific and socially differentiated, exacerbating existing vulnerabilities and uncertainties. In such situations, the innovations and adaptive strategies of communities living in conditions of rapid change can provide valuable lessons 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 presents three case studies of systems of innovation operating in contrasting socio-economic, geographical and agro-ecological contexts and facing different challenges. In Southeast Asian post-Green Revolution rice cultivation we trace innovations responding to 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. We review each case in terms of four features of innovation systems more likely to build, sustain and/or enhance food security in situations of rapid change and uncertainty: a) recognition of the multi-functional nature of agriculture and the opportunity to realize multiple benefits; (b) access to diversity as the basis for flexibility and resilience; (c) concern for enhancing the capacity of decision makers at all levels; and (d) perseverance and continuity of effort aimed at securing well-being for those who depend on agriculture and its outputs. Finally we draw implications of this analysis for policy makers and other stakeholders in agricultural innovation systems.

## 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 in the last fifty years. In its State of the Food Insecurity in the World Report (SOFI) of 2009, the Food and Agriculture Organisation (FAO) announced that the number of hungry people world had exceeded one billion (FAO 2009).

The food price surges of 2007/8, the worst since 1973, exposed both the complexity and fragility of globalised agri-food systems to multiple shocks and stresses; a situation now further complicated by an emerging market in biofuels, bringing new tradeoffs between land-use demands associated with food and energy (Borras et al. 2010). The FAO report attributed the food crisis, not to poor global harvests but to a global economic crisis which had disproportionately affected the ability of the poor to access food. The urban poor were highlighted as being particularly vulnerable to food price shocks, reflecting a global trend of accelerating urbanisation, particularly in lower and middle income countries (DESA 2005). Concerns continued into 2010, with fears of a resurgence of wheat price spikes[1] and the discovery - after a fifty-year absence - of new strains of wheat rust on farms in South Africa and India's Punjab State (Economist 2010). Towards the end of the year the FAO predicted food prices would rise in 2010 to 2008 levels, although with current reserves this is unlikely to lead to similar food shortages in 2011. The real concern, according to FAO lies beyond 2011, with plantings of staple food crops in 2011/12 likely to decline in the context of intensified competition for land and resource use from non-food agricultural commodities.

Climate change and variability presents new challenges for agriculture, in ways that will compound already existing uncertainties and volatilities. Of particular concern is the potential impact on smallholder farmers; who are the mainstay of food production in developing countries (FAO 2009), and therefore key to economic growth, although the latter point has been much debated (FAO, 2009; Ellis and Biggs 2001; Tiffin and Irz 2006; Pingali 2007; Juma 2010). What is clear is that productivity gains secured since the Green Revolution (Hazell 2009; Spielman and Pandya-Lorch 2009), while uneven and not without costs (Loevinsohn 1987; Glaeser 1987; Griffin 1979), have been eclipsed by a proliferation of new challenges in a rapidly changing world (Thornton et al. 2011; IPCC 2007; Yamin et al. 2005; Howden et al. 2008; Thompson et al. 2007). Thornton et al (2011:118) predict intensified pressures on global food systems driven by a combination of climate change, population growth, urbanization, income growth (stimulating greater demand for animal products) and the globalization of diets (see also Hawkes 2006). The effects, while widespread, will be experienced as locally specific and socially differentiated, since the consequences of climate change 'do not occur in a vacuum', but '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; Eakin and Wehbe 2009).

[1] http://www.future-agricultures.org/index.php?option=com_easyblog&view=entry&id=37&Itemid=527 (27 December 2010).

In this context, studying community-level adaptive strategies that build resilience to shocks and robustness to stresses in ongoing conditions of rapid change may be more instructive than interventions of formal interventions that attempt to re-establish stability (Scoones et al. 2007). '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' (Thornton et al. 2011:118). This paper draws lessons from selected country experiences of adaptation and innovation in pursuit of food security goals. However, as global temperatures rise towards 4$^{o}$c, incremental adaptations may not be sufficient, and communities may be forced into 'system flips', for example from mixed/rain-fed cropping to rangeland systems (Thornton et al. 2010; Jones and Thornton 2009). In this case 'farmers need support to switch strategies' (Thornton et al. 2011:128). The question then is what constitutes appropriate support, for ongoing adaptation as well as these cases of more radical transformation, and from whom, and what kind of institutional arrangements are needed to facilitate this? These are the questions that this paper attempts to address.

***An innovation systems approach***

This paper uses an 'innovation systems' approach to draw lessons from contrasting cases, presented in the next section, of people's responses in situations of rapid change. The term 'innovation' refers to 'any new knowledge introduced into and utilised in an economic or social process' (Spielman 2005:12). A broader than invention; innovation encompasses factors affecting the demand and use, as well as the creation of knowledge (World Bank 2006:15). The 'systems of innovation' approach emerged from historical analyses of innovation processes in industrialised economies; highlighting the particular and historically situated configurations of actors, institutions and policies that secured economic success in Japan and South Korea in the 1970s and 1980s (Freeman 1995; Edquist 1997). More recently, this approach has been recommended as a framework more suited to the analysis of agricultural innovation than conventional, linear models that privilege formal R&D as the source of innovation (Hall 2007; Hall 2005; Clark 2002). This reflects the particular nature of agricultural innovation as inherently site specific (Biggs and Clay 1981; Richards 1985) and agricultural innovation systems as constituted from multiple sources of innovation (Biggs 1990).

The agricultural innovation systems (AIS) approach is still relatively new and the subject of debate; in particular its application to the development of 'pro-poor' agricultural innovation systems in low and middle income countries (Berdegue 2005; Hall 2005; Hall 2007; World Bank 2006). It has been proposed as a successor the NARS (National Agricultural Research System) and AKIS (Agricultural Knowledge and Information System) frameworks as more reflective of the heterogeneity of actors and institutions that are part of the innovation process, particularly in an era of public-private partnerships (Hall 2007). Importantly, the AIS framework is not prescriptive about membership. Furthermore, its evolutionary nature reflects the reality that an AIS 'looks' different to different stakeholders, at different times. As Clark et al. (2003) reminds us, the innovation system framework is not a blueprint, but 'a set of analytical principles' that can be used by various stakeholders to map these complex, evolving systems and so make better-informed decisions about appropriate interventions and their likely effects on different parts of the system. An innovation systems perspective recognises the evolutionary nature of innovation through the cumulative effect of interactions between the agents on the supply and demand sides of the system. As such, innovation systems are path dependent and shaped as much by the existence of formal and informal institutions, supportive policies, stakeholder involvement and organised demand articulation as by formal R&D infrastructure (Hall 2005).

Hall (in World Bank 2006) has identified two types of trajectory though which innovation systems develop, depending on the context in which they evolve; which he calls the 'orchestrated trajectory' and the 'opportunity-driven trajectory'. The factor differentiating them concerns how 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. In this paper we use this terminology but in a different way. The critical distinction, we argue, is the extent to which the system is endogenous in origin, emerging in response to and interaction with a local context, or whether it has been designed and 'orchestrated' primarily by external actors (from whichever sector they come). An innovation system developing along an opportunity-driven trajectory is an open system more able to accommodate a multiplicity of actors, knowledge sources and institutional forms in the process of responding to a changing context. An innovation systems travelling along an orchestrated trajectory, on the other hand, is more closed, delineated by clear membership rules (which may be based on sector, discipline, institutional base etc.). While an opportunity-driven innovation system is not 'owned' by an organisation or programme, an orchestrated trajectory is more likely be perceived as such, usually by formal institution(s), and arranged in a hierarchical manner.

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 way innovation systems have evolved in the respective regions. Notably, the Sub Saharan African (SSA) context is characterised by a series of attempts to introduce orchestrated trajectories of innovation, in a top down fashion and driven by concerns in terms defined and expressed elsewhere. These can be categorised as either 'technical fixes' which address problems narrowly defined in terms of input constraints; 'market fixes' based on the Washington Consensus maxim of getting the State out and the prices right; or 'policy fixes' based on the latest policy blueprint; from the Green Revolution of the 1960s, integrated rural development programmes (IRDPs) of the 1970s, structural adjustment in the 1980s and 1990s to the millennium development goals (MDGs) in the 2000s (Scoones et al. 2005). This legacy of shifting donor 'paradigms' has occupied the spaces in which innovation systems more responsive to local, changing circumstances might have otherwise evolved. This has serious implications today, as households and communities across the region face unprecedented levels of change and uncertainty.

***Innovation systems for food security in situations of rapid change***

Our concern in this paper is with the nature of innovation systems that build or enhance food security in situations of rapid change. 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. Importantly, 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 of rapid change. 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.

a) **Recognition of the multi-functional nature of agriculture and the opportunity to realize multiple benefits**: 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 services. These include recycling and purifying inputs such as water, conserving local biodiversity, regulating disease and offering important cultural and amenity values. This **multifunctional** view of agriculture (IAASTD 2009; Hawkes and Ruel 2006) emphasizes the range of functions that agriculture performs and provides a framework for better valuing interventions and orienting policy across sector divides. Recognition of these multiple functions is of particular importance in the context of rapid environmental change because the connections that underpin them are often fragile. Indeed, it is often as a consequence of disruptions to agricultural systems and the livelihoods that derive from them that we become aware of these connections. Famines or sharp price rises which constrict nutrition, particularly of the most vulnerable, give rise to a range of effects – 'cascading bads' – among them on health, demography and criminality, effects that reach across sectors (an example of this is highlighted in Case 3: Maize-centred mixed farming in Sub Saharan Africa). Such situations can also provide insight into actions that can help remediate and preserve agriculture's multiple functions.

Alternative or competing policy choices and investments may be promoted where advancing one function is perceived to entail reducing another: a trade-off situation. For example, the intensification of arable agriculture may be seen to threaten farmland's role as habitat for valued wildlife. Subsidies may be offered to promote one or the other outcome. However, in many instances different functions can be advanced through a single intervention. Improving access to food through an action that extends crop production into the dry season by capturing water can yield important benefits in terms of maternal and child nutrition, reduced maternal mortality and enhanced child development (see Case Study 2). These **multiple benefits** are not automatic – food may not be equitably shared within the household, for example – but the agricultural innovation removes a critical constraint and makes the health outcome more likely. Multiple benefits (also referred to as co-benefits) are not restricted to agricultural and health interactions. They are receiving increasing attention in relation to climate change mitigation for example. Measures that store carbon in soils in the form of biochar may hold promise of enhancing fertility and water moisture while at the same time reducing greenhouse gases (a promise that has yet to be tested, it must be noted) (Lehmann and Joseph 2009; Leach et al. 2011).

b) **Access to diversity as the basis for flexibility and resilience:** Social, cultural, economic, technological diversity at all levels is particularly important in the context of climate uncertainty and market volatility. Diversity refers to more than mere variety; it is underpinned by responsiveness to the heterogeneity existing within a particular context (Stirling 2007, 2008). For example, an increased range of crop varieties accessed through similar commercial channels does not represent diversity in the way as a portfolio of cultivars maintained over time by farmers within diverse farming systems; each shaped by particular combinations of agro-ecological and socio-economic contexts and climactic and seasonal variations.

Institutional diversity is as important as technical diversity. The diversity of institutions within an innovation system - both governmental and non-governmental, representing different sectors (each of which have an interest in the multiple benefits that improvements in agriculture can bring) and at different scales (local, national, regional) is critical to the processes of learning that enable the systems to evolve in response to a changing context. For example, NGOs are often in a position to provide intensive support at a local level. While not scalable as such, such activities provide valuable lessons that can be shared with governmental institutions operating at the national level, through dialogue or collaboration. In this way, such institutional diversity can contribute to inter-institutional learning and improved practice. Similarly, the openness of an innovation system shaped by opportunity-driven trajectory creates more space for a multiplicity of stakeholder perspectives. Ultimately, access to 'useful diversity' implies more than the mere availability of a range of options. It requires mechanism through which people access, compare, weigh and judge alternative options. It is this diversity that provides the basis for choice and flexibility of response, and therefore resilience and robustness to shocks and stresses (Scoones et al. 2007). It is therefore closely connected to question of capacity.

c) **Concern for enhancing the capacity of decision makers at all levels:** The capacity to innovate is central to adaptation to climate change as it has been to adaptation to the changing circumstances that have always confronted farmers. It is this underlying, quintessentially local capacity that underlies the diversity of agricultural systems and their constituents – that predate 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 and makes free use of its outputs to the extent they are found useful (Winarto 2004). How to create constructive alliances between the two 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 growing variability increases the importance of that local capacity and the urgency of sustaining and allying with it (Cristopolos et al. 2009).

d) **Perseverance and continuity of effort aimed at securing well-being for those who depend on agriculture and its outputs**: The development of farming systems that can provide food security in heterogeneous and risk-prone environments is no simple task. It requires repeated cycles of innovation, trial and assessment in the context of practice. This demands sustained attention from all actors who support innovation at the farm level and further down commodity chains. That attention is all the more crucial in a situation of accelerating climate change and variability which is likely to see periodic disruptions that call for urgent adaptation. Creating and maintaining a policy environment that favours that continuity is critical. 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 programs and make possible corrections. To be clear: the sustained attention we refer to is not a dogged pursuit of particular technical options – a specific crop, for example – or to maintaining people perpetually in agriculture when they may see better prospects elsewhere but a commitment to a dynamic rural sector whose inhabitants may decide to migrate but will do so deliberately, rather than in distress. That kind of sustained attention is undermined when, as in too many cases where key institutions are weak, a succession of external "fixes" that derive from external analyses 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 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.

### 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 to 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 programs and often promoted by subsidized credit schemes. Farmers taking up these materials 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 appeared to be substantial, consistent and stable and involved materials some of which farmers had had only limited previous experience with. In Central Luzon, Philippines, less than 10 years after farmers had begun 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 extension. 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 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 substantially 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, hunt brown planthoppers and other insects. They saw both pests and predators dead on 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 other farming systems 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; 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 make out the kind of sustained political commitment that has characterized watershed development in India.
- Contentious issues have persisted without resolution. The most substantial 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 programs and the role that simple messages may sometimes play. The prospects for a more constructive and considered outcome are more likely where political commitment and research focus are more 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 program continues to be pursued in parallel with conventional extension approaches (Matteson 2000).

However this contestation evolves, enhanced farmer capacity and access to information, however achieved, hold out the prospect of developing 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 – 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. SRI thus represents a very different perspective of "intensification" than embodied in the Green Revolution introduced some three decades earlier.

SRI also differs in terms of the innovation system that shapes 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. Some Chinese and Indonesian research centres have also undertaken studies on SRI. Conspicuous by its absence from research on SRI is the International Rice Research Institute (IRRI), which had the lead role in the Green Revolution (Prasad 2009, Uphoff 2009). One sees here, as in the earlier situations described above, "parallel systems of innovation", between which there is limited and asymmetrical flows of information. We take up this point again below.

**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 have been largely bypassed 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 with 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 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 ran 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 had also 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 the landless rights 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).

These projects were extremely influential and inspired a range of efforts by both government and NGOs. While few were able to replicate the particular social innovations, 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" ().

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 programs 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 programs 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. In all projects, however, at least some of the landless reported that they had been harmed by the activities (Kerr et al. 2002).

In these well-conceived and executed programs, 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 been significantly reduced (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 committees, some with broad participation, that have been tasked with drawing up and revising guidelines for planning, implementation and evaluation (; ; GOI 2008). Taken as a whole, their thrust has been to enlarge the concern of watershed programs to resources from ridge to valley, including forest, pastures and livestock and to promote the broadening of social objectives described above.
- A series of evaluations of watershed development programs 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 to meet the standards required by the evolving guidelines (Hanumantha Rao 2000; Shah 2001a,b; Joy et al. 2006; Wani et al. 2008) .
- 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 NGOs implementing projects, trained personnel in line ministries, support agencies and district and local government and have seconded their own staff to these institutions. Some NGO leaders have contributed to the aforementioned committees and one sits on the Planning Commission.
- Watershed development programs 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 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) as well as 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 been increased and extended through the year, nutrition and access to drinking water have been 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 stakes for getting watershed development "right" and further ratchetting 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 downstream consumers in agriculture, industry and urban centres 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 ( ). Climate change and variability are also challenges to current natural resource management practices in watersheds. Excessive, poorly regulated groundwater extraction exacerbate these threats (Joy et al. 2006).

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 sketched above. Critical to that system are a consistent political commitment (some $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, review and standard setting that can propel improvement (Kerr 2002).

**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). Concerns about climate change impacts on African agriculture have reignited debates about the wisdom of overreliance on maize, however it is a phenomenon that has proved difficult to reverse for a complex of political, economic and cultural reasons. In much of Southern and East Africa today; 'maize is life' (Smale 1995).

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 innovation system in place had evolved in response to the needs of (white settler, then African) large scale commercial farmers, and not the smallholders that, in terms of acreage, 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 smallholder farms. These were based on recognition of the value of farmers' knowledge based on their adaptations to the complex, diverse and risk-prone environments that agro-ecologies in which they live (Chambers et al. 1989; Scoones and Thompson 1994). ***Participatory plant breeding (PPB)*** is one such example. 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 decentralised 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 often give a voice those normally excluded from crop research, particularly women and poorer farmers (Ceccarelli and Grando 2007) and may also foster intra crop specific biodiversity, though this is not always the case (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 institutional cultures (between CIAT and CIMMYT), 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 CIMMYT's Southern Africa Drought and Low Fertility programme (SADLF), operationalised what McCann et al. called a shift to a 'smallholder paradigm' (McCann et al. 2007). This 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 is that with PVS farmers are invited to evaluate already stabilised 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 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[2] 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).

More recently, concerns about the impact of climate change on agriculture, especially in Africa, and an injection of funds from a new donor, the Bill and Melinda Gates Foundation (BMGF), have created a momentum for scaling up efforts to breed drought tolerant maize varieties. Two large-scale maize improvement initiatives have been launched: a public sector, CIMMYT-led programme called Drought Tolerant Maize for Africa (DTMA) and an AATF-brokered public-private partnership called Water-Efficient Maize for Africa (WEMA). In the process, valuable lessons from PPB/PVS and the 'smallholder paradigm' appear to have been sidelined (Brooks et al. 2009). These programmes are based on a technology 'pipeline' model that leaves little scope for meaningful farmer participation (Ashby 2007). Furthermore, the aim is to generate hybrid varieties, not OPVs. These are to be made available, together with other commercial inputs such as inorganic fertilisers, through a growing network of private providers. This commercial model is reflected in UPOV 1991-derived seed regulatory systems in place or under development across the region, which reward varietal uniformity and discourage farmer-to-farmer seed exchange.

One notable example of a Green Revolution-style seed plus fertiliser package at the national level was Malawi in 2004/5 and 2008/9. While they built on earlier input subsidy schemes from the late 1990s, 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 of higher yielding hybrid seeds and inorganic fertilisers as a way to break the ''low equilibrium poverty cycle' of unproductive, subsistence maize cultivation (Dorward and Chirwa 2011; Levy 2005), it has also functioned as a longer term social protection mechanism which reduces the need for food aid, for example (Future Agricultures Consortium 2009). Despite opposition at the outset, the 'smart subsidy' is now regarded by donors as a legitimate agricultural policy instrument (Chinsinga 2007). Most importantly, it worked. Food security, at least in the short term, was achieved through a

[2] International Institute for Tropical Agriculture.

‘significant increase in national maize production and productivity’ and leading to ‘increased food availability, higher real wages, wider economic growth and poverty reduction’ (Dorward and Chirwa 2011:1). Questions remain, however about the longer term sustainability of subsidised inorganic fertiliser use, in economic and ecological terms. However the prospects of a transition to more sustainable but also more demanding integrated soil fertility management (ISFM) methods 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, as well as particular adaptation strategies that point the way to more lasting solutions based on ***crop and livelihood diversification*** rather than further ‘lock in’ to maize. 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). On the other hand, an analysis of distress migration patterns during the famine shows how people gravitated towards cassava growing areas, highlighting the role of cassava as a ‘classic famine crop’.

That people fall back on cassava in times of distress despite decades of policy discouraging its cultivation in favour of maize is telling. This strategy yielded multiple benefits, not least a greater resilience to HIV infection (Loevinsohn 2011:9). While not a panacea, cassava plays an important role as a counter-seasonal crop to bridge the hungry season. Furthermore it 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). More recently, researchers on the CATISA (cassava transformation in Southern Africa) project have highlighted the potential of cassava as a buffer crop that could be incorporated into *regional* food security planning. Furthermore, cassava can provide the basis for further diversification through value addition, Together, these alternatives have potential to provide more genuine diversity (across crops, livelihood options and seasons) than further investment in maize (Haggblade et al. 2009).

Attempts to convince farmers to diversify out of maize face many obstacles. For example, in areas of Eastern Kenya covered by the World Bank funded Arid Lands Resource Management Project (ARLMP), farmers participating in an innovative seed multiplication initiative targeting traditional dryland crops such as sorghum, millet and green gram only did so on the condition that the initiative was extended to maize. Meanwhile, new urban-rural linkages are emerging in which people with salary or remittance income are able to invest in new agricultural pathways such as horticulture, notably fruit tree cultivation (Brooks et al. 2009). Taken together; these experiences point to the limitations of projects attempting to ‘push’ people towards diversification, as opposed to build on people’s own adaption strategies. However, the innovation system underpinning these various interventions is limited in its responsiveness to local innovation, for the following reasons:

- These are examples of attempts by external actors to ‘orchestrate’ innovation systems rather than allowing them to evolve. The example of maize shows the persistence of a top down, technology ‘pipeline’ model driven by a series of ‘paradigms’ emanating from international donors and other external actors. Even attempts to promote diversity (more choice of maize varieties, more diversified cropping) are constrained by a lack of lack of context-responsiveness upon which genuine diversity is depends.

- A key problem is a lack of organised, articulated demand (Wiggins 2005; Jones 2005). The predominant conception of the agricultural innovation system is one that is supply-led, making it easy to fall back on a top-down *modus operandi*, in ways that highlight an enduring accountability deficit built into the design of institutions such as the CGIAR. Thus far, farmers' organisations and other intermediaries have played a limited role but this may be changing. PPB/PVS 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 and organised farmer demand (Southeast Asia Regional Initiatives for Community Empowerment 2007; Sahai et al. 2005), in SSA the ‘voices’ in favour of alternatives such as PPB are as much from external sources international scientists and donors), as conventional breeding programmes; while civil society mobilisation around this issue remains limited. However, as in the case of formal rice research and SRI (see Case Study 1), these remain parallel systems of innovation between which there is limited learning and exchange.

- As a result the examples presented here indicate externally-driven adherence to narrow pathways and recycled paradigms rather than genuine perseverance, though evolutionary learning embedded in local institutions. As Ashby (2007) points out, participatory approaches demand more, not less, from formal systems, particularly where it requires a transformation of hierarchical relations between international, national and local systems as is the case in public agricultural research. Contestation does occur, but largely among external actors, rather than emerging from locally accountable organisations cognisant of local innovation capabilities, constraints and possibilities. Meanwhile under-resourced national systems are diverted from local needs and priorities by international collaborative programmes that offer much needed resources (Sumberg 2005). The growth of public-private partnerships is likely to narrow research agendas further, with technology pathways ‘increasingly … fashioned by elite science, corporate funding and interests, resulting in a lack of involvement with wider stakeholders’ (Scoones 2005: 113).

## 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 characterised 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.

a) **Recognition of the multi-functional nature of agriculture and the opportunity to realize multiple benefits**:

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 (GR) 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, 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: human health impacts 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) have 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, 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. Important multiple benefits from effective, equitable 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 programs. 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 SSA, 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 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.

b) **Access to diversity as the basis for flexibility and resilience:**

Each case highlights different dimensions of diversity. The case of pest management in Southeast Asia highlighted the transition from the Green Revolution to IPM 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 participating in a system characterised by multiple sources of innovation (cf. Biggs 1990) including intensive farmer-led experimentation. IPM brings together a range of options (in which pesticide use is just one option; and the option of last resort) which has its roots in these processes of experimentation and learning that evolved, at least initially, from the challenges presented by unintended effects of the Green Revolution package. Similarly, WSD in India is also a story of multiple sources of innovation, at multiple levels, evolving over time from an initial, technical problem definition to a multidimensional socio-technical change process.

Watershed areas are characterised 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 reflected this heterogeneity, creating a space or 'enabling environment' (World Bank 2006) for a range of social, institutional and technical innovations. A key feature of this 'opportunity-driven' trajectory has been, not only the participation of heterogeneous institutions, operating at different scales, but the interactions between them leading to highly productive cross-fertilisation 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 overall. 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 emergent in 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 points to the potential for cassava as a regional buffer crop to 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.

In the case of maize breeding, participatory plant breeding remains a relatively marginal activity within research programmes in which the CGIAR plays a major role (Ashby 2007). 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 transform breeding programmes towards a more decentralised approaches which would make it possible to these parallel systems to interact in a productive way (cf. Sperling et al. 2001; McGuire 2008)?

### c) Concern for enhancing the capacity of decision makers at all levels:

The cases here highlight the importance of investing in the capacity to manage. Management cannot be wrapped in the seed or left as an add-on to already "finished" technologies (cf. Douthwaite et al. 2001) although large-scale, GR-style breeding initiatives now underway 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 SE Asia and other regions. Where watershed development approaches have succeeded is in enabling farm households and communities to better secure livelihood and access to food, taking on board local understandings of constraints and opportunities has been key. 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 though cross-fertilisation 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 some agreement that the quality of learning in large programs is often poor though less agreement on what conclusions should be drawn. Thus far, the approach has yet to become established at the national level remains dependent on individual researchers and ‘champions’.

Experience to date with participatory approaches to plant breeding and varietal selection show 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. In this context, initiatives that focus on varietal selection criteria and emphasise building the 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 practice to emerge (cf. Brooks 2010).

d) **Perseverance and continuity of effort aimed at securing well-being for those who depend on agriculture and its outputs**:

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 organisation, 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; as well, it was 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 organisation 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 programs. 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. 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 some agreement that the quality of learning in large programs is often poor, though less agreement on what conclusions should be drawn.

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 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 harmonisation 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 analysis of the three cases. They are relevant not just to public policy and policy makers but also to other actors and stakeholders in agricultural innovation 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 governing bodies. Ensuring the consistent engagement of these public sector organizations demands political will which, in functioning democracies, can only 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 key 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 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, "pipeline" model of innovation and of an

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

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

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 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 ***parallel systems of innovation*** are perpetuated between which there is limited communication. The wheel is still in spin with respect to SRI and more positive responses are emerging for example in India, China and Indonesia. But the delay and the continued failure of major national and international institutions to engage with SRI mean that important technical and social issues are not receiving the sustained research attention they merit. Opportunities to improve on SRI's benefits and curtail negative consequences are being missed. Dispassionate assessments the agro-ecological contexts to which it is suited or in which modifications are required are still lacking. The water savings and the enhanced resistance to extreme weather events that are claimed for SRI are of potential significance for many farmers today. They will be all the more so as and where water scarcity grows and climate becomes increasingly variable and uncertain.

It was suggested that in India a more facilitating environment was created around watershed development. 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. Guidelines set and revised 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 for 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 reduces the diversity 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 needn't require choosing one over the others: complementary or hybrid approaches may facilitate greater reach and impact, for example interactive rural radio (Tripp 2009) alongside a Farmer Field School program.

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 is inter-disciplinary research which often proves difficult to organize and fund. However, it should be recognized as strategic, deserving of investment by national and international donors. Its complexity should not be exaggerated: some of the underlying linkages are obvious to people at the grass roots such as those between health and livelihood; it is at the level of 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 mind of R&D professionals, the incentive structures of their organizations and the interests of companies, such as those involved in centralized breeding and seed supply. We acknowledge 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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