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The adaptation and mitigation potential of traditional agriculture in a changing climate

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Abstract The threat of global climate change has caused concern among scientists because crop production could be severely affected by changes in key climatic variables that could compromise food security both globally and locally. Although it is true that extreme climatic events can severely impact small farmers, available data is just a gross approximation at understanding the heterogeneity of small scale agriculture ignoring the myriad of strategies that thousands of traditional farmers have used and still use to deal with climatic variability. Scientists have now realized that many small farmers cope with and even prepare for climate change, minimizing crop failure through a series of agroecological practices. Observations of agricultural performance after extreme climatic events in the last two decades have revealed that resiliency to climate disasters is closely linked to the high level of on-farm biodiversity, a typical feature of traditional farming systems.

Based on this evidence, various experts have suggested that rescuing traditional management systems combined with the use of agroecologically based management strategies may represent the only viable and robust path to increase the productivity, sustainability and resilience of peasant-based agricultural production under predicted climate scenarios. In this paper we explore a number of ways in which three key traditional agroecological strategies (biodiversification, soil management and water harvesting) can be implemented in the design and management of agroecosystems allowing farmers to adopt a strategy that both increases resilience and provides economic benefits, including mitigation of global warming.

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1 Introduction

The threat of global climate change has caused concern among scientists as crop growth could be severely affected by changes in key climatic variables (i.e., rainfall and temperature) thus compromising agricultural production and food security both globally and locally. Although the effects of changes in climate on crop yields are likely to vary greatly from region to region, anticipated changes are expected to have large and far-reaching effects predominantly in the developing world. Hazards include increased flooding in lowland areas, greater frequency and severity of droughts in semiarid areas, and excessive heat conditions, all of which can limit crop growth and yields. Official statistics predict that poor farmers in developing countries will be especially vulnerable to these impacts of climate change because of their geographic exposure, low incomes, greater reliance on agriculture as well as limited capacity to seek alternative livelihoods (Rosenzweig and Hillel 2008). The majority of the world's rural poor, about 370 million of the poorest, live in areas that are resource-poor, highly heterogeneous and risk-prone. The worst poverty is often located in arid or semiarid zones, and in mountains and hills that are ecologically vulnerable (Altieri 2002). For these vulnerable groups, even minor changes in climate can have disastrous impacts on their lives and livelihoods. Implications can be very profound for subsistence farmers located in remote and fragile environments, where yield decreases are expected to be very large, as these farmers depend on potentially affected crops e.g., maize, beans, potatoes, rice, etc.) for their food security.

Jones and Thornton (2003) predict an overall reduction of 10 % in maize production by the year 2055 in Africa and Latin America, equivalent to losses of \$2 billion per year, affecting principally 40 million poor livestock keepers in mixed systems of Latin America and 130 million in sub-Saharan Africa. The authors argue that these yield losses will intensify as temperatures increase and rainfall differences are less conducive to maize production. Some researchers predict that as climate change reduces crop yields, the effects on the welfare of subsistence farming families may be quite severe, especially if the subsistence component of productivity is reduced (Rosenzweig and Hillel 2008).

Although it is true that extreme climatic events can severely impact small farmers, the statistics are exaggerated and utilized by biotechnology proponents to push "climate smart genes" (drought or flood resistant transgenic crops) as the only viable option for small farmers to adapt to climate change (Tester and Langridge 2010). Available data is just a gross approximation at understanding the heterogeneity of small scale agriculture, ignoring the myriad of strategies that thousands of small farmers have used and still use to deal with climatic variability (Altieri and Toledo 2005). Perhaps the most relevant aspect of the relationships between climate change and peasant agriculture is the realization that many small farmers cope with and even prepare for climate change, minimizing crop failure through increased use of drought tolerant local varieties, water harvesting, mixed cropping, agroforestry, soil conservation practices and a series of other traditional techniques (Altieri and Koohafkan 2008).

Observations of agricultural performance after extreme climatic events in the last two decades have revealed that resilience to climate disasters is closely linked to the level of on-farm biodiversity. Managing risk exposure is an important preoccupation of agricultural households in marginal environments and the only insurance mechanism available to these farmers is derived from the use of inventive self-reliance, experiential knowledge, and locally available resources (Altieri 2002).

2 The extent and ecological features of traditional farming systems

Well into the second decade of the twenty-first century, there are 1.5 billion smallholders, family farmers and indigenous people on about 350 million small farms occupying no more than 20 % of the world's arable land, but contributing with no less than 50 % of the global agricultural output for domestic consumption (ETC 2009). Most of the food consumed today in the world is derived from 5,000 domesticated crop species and 1.9 million peasant-bred locally adapted plant varieties mostly grown without agrochemicals (ETC 2009). It may be extremely difficult to establish the actual numbers, but some estimate that approximately 50 % of these peasants use resource conserving farming systems –representing a testament to the remarkable resiliency of traditional agroecosystems in the face of continuous environmental and economic change – while contributing substantially to food security at local, regional and national levels (Toledo and Barrera-Bassols 2008).

Most developing countries have a significant peasant population embedded in hundreds of ethnic groups with a history that can be traced back more than 10,000 years practicing traditional agriculture. In Latin America, about 16 million peasant production units occupying about 20 % of the arable land produce approximately 41 % of the agricultural output for domestic consumption. In the region peasants are responsible for producing at the regional level 51 % of the maize, 77 % of the beans, and 61 % of the potatoes (Altieri 2002). Africa has approximately 33 million small farms, representing 80 % of all farms in the region. The majority of African farmers (many of them are women) are smallholders, with two thirds of all farms below 2 ha and 90% of farms below 10 ha (Hart and Vorster 2007). Most small farmers practice “low-resource” agriculture producing the majority of grains, almost all root, tuber and plantain crops, and the majority of legumes consumed in the region. In Asia, China alone accounts for almost half the world's small farms (on 193 million ha), followed by India with 23 %, and Indonesia, Bangladesh, and Vietnam. Of the majority of more than 200 million rice farmers who live in Asia, few cultivate more than 2 ha of rice. China has probably 75 million rice farmers who still practice methods similar to those used more than 1,000 years ago (Critchley et al. 2004). Local cultivars, grown mostly on upland ecosystems and/or under rain-fed conditions, make up the bulk of the rice produced by Asian small farmers (Koohafkan and Altieri 2010).

Most forms of traditional agriculture are place specific, evolving in time in a particular habitat and culture, but many share common agroecological features (i.e. high number for plant and animal diversity, high structural diversity, exploitation of a full range of microclimates, dependence on local resources and crop varieties, etc.) which have been shown by scientists to enhance stability and resiliency of farming systems. The realization of the contribution of indigenous and peasant agriculture to food security in the midst of scenarios of climate change, economic and energy crisis led to the concepts of food sovereignty and agroecologically based production systems to gain much worldwide attention in the last two decades (Altieri and Toledo 2005). Two recent major international reports (IAASTD 2009; de Schutter 2010) state that in order to feed nine billion people in 2050, we urgently need to adopt the most efficient farming systems and recommend for a fundamental shift towards agroecology as a way to boost food production and improve the situation of the poorest. Both reports, based on broad consultations with scientists and civil society and industry representatives, contend that small-scale farmers can double food production within 10 years in critical regions by using agroecological methods already available.

Given the present and predicted near future climate, energy and economic scenarios, agroecology has emerged as one of the most robust pathways towards equitable and sustainable development available today. Such agroecological systems are deeply rooted

in the ecological rationale of traditional small-scale agriculture, representing long established examples of successful agricultural systems characterized by a tremendous diversity of domesticated crop and animal species maintained and enhanced by ingenious soil, water, and biodiversity management regimes, nourished by complex traditional knowledge systems. Many such systems comprise biodiverse, resilient, energetically efficient, socially just forms of agriculture, serving as the basis of an energy, productive, climate smart agricultural strategy that have fed much of the world's population for centuries and continue to feed people in many parts of the planet (Koohafkan and Altieri 2010). For these reasons most agroecologists acknowledge that traditional agroecosystems have the potential to bring solutions to many uncertainties facing humanity in a peak oil era of global climate change and financial crisis (Denevan 1995; Altieri 2004).

3 Models of climate smart traditional agriculture

3.1 Raised fields

The archaeological record provides an important source of data on agricultural systems that provide examples of sustainability and resiliency. Examples of such systems include the remnants of more than 170 000 ha of 'ridged-fields' in Surinam, Venezuela, Colombia, Ecuador, Peru, and Bolivia uncovered by researchers (Denevan 1995). Many of these systems apparently consisted of raised fields on seasonally-flooded lands in savannas and in highland basins. Thus raised bed cultivation systems have been used since time immemorial by farmers in many parts of the world. The origin and use have traditionally been associated with water management issues, either by providing opportunities to reduce the adverse impact of excess water on crop production, to actively harvest excess water or to irrigate crops in times of rainfall scarcity. Examples of farming in wetlands subjected to temporal flooding are the 'chinampas' used in the Valley of Mexico, the 'waruwarus' used near lake Titicaca in Peru and Bolivia (Wilken 1987).

The *chinampas* consist of 'islands' of raised platforms (from 2.5 to 10 m wide and up to 100 m long) constructed with mud scraped from the surrounding swamps or shallow lakes. The Aztecs built their platforms up to a height of 0.5 to 0.7 m above water and reinforced the sides with posts interwoven with branches and trees planted along the edges (Armillas 1971). New *chinampa* beds were, and still are today, built of alternating layers of aquatic weeds, bottom muck, and earth packed inside rectangular cane frames firmly rooted to the lake floor. The narrowness of the beds assured that the water in the surrounding canals filtered evenly through the plots at root level. Soil fertility was maintained through regular applications of swamp muck, aquatic plants, and manure. Canals 1-m to 3-m wide separated the *chinampas*, forming a network of islands reachable only by water (Gliessman et al. 1981). On the *chinampas*, farmers concentrate the production of their basic food crops as well as vegetables. Maize reached yields between 4 and 6 tons/ha, and together with other crops 1 ha of *chinampa* produced enough food to supply 15 people per year, as 3–5 crops were produced each year, supplemented by *quelites*, fruits and abundant aquatic life such as fish, salamanders, frogs, turtles, and all manner of fowl provided valuable sources of protein for the local diet (Rabiela 1993).

Waru-Warus consisted of platforms of soil surrounded by ditches filled with water and were able to produce bumper crops in the face of floods, droughts, and the killing frosts common at altitudes of almost 4,000 m. Around Lake Titicaca, remnants of over 80,000 ha of them can still be found. The combination of raised beds and canals has proven to have

important temperature moderation effects extending the growing season and avoiding the devastating effects of frost (Vietmeyer 1984). During droughts, moisture from the canals slowly ascends to the roots by capillary action, and during floods, the furrows drain away excess runoff. Waru-warus also reduce the impact of extremes of low temperature. Water in the canals absorbs the sun's heat by day and radiates it back by night, thereby helping protect crops against frost. On the raised beds, night time temperatures can be several degrees higher than in the surrounding region. (Erickson and Chandler 1989). All these sophisticated environmental effects lead to higher productivity on the Waru-Warus compared to chemically fertilized normal pampa soils. In the Huatta district, reconstructed raised fields produced impressive harvest, exhibiting a sustained potato yield of 8–14 t ha⁻¹ year⁻¹. These figures contrast favorably with the average Puno potato yields of 1–4 t ha⁻¹ year⁻¹ (Erickson and Chandler 1989).

3.2 Dryland agriculture

In more arid and semiarid regions, farmers have over generations developed management options that can increase the soil's ability to store water for plant use, reduce vulnerability to drought as well as help halting soil erosion and degradation (Barrow 1999). In water-limited situations, for example in Nigeria, ridges are included at regular intervals across furrows between crops which are planted on raised beds. Referred to as 'tied ridges', these structures help to hold rainfall, prevent runoff and promote water infiltration. Farmers in Tigray (Ethiopia) use to make contour furrows at 2–4 m wide intervals for *teff* production, which are locally called *terwah*, to trap water in the ridges so that after a storm their fields appear to be chequered with elongated pools of retained water for later crop use instead of being lost as runoff (Boers and Ben-Asher 1982).

A widely used technique is rainwater harvesting (RWH) which consists in the collection and concentration of runoff from small catchment areas (Critchley 1989). Small earthen basins are a simple method of trapping rainfall and thereby holding soil in situ. The basins found on the Dogon Plateau of Mali consist of a network of semi-permanent ridges constructed by hand. Similar basins are apparently also found amongst the Kofyar of the Jobs Plateau of Nigeria. Enlarged planting holes, or pits, are a feature of certain relatively flat semi-arid regions of West Africa. Traditions of hand-dug pits for land rehabilitation have been successfully revived by projects in Burkina Faso (where pits are known as *zay*) as well as in Niger (*tassa*) (Reij et al. 1996). The pits act as microcatchments, not just holding, but also concentrating, rainfall from the area between them. The application of manure in the pits further enhances growing conditions, and simultaneously attracts soil-improving termites. Larger, deeper pits are typically found on steeper slopes. The most renowned are these pits of southwest Tanzania, which have apparently been in use for several centuries and currently extend over some 18,000 ha (Stigter et al. 2005). Online Resource 1

4 Performance of biodiverse agroecosystems under extreme climatic events

A survey conducted in Central American hillsides after Hurricane Mitch showed that farmers using diversification practices such as cover crops, intercropping and agroforestry suffered less damage than their conventional monoculture neighbors. The survey, spearheaded by the *Campesino a Campesino* movement, mobilized 100 farmer-technician teams to carry out paired observations of specific agroecological indicators on 1,804 neighboring sustainable and conventional farms. The study spanned 360 communities and

24 departments in Nicaragua, Honduras and Guatemala. It was found that sustainable plots had 20 to 40 % more topsoil, greater soil moisture and less erosion and experienced lower economic losses than their conventional neighbors (Holt-Giménez 2002). Similarly in Sotonusco, Chiapas, coffee systems exhibiting high levels of vegetational complexity and plant diversity suffered less damage from Hurricane Stan than more simplified coffee systems (Philpott et al. 2009). Forty days after Hurricane Ike hit Cuba in 2008, researchers conducted a farm survey in the Provinces of Holguin and Las Tunas and found that diversified farms exhibited losses of 50 % compared to 90 or 100 % in neighboring monocultures. Likewise agroecologically managed farms showed a faster productive recovery (80–90 % 40 days after the hurricane) than monoculture farms (Rosset et al. 2011).

All the above studies emphasize the importance of enhancing plant diversity and complexity in farming systems to reduce vulnerability to extreme climatic events. The above observations have bolstered a new recognition that biodiversity is integral to the maintenance of ecosystem functioning and points to the utility of crop diversification strategies used by traditional farmers as an important resilience strategy for agroecosystems (Lin et al. 2008). Diversification occurs in many forms in traditional agriculture (genetic diversity and species such as in variety mixtures and polycultures) and over different scales (within field and landscape level as in the case of agroforestry, crop-livestock integration, hedgerows, corridors, etc.), giving farmers a wide variety of options and combinations for the implementation of this strategy. Thus traditional farmers create diversity temporally as well as spatially, adding even greater functional diversity and resilience to systems with sensitivity to temporal fluctuations in climate (Perfecto et al. 2009). Diversified farming systems such as agroforestry, silvopastoral and polycultural systems provide a variety of examples on how complex agroecosystems are able to adapt and resist the effects of climate change. Online Resource 2

Many traditional farmers seem to understand that the integrity of their agroecosystems relies on synergies of plant diversity and the continuing function of the soil microbial community supported by a soil rich in organic matter (Wilken 1987). Researchers have demonstrated that additions of organic matter enhance below ground biological diversity which in turn creates the conditions that are hospitable to plant roots, allowing the development of strong, healthy and resilient crops. SOM improves the soil's water retention capacity enhancing the drought tolerance by crops and improves infiltration-diminishing runoff avoiding that soil particles will be transported with water under intense rains (Diaz-Zorita et al. 1999). SOM also improves surface soil aggregation holding tightly the soil particles during rain or windstorms. Stable soil aggregates resist movement by wind or water (Magdoff and Weil 2004). Online Resource 3

The fact that many peasants commonly manage polycultures and/or agroforestry systems points at the need to re-evaluate indigenous technology as a key source of information on adaptive capacity centered on the selective, experimental and resilient capabilities of farmers in dealing with climatic change. Understanding the agroecological features of traditional agroecosystems can serve as the foundation for the design of climate change resilient agricultural systems (Altieri and Koohafkan 2008).

5 The mitigation potential of traditional farming systems

By enhancing diversity at the farm level and being inserted in high diversity landscapes, traditional systems also may reduce significantly GHG emissions and therefore, may contribute to mitigating global warming (Tschamtkke et al. 2005). The GHG emissions that

are the result of pesticide and fertilizer production could thus be greatly reduced by traditional farmers who do not use agrochemical inputs, but instead diversify their traditional farms and rural landscapes.

Because traditional biodiverse farms use less energy, pesticides and fertilizers their emissions avoidance is achieved through (Niggli et al. 2008):

- lower N₂O emissions (due to lower nitrogen input)—it is usually assumed that 1–2 % of the nitrogen applied to farming systems is emitted as N₂O
- less CO₂ emissions through lower erosion (due to better soil structure and more plant cover)— in diversified farming systems than in monocultures.

Agroforestry systems (SAFS) are prevalent diversified systems used by tropical small farmers and consist in the production of livestock or food crops in combination with growing trees, either for timber, firewood, or other tree products. Some of these systems, especially the traditional ones, contain high species diversity within a small area of land, protecting soil from erosion and providing litter for organic material and soil nutrients, reducing the need for synthetic fertilizer (Montagnini and Nair 2004).

Evidence is emerging that SAFS have great potential for increasing above ground and soil C stocks, reduce soil erosion and degradation, and mitigate GHG emissions (Mutuo et al. 2005). In agroforestry systems the standing stock of the carbon above ground is usually higher than the equivalent land use without trees. SAFS have a higher potential to sequester C than pastures or field crops. This is due to the fact that tree incorporation in croplands and pastures usually results in greater net aboveground as well as belowground C sequestration (Albrecht and Kandji 2003).

In a review of 42 studies it was estimated that the C sequestration potential of agroforestry was 2.6, 3.9, 6.1, 10 Mg C/ha/yr for the semi-arid, temperate, sub-humid and humid regions respectively (Nair et al. 2009). Agroforestry systems with *Erythrina poeppigiana*, sequestered C was attributed to 0.4 Mg C/yr in coarse roots, 0.3 Mg C/yr in tree trunks, 1.4 Mg C/yr in tree branches and leaves added to the soil as mulch, and 3.0 Mg C/yr from crop residues. The latter two contributions resulted in an annual increase of SOC pool by 0.6 Mg C (Mutuo et al. 2005). For smallholder agroforestry in the tropics, potential C sequestration rates range from 1.5 to 3.5 Mg C/ha/yr (Montagnini and Nair 2004). Agroforestry systems with perennial crops, such as coffee and cacao, may be more important carbon sinks than those that combine trees with annual crops. The potential of agroforestry for aiding in the curbing of GHG emissions is not limited to carbon sequestration. A review of agroforestry practices in the humid tropics shows that these systems were also able to mitigate N₂O and CO₂ emissions from the soils and increase the methane sink strength compared to annual cropping systems (Mutuo et al. 2005). In a study of the Peruvian Amazon, a tree-based agroforestry system emitted less than a third N₂O than a high (fertilizer) input annual cropping system, and half of the low input cropping system. Data from several countries strongly suggest that agroforestry systems can partially offset CH₄ emissions, while conventional high-input systems exacerbate CH₄ emissions (Montagnini and Nair 2004).

Most researchers would agree that soil carbon sequestration is enhanced through agricultural management practices used by traditional farmers such as increased application of organic manures, use of intercrops and green manures, incorporation of trees within farms or in hedges, etc. (Stigter et al. 2005). Such practices (manure addition, green manures, cover crops, etc.) promote greater soil organic matter (and thus soil organic carbon) content and improve soil structure. Increasing soil organic carbon in agricultural systems has been pointed out as an important mitigation option by IPCC. Very rough estimates for the global

mitigation potential of C sequestering farming systems such organic agriculture, estimate reductions of 3.5–4.8 Gt CO₂ via carbon sequestration (around 55–80 % of total global greenhouse gas emissions from agriculture) and a reduction of N₂O by two-thirds (Niggli et al. 2008).

In the Brazilian Amazon region, dense populations once successfully farmed poor oxisols for at least 2,500 years, leaving behind the rich ‘Terra Preta’ soils. ‘Terra Preta’ soils are derived from oxisols by enrichment with black carbon from residues of incomplete burning produced by the early Amerindian population. Due to the highly aromatic structure of black carbon, it is assumed to be chemically and microbially stable and persists in the environment over centuries or millennia. The enhanced fertility of ‘Terra Preta’ soils is expressed by higher levels of soil organic matter (SOM), nutrient-holding capacity, and nutrients such as nitrogen, phosphorus, calcium and potassium, higher pH values and higher moisture-holding capacity than in the surrounding soils. These dark soils are considered to have great importance as a store, source and potential sink of CO₂. SOC stocks of 147–506 Mg C ha⁻¹ m⁻¹ in Amazonian Dark Earths around Manaus and in the Belterra area compared to 72–149 Mg C ha⁻¹ m⁻¹ in adjacent Ferralsols. This reveals a highly significant C accumulation in the Amazonian Dark Earths by factors ranging from 1.5 to 4.6, especially in the agronomically important topsoil (0–30 cm depth) (Sombroek et al. 2003).

6 Conclusions

Many studies of traditional farming systems emphasize the importance of enhancing plant diversity and complexity in farming systems to increase yield stability and reduce vulnerability to extreme climatic events. Undoubtedly, the myriad of traditional systems and indigenous technologies (Table 1) still existing throughout the world comprise a globally important ingenious agricultural heritage that reflects the value of the diversity of agricultural systems adapted to different environments and the vagaries of a changing physical and material environment from generation to generation (Altieri and Koohafkan 2008).

The studies reported herein suggest that more diverse plant communities are more resistant to disturbance and more resilient to environmental perturbations derived from extreme climatic events (Lin et al. 2008). Crop diversification represents a potential long-term strategy for farmers who are experiencing either hurricane and/or decreasing rainfall patterns and increasing temperature variability. Adding copious amounts of organic matter into soils is particularly strategic when confronting droughts as SOM increases water holding capacity, infiltration, drainage, aeration and biological activity which enhances water use efficiency. Managing cover crops and green manures protects soil from erosion but also adds biomass, which in turn contributes to increased levels of SOM (Magdoff and Weil 2004).

Despite the ecological and cultural significance of traditional agriculture and the wealth of accumulated knowledge and experience of indigenous farmers in the management and use of natural resources in the midst of change, very few efforts have been devoted to elucidate the mechanisms that explain why traditional agroecosystems have stood the test of time (Koohafkan and Altieri 2010). One of such initiatives is the project REDAGRES (“Red IberoAmericana para el Desarrollo de Sistemas Agrícolas Resilientes al Cambio Climático”-www.redagres.org) whose objectives are to identify Latin American peasant farming systems that exhibit resiliency features against extreme climatic variability, in order to derive socio-ecological principles and mechanisms that explain why systems and communities resisted and recovered from such events. Such principles can establish the agroecological

Table 1 Examples of Agroecological practices (diversification and soil management) known to affect soil and water dynamics thus enhancing agroecosystem resiliency

	Soil organic build up	Nutrient cycling	>soil cover	Reduce ET	Rumoff reduction	> water holding capacity	> infiltration	Microclimatic amelioration	Reduction soil compaction	Reduction soil erosion	> hydrological regulation	> water use efficiency	> mycorrhizal network
Diversification													
• Mixed or intercropping			✓	✓	✓			✓	✓	✓		✓	
• Agroforestry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
• Intensive sylvopastoral system	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
• Crop rotation	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	
• Local variety mixtures			✓									✓	
Soil Management													
• Cover cropping	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
• Green manures	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	
• Mulching	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	
• Compost applications	✓		✓	✓	✓	✓	✓		✓	✓		✓	✓
• Conservation agriculture (organic - no till)			✓	✓	✓				✓	✓		✓	
Soil Conservation													
• Contour farming				✓	✓		✓		✓	✓	✓		
Grass strips/living barriers			✓	✓	✓		✓			✓	✓		
• Terracing				✓	✓		✓			✓	✓		
• Check dams along gullies				✓	✓		✓			✓	✓		

foundations for thousands of small farmers to design resilient systems thus avoiding excessive yield and economic losses when affected by droughts or hurricanes.

Most of the examples of traditional agroecosystems focus on the ecological resiliency of such systems - that is on the ability of such systems to absorb perturbations - or their speed of recovery from climatic disturbances. Little has been written about the social resilience of the rural communities that manage such agroecosystems. Social resilience has been defined as the ability of communities to withstand external shocks to their social infrastructure. This is particularly apposite for resource-dependent communities where they are subject to external stresses and shocks, both in the form of environmental variability (such as agricultural pests or the impacts of climatic extremes), as well as in the form of social, economic and political upheaval (Adger 2000).

Clearly, agroecological strategies that enhance the ecological resiliency of farming systems are a necessary but not sufficient condition to achieve sustainability. The ability of groups or communities to adapt in the face of external social, political, or environmental stresses must go hand in hand with ecological resiliency. To be resilient, rural societies must generally demonstrate the ability to buffer disturbance with agroecological methods adopted and disseminated through self-organization and collective action (Tompkins and Adger 2004). Reducing social vulnerability through the extension and consolidation of social networks, both locally and at regional scales, can contribute to increases in agroecosystem resilience. As seen in Fig. 1 the vulnerability of farming communities depends on how well developed is their natural and social capital which in turn makes farmers and their systems

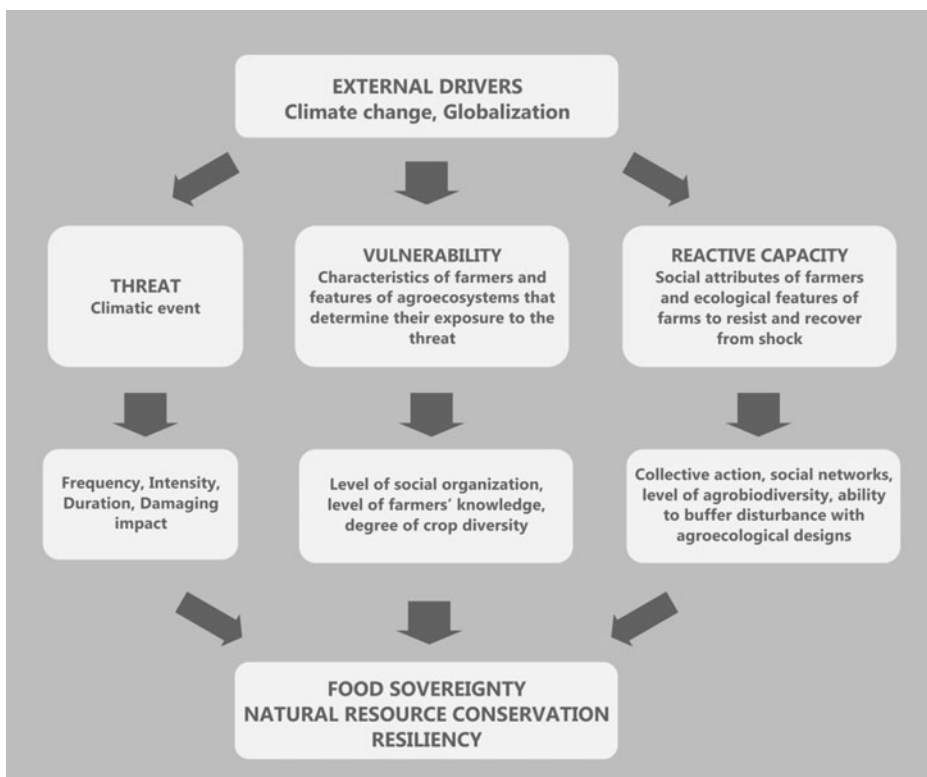


Fig. 1 Factors affecting the vulnerability of rural communities to climatic events and the reactive capacity to enhance socio-ecological resiliency

more or less vulnerable to climatic shocks. Adaptive capacity refers to the set of social and agroecological preconditions that enable individuals or groups and their farms to respond to climate change in a resilient manner. The capacity to respond to changes in environmental conditions exists within communities to different degrees but not always all responses are sustainable. The challenge is to identify the ones that are in order to upscale them so that vulnerability can be reduced by enhancing the reactive capacity of communities to deploy agroecological mechanisms that allow farmers to resist and recover from climatic events. Social organization strategies (solidarity networks, exchange of food, etc.) used collectively by farmers in order to cope with the difficult circumstances imposed by such events are thus a key component of resiliency.

Traditional farming systems have an important role to play in mitigation of climate change especially through carbon sequestration because of the carbon storage potential in its multiple plant species and soil (Mutuo et al. 2005). Although the potential seems to be substantial and agroecological improvement of the design and management of such systems can make them even more effective carbon sinks, small diversified farms occupy less than 20 % of the total arable land, and could not offset the emissions produced by industrial agriculture which occupies 80 % of arable land with input intensive monocultures responsible for between 19 and 29 % of total greenhouse emissions.

Although traditional agricultural practices do reduce GHGs or better store carbon compared to industrial agriculture, carbon offset credits are unlikely to be suitable to support mitigation potential of traditional agriculture. Although some authors argue that C trading represents an economic opportunity for subsistence farmers in developing countries, via selling the C sequestered in their farms to industrialized countries, such benefits will be offset by the high transaction costs and low returns.

Despite the fact that some indigenous and small farmer groups support REDD+ solutions, the Via Campesina, the largest peasant organization in the world, rejects REDD and all other market solutions, and call for global organizations to recognize and support the sustainable agriculture of family farmers and indigenous people as a way of maintaining global biodiversity and mitigating gas emissions (Via Campesina 2010). In fact they contend that if well supported and scaled up, peasant and indigenous peoples could reduce current global emissions to 75 % by increasing biodiversity, recuperating soil organic matter, replacing industrial meat production with small-scale diversified food production, expanding local markets, halting deforestation and practicing integrated forest management (Altieri and Toledo 2011).

Clearly the mitigation community needs to engage in talks with the small farmers organizations on this issue and jointly think of other enabling conditions to put in place to support resiliency of traditional agriculture and ensure food security. This could impact on the development of NAMAs (Nationally Appropriate Mitigation Action plans) which are linked to measurable emission reductions, and could therefore induce political and economic policy changes that better support traditional agriculture.

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