Title: Building resilience into marginal agroecosystems – a global priority for socio-ecological sustainability

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ABSTRACT

A number of important risks are emerging for global agricultural ecosystems and in direct association, global socio-ecological systems. Some of these risks are associated with environmental change including climate change and ongoing resource degradation; others are associated with impacts of underdevelopment including social inequality and rural poverty; yet others are being compounded by the process of globalisation, including enhanced market and labour risks, rising input prices, agricultural homogenisation and the spread of invasive species. Of particular concern in the immediate future is that as nations' food supplies have become increasingly interdependent, the inequalities of access to food, both between rich and poor nations and within developing societies, have also increased rapidly. The author draws from transdisciplinary agro-ecological research undertaken in Europe, Asia and Australia to argue that it is the margins that contain many of the most vulnerable communities on Earth and it is marginal socio-ecological systems that must become an immediate focus for building resilience. Where a singular modernisation paradigm could be seen to be failing to overcome malnutrition and poverty for many within those margins, an alternative, complementary human ecology development approach must be advocated and supported that incorporates the local diversity of ecosystems and the complexity of anthropogenic values and activities. Such alternative systems would not be dominated by aims of higher short-term productivity, but by goals of resilience, diversity, flexibility, risk-avoidance and longevity. Without a mainstreaming of complex local alternatives, the failures and limitations of dominant global systems in an emerging era of risk will continue to act to undermine any attempts at building a broader resilience into global society.

INTRODUCTION

Global agricultural development has moved rapidly into a new era over the last decade, with a fundamental shift in the relationship between socio-ecological risk and global food production. Simultaneously, the globalisation of society is generating a broader awareness of the human ecological imperative. Of immediate concern is that as nations' food supplies become interdependent, inequalities of access to food, both between rich and poor nations and within developing societies, are increasing rapidly. A range of emerging global risks are associated with environmental change including climate risk and ongoing resource degradation; others are associated with impacts of social inequality; yet others are being compounded by the process of globalisation, including enhanced market and labour risks, agricultural homogenisation, the spread of invasive species and rising input prices, particularly associated with the growing importance of bioenergy production. The focus of the risk analysis for this paper is on the emerging risk of climate change for agroecosystems.

There is a significant body of literature describing changes to climate due to anthropogenic forcing, and considerable research into the likely impacts of that change on social and ecological systems (Pittock, 2003; Brooks et al., 2005; IPCC, 2007). The level of risk associated with climate change is such that there is a need for societies to transform their socio-ecological processes to ensure the sustainability of food production systems (Orr, 2002; Adger, 2003; Adger et al., 2005; Kok and de Coninck, 2007). In fact, new levels of resilience will be required in all systems that tie humanity with the environment (Cohen, 1997; de Haen et al., 1998; Olesen and Bindi, 2002; Preston and Jones, 2006; Homer-Dixon, 2007). Informed local managers, aware of the importance of climate change and grounded in the local cultural interpretations of place and environment, can be the most effective managers

ecological risk (Pelling and High, 2005; Bardsley and Edwards-Jones, 2007). It is the margins that contain many of the most vulnerable communities on Earth and it is the sustainability of marginal socio-ecological systems that must become an immediate focus for an alternative agroecological paradigm in an emerging era of risk.

Looking at the example of southern Australian agriculture, it is clear that the sector is already coming under severe stress due to significant increases in climatic variation and future projections of a warming, drying trend will limit opportunities for sustainable management of dryland and irrigated agroecosystems (Pittock, 2003; Bardsley, 2006a). The governance responses that have been put in place are focussing on threat abatement, rather than reforming systems to adapt to future climate. For example, southern Australia has seen an extended drought across much of the settled areas over the last decade. Many irrigators on river systems in the Murray-Darling Basin have had little or no water allocations in early 2008, which for many producers was a completely new level of climate-related risk. On the other hand, Australian agriculture has proved itself to be highly adaptive if people own risk and respond based on good information, from short term responses to seasonal projections, to longer term responses to global market drivers. For example, even as southern Western Australia has experienced a drying trend since the 1970s, average productivity and profitability for annual crop production has increased (Turner, 2004). Exceptional circumstances assistance packages are available from the Australian Commonwealth Government to address severe and sustained drought responds to “rare events”: those that occur on average once every 20-25 years and are not considered part of normal risk management (Drought Review Panel, 2004). However, there are now substantial questions as to whether current rainfall averages will remain valid in a changing climate, and whether drought relief via direct economic assistance acts to support practices that are unsustainable in

the long-term (Heathcote, 2002). Increasingly, adaptation policy needs to support rural communities to understand, respond to and manage risk by formally recognising the multifunctional roles of sustainable agro-ecological management to a society at risk (Bardsley, 2003; Botterill and Fisher, 2003; Hatfield-Dodds et al., 2007).

An examination of the types of adaptation and resilience-building responses for agroecosystems outlined above and elsewhere (see for example Anderson, 2003), suggest that that there is a wide range of technical, organisational, and economic management options to support farmers and their production systems in industrialised countries. Yet, adaptation options such as the implementation of complex governance arrangements, state assistance programs or the broader application of agricultural biotechnologies are almost wholly inappropriate or inapplicable in the context of most marginal agroecosystems in developing countries. For example, increases in food and transportation prices in Australia may be absorbed by most consumers, with comparatively little impact on the majority living in urban centres. In contrast, increases in food and fuel prices in developing countries in 2007 have led to cases of food riots and increasing impacts of malnutrition (Ridgeway, 2007). Moreover, marginal agricultural producers will be less likely to have the resources to cope with climate change risk (Smit and Skinner, 2002; Parks and Roberts, 2006).

Where a singular agricultural modernisation paradigm could be seen to be failing to overcome malnutrition and poverty for many within the rural margins, an alternative, complementary human ecology development approach must be advocated and supported that incorporates the local diversity of ecosystems and the complexity of anthropogenic values and activities (Bardsley, 2003). Where possible, communities on the margins must be supported to build and maintain their own internally resilient food production systems. Such alternative systems

would not be dominated by aims of higher short-term productivity, but by goals of resilience, diversity, flexibility, risk-avoidance and longevity. The resources available to marginal rural communities in the form of local biological, cultural and social diversity also need to be re-evaluated from a global perspective, in light of the increase levels of risk within global society. Without a mainstreaming of complex local alternatives, the failures and limitations of dominant global systems in an emerging era of risk will continue to act to undermine any attempts at building a broader resilience into global society.

POLICY TO CONSERVE AGROBIODIVERSITY ON THE RURAL MARGINS

A broad-based international program of in situ agrobiodiversity conservation would form a vital part of an effective response to the risks emerging from the global homogenisation of socio-ecological practices. Partly in response to emerging concerns with ongoing losses of agrobiodiversity, on-farm conservation is moving beyond conservation reserves and genebanks and is becoming a vital aspect of sustainable development (FAO, 2006). Emerging roles for in situ, on-farm agrobiodiversity conservation act to alleviate risk and provide opportunities for improving the socio-ecosystems sustainability (Table 1).

Table 1 Roles for on-farm, in situ agrobiodiversity conservation (from Bardsley and Thomas, 2006)

1	The preservation of genetic material separate from genebanks
2	The dynamic conservation of evolving genetic material
3	The dynamic conservation of associated biodiversity, agroecosystems and landscapes
4	The support of associated traditional cultures and human processes
5	Retention of diversity in fields for community-level risk reduction
6	Retention of extant alternative agroecosystems to alleviate societal risk
7	Compensation to farmers for intellectual property and existing conservation activities
8	Sustainable development of marginal agricultural regions

Academic discussions of the roles of on-farm agrobiodiversity often focus on either the importance of genetic conservation, the commercial economic value of agrobiodiversity, or the socio-cultural roles of agrodiversity to support rural livelihoods (Hammer et al., 2003; Connell and Waddell, 2006; Pascual and Perrings, 2007). There is a perceived conflict between those that advocate the importance of on-farm agrobiodiversity for socio-ecological resileince, and those who wish to present such a stance as an attack on the importance of agricultural modernisation (Bardsley, 2006b; Wood and Lenné, 2006). These juxtaposed debates continue to undermine attempts to recognise the complexity of particular local scenarios and cloud strong arguments for the development of policies which explicitly recognise the increasing importance of agrobiodiversity to support socio-ecological resilience.

While it remains contentious to advocate for the retention of local agrobiodiversity in those cases where value can be attributed to the local community above and beyond that achieved from modernising local systems, there are real-world examples emerging of explicit re-evaluations of the value of diversity to alleviate risk (Shand, 1997; Brush, 2000; Trinh et al., 2003; Zimmerer, 2003; Aksoy, 2005; Bardsley and Thomas, 2006). Most policies that governments have developed to conserve agrobiodiversity in-situ are explicit about specific outcomes for genetic conservation. However, the implicit outcomes for on-farm diversity conservation to enhance the resilience of extant socio-ecological systems are also of increasing importance. The discussion below critiques approaches to support farming communities in three countries at different stages of development: Nepal, Turkey and Switzerland. In these societies, policies and practices are being developed that support agrobiodiversity conservation in mountain communities through a range of direct and indirect mechanisms. The focus of the analysis is on the conservation of cereal landraces (see Thrupp, 2000) and the role of such agrobiodiversity for reducing socio-ecological risk (Table 2).

Table 2 Opportunities for mitigating and adapting to agro-ecological risk provided by agrobiodiversity

1	Heterogeneity of the crop variety
2	Genetic conservation allowing for crop development over time
3	Mixtures of varieties and species within and between crops
4	Difference between crops on a farm and across agro-ecological niches
5	Diversity of crops and farming practices across a landscape, region or country
6	Retention of some crops less dependent on external inputs
7	"Diversity" products for niche markets
8	Non-productivist, government, NGO & private support for on-farm conservation as an alternative income stream

There is a range of available approaches to support on-farm agrobiodiversity conservation and these approaches are more or less applicable in different societal contexts. Research, which involved the in-depth interviewing with key stakeholders (for detail see Bardsley and Thomas, 2006), suggests that the less-developed countries will rely more heavily on less formal conservation approaches than industrialised nations (Table 3). The discussion below expands on the rationale behind this categorisation of approaches for different societal contexts.

Table 3 Stakeholder support for on farm agrobiodiversity conservation approaches in Nepal, Turkey and Switzerland (adapted from Bardsley and Thomas, 2006)

*** more appropriate approach; ** appropriate approach; * less appropriate approach.

Approach	**Level of support for approach**		
	Nepal	**Turkey**	**Switzerland**
De facto conservation	***	***	*
State assistance	*	*	***
Marketing	**	**	***
Scientific	***	**	***
Reserves	**	**	*
Community	**	*	***
Awareness raising	***	***	**

De facto conservation approaches

As the dominant modern agricultural development approach has entered a region it has generally led to a streamlining of agroecological activities to provide products for the market using universally recognised production systems. In the Swiss case, initial agricultural reforms came largely from within the country in the late Nineteenth Century, and development, and associated genetic erosion, was experienced initially on the plains, rather than in the mountains where yield potential was not as great and the new high-yielding varieties were not adapted to extreme local conditions (Ingold, 1998). Those farmers who were unable to access the new varieties or other modern inputs, due to lack of capital or transport difficulties, had to continue to rely upon their local diversity to maintain productive systems. The modernisation of agriculture since World War 2 has also been concentrated in the core regions of Turkey and Nepal, and the peripheries of those countries, largely associated with more mountainous regions, remain dependent on a limited array of modern technologies and the retention of largely traditional systems (Aydin, 1993; NARC, 1997; Aksoy, 2005). While industrialised countries are able to reform their marginal regions and developing countries modernise areas of high productivity potential, a third level remains in the most marginal rural areas: a state of ongoing under-development and high socio-ecological risk.

Many farmers do not have access to high-yielding crop varieties; others make choices between high-yielding varieties and landraces based on their need to integrate varieties into alternative agronomic practices that they are unable or unwilling to modernize. Often, however, de facto conservation is reliant upon the farmers' retention of traditional value systems, because people's daily activities, worldviews and self-images are often intricately linked to agroecosystems (Shand, 1997; Brush, 2000). Rice varieties and their production

systems provide the seminal cultural influences in Nepal (Bardsley and Thomas, 2005a). In Northeast Turkey, the landrace Kirik is used to make the local high-quality unleavened lavash bread; the tall straw and the absence of awns that make it a valuable livestock feed; and the seed that is sown in either the Autumn or the Spring to assist management in relation to extreme Winter conditions (Bardsley and Thomas, 2005b). While the de facto approach may not be sustainable by itself over the long-term, there is a wealth of opportunity to utilize local ideas and perceptions within formal approaches to in situ conservation.

Where modernisation has substantially altered agroecosystems, as in Switzerland, there is virtually no continuous ongoing de facto conservation of landraces (Bardsley and Thomas, 2004). Only a few farmers in the mountainous cantons Wallis and Graubünden are conserving local landraces out of a sense of the worth of their heritage and a pride in such work. Thus, cultural aspects of agrobiodiversity value may not be steeped in historical tradition, but may rather be linked to modern philosophies of the existence, recreational or aesthetic values of socio-ecological diversity. Such local cultural attributions of value can not only impact the price that a person is willing to pay for a "diversity" product, but also whether a farmer will produce a landrace for self-consumption. Diversity farmers are able to buffer their production levels and income, by cultivating a range of crops and exploiting differences in their agroecosystems (Table 2).

State assistance approaches

There have been substantial direct and indirect costs to societies from the extinction of local agrobiodiversity (Pascual and Perrings, 2007). For example, the loss of genetic diversity undermines opportunities for current and future generations to produce varieties adapted to changing environmental conditions. Yet the process of genetic erosion largely remains an

economic externality to agricultural systems, and governments can exacerbate this market failure by providing incentives to modernise that disregard the value of local diversity. In response, the State compensates diversity farmers for any losses in profitability or productivity associated with conservation activities. Methods of assistance for Swiss farmers, for example, are increasingly linked to the ecological, cultural and welfare concerns of the Swiss public (BLW, 1999). In this manner, the national government is avoiding trade restrictions associated with supporting agriculture through price support and import restrictions, by effectively employing farmers as stewards of agro-ecological, aesthetic and cultural heritage (Josling and Tangermann, 1999; Bardsley and Thomas, 2004). To obtain the environmental direct payments, farming systems must change from conventional production systems to use integrated production techniques, including such practices as applying less agrochemicals, developing extensive crop rotations and pastures, and retaining valuable natural and agroecological habitats. The payments rely upon the Swiss people continuing to support the multifunctional aspects of agriculture, linked to landscape management, cultural identity and social welfare, which they see as valuable beyond the possibilities for production. International aid mechanisms could guide a similar evolution of diversity conservation initiatives in developing countries (Frisvold and Condon, 1998).

In recognition of farmers' rights to access vital germplasm, initially the FAO in 1989 and later the Convention on Biological Diversity and the Leipzig Declaration, called for nations to compensate those communities who were the source of the genetic resource (UNEP, 1992; FAO, 1996; Swanson, 1997). The identification and recognition of intellectual property rights for agrobiodiversity has become an essential task for government (Gunnigham and Young, 1997). This can be very difficult in developing societies where the capacity to undertake conservation programs is still weak and relationships with developed nations are

not equal (Belbase, 1999). To attempt to overcome this problem, *sui generis* (free standing or "unique") systems can be applied, which provide opportunities for the holders of biodiversity to apply their own definitions of intellectual ownership within a locally recognised framework (Lesser, 2000; Chiarolla, 2006). By formalising links with traditional agricultural resources and practices, in situ conservation provides mechanisms to define ownership rights and direct compensation to diversity farmers for their dynamic genetic conservation activities.

Marketing approaches

As globalisation leads to greater homogeneity between and within societies, the "difference" that remains within the agricultural margins is likely to become a resource in itself. Cultural values of local agrobiodiversity are eroding in many societies as dominant food cultures and agricultural production systems infiltrate or replace traditional values and activities. Where traditional food cultures can be advocated, great opportunities exist to link agrobiodiversity conservation to local, tourist and international marketing of diversity products in Nepal and Turkey (UNEP, 1992; Friedmann, 1998; Bardsley and Thomas, 2005a,b). Switzerland's highly developed market structures facilitated private investment into regional, organic and biodynamic production systems associated with agrobiodiversity conservation (Bardsley and Thomas, 2004). As Swiss mountain farmers struggle to compete internationally due to high production costs, the marketing of specialty products could be the greatest chance for them to be competitive in the Euroepan and global markets (Willer and Ingold, 1996). The market does not need to be very large to support the small number of farmers in the inner Alpine zone. The Swiss supermarket chain COOP has teamed up with the NGO, Pro Specie Rara to market vegetable crops, breads and beers produced from old varieties of grain. Diversity farmers often have a proximate market of people willing to pay a premium price for goods that are produced in an ecologically benign manner, support animal welfare, support mountain

development and have a minimal chance of containing toxic chemicals, diseases or genetically modified organisms.

Scientific approaches

Scientific initiatives include the monitoring and assessment of current and changing levels of agrobiodiversity in farmers' fields. Such information is currently lacking in Nepal and Turkey, but is vital for any in situ approach that attempts to formalize the de facto conservation process. Modern crop breeders have played a major role in the erosion of agrobiodiversity through the Green Revolution. Therefore, for the effective in situ conservation of landraces, it is no longer tenable that modern breeding programs fail to recognize and respond to the social and ecological implications of their activities. By way of contrast, participatory plant breeding, can involve farmers in the breeding process by focussing on local needs and local germplasm in the development process (Ceccarelli et al., 1995; FAO, 1996; Joshi and Witcombe, 1998; Sthapit, 1998). The approach is being applied in Nepal and offers significant technical opportunities for linking the development of local resources and knowledge in a manner that empowers local people. Like increasing numbers of crop-breeding programs around the world, some alternative Swiss breeding programs are being developed by NGOs, such as Getreidezüchtung and Genossenschaft Gran Alpin. These programs aim to provide varieties that satisfy farmers' needs to match the complexity of local agroecosystems, while maximising the use of local germplasm.

Reserve approaches

An in situ agrobiodiversity conservation approach that excludes local populations is guaranteed to fail because the target diversity is created, managed and owned by the people themselves. Reserves requiring less extreme levels of preservation could provide niches in

the agricultural and conservation landscapes for both the retention of diversity and unique forms of development. For example, in Nepal, the Annapurna Conservation Area Project has revolutionised the approach to conservation by focusing on the requirements of the local population (Bajrachrya and Thapa, 1999; Gurung, 1999). The concept behind the Annapurna Project integrates many of the concepts of Biosphere reserves by re-classifying land tenure and providing alternatives to the exploitation of local resources for long-term sustainability. Turkey has relied largely upon the wealth of land available to construct reserves that limit agricultural activities within areas of high, endemic diversity (Karagöz, 1998; Tan, 1998). The Global Environment Facility sponsored the establishment of Gene Management Zones, which are areas set-aside from production practices to manage in situ the conservation of wild crop relatives. Where the government already had substantial influence over the methods of land management, such as within State Parks, the Gene Management Zones are working effectively.

Switzerland has attempted to conserve agrobiodiversity in reserves (Bardsley and Thomas, 2004). The Sortengarten (variety garden) in the canton Wallis is examining and providing to farmers local crop landraces from the Swiss genebank. Where small areas could be set-aside to concentrate on the channelling of materials between genebanks and farming communities, the activities of local farmers are not substantially hindered. During the successful establishment of Entlebuch Biosphere reserve, the management obtained support from the local farming community and subsequently, has assisted farmers with marketing initiatives linked to the Biosphere brand. Where the formal conservation role of farming communities can be recognised spatially, non-productivist values of agrodiversity are effectively compensated.

Community approaches

Community conservation initiatives are guided both by the supporters of biodiversity conservation and by those people who recognize the availability of regional development opportunities linked to the support of local diversity. Local NGOs have been able to facilitate the cooperation of like-minded people who assist each other to develop new markets for agrobiodiversity, lobby governments, share materials and to maintain alternative agricultural systems. In Nepal, cooperatives could be strongly linked to the particular community in which landraces are grown to generate sufficient local capacity to produce and market their diversity product externally. There are attempts to utilize the village structure to stimulate cooperation on this and other conservation and marketing issues. Swiss producer cooperatives such as Genossenschaft Gran Alpin, which is a marketing cooperative of cereal farmers in canton Graubünden, are becoming more popular in the mountain areas to improve the organisation of the alternative systems. By coordinating activities through production or marketing cooperatives economic efficiencies can be created from a group of small-scale diversity farmers, reducing production and processing costs and improving marketing opportunities.

Awareness raising approaches

For all in situ conservation processes to be successful, it is an essential step that stakeholders and the public become aware of the range of values of agrobiodiversity. Activities such as roadside dramas in Nepal, where troupes visit villages to perform plays that re-enforce the agronomic and cultural values of local biological resources, are useful methods for reaching farming communities in the margins. In the short-term, the erosion of local cultural values presents a substantial threat to the production and marketing, and consequently, the conservation of local diversity. Turkey's greatest opportunities for raising awareness of the

importance of local agrobiodiversity are linked to the need to recognize that other models for development alternative to the dominant process of modernisation are available. Once there is such a change in perception, the traditions associated with local food cultures and agricultural activities need not be discounted during the period of societal change. In comparison, the awareness of agro-ecological issues is high amongst the general public in Switzerland relative to the other nations studied. In many cases, where Swiss state assistance programs aim at assuring ecological sustainability, and consumers are aware of the value of production in and from the mountain valleys, diversity offers the marginal agricultural systems a vital niche in an increasingly liberalised economy. The growing awareness amongst governors and scientists can lead to the removal of disincentives to appreciate diversity and provide the policy impetus to support farmers to move away from a productivist paradigm to consolidate resilient agroecosystems in the margins.

Conclusion

As globalisation of markets, companies and agricultural inputs increasingly makes those agroecosystems interdependent, levels of internal resilience within socio-ecological systems become even more important. In particular, the challenges for effective climate change adaptation are significant, not least because the impacts will not strike evenly and the sensitivity to those impacts will vary considerably spatially, temporally and between social groups. There is a significant risk that societies will lurch from one crisis to another as they chase the apparent trends and projected changes, rather than implementing the significant transformation required for our socio-ecological systems to significantly enhance their resilience and flexibility to respond to change. While the core of wealthy societies is most likely to have the economic capacities to adapt, the marginalised must be supported to retain

and develop their local socio-ecological resources. The uncertainty of future agroecological conditions suggests a meta-adaptation role for the key resources of agrobiodiversity. In situ conservation has the potential to internalise socio-ecological costs of production into the market price and create awareness amongst the general public of the value of biodiversity. More importantly perhaps, the process of conservation could empower farmers to recognize that local diversity provides them with opportunities that can surpass the benefits available to them within a productivist agricultural development paradigm. Once the values of diversity in agroecosystems are better recognised, levels of diversity promise to become an important indicator of resilience for the rural margins. Without policy to develop complex local alternatives, the failures and limitations of the dominant global system will continue to act to undermine attempts at building a broader resilience into societies during an era of risk.

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