Agro-ecological approaches to enhance resilience

Clara Ines Nicholls and **Miguel A. Altieri**

The Green Revolution has performed well in well-endowed areas with a stable climate, adequate water supply and access to inputs and cheap energy. It has led to millions of hectares being transformed into large-scale, specialised and input dependent farming systems. But the necessary fertilizers, pesticides, farm equipment and fuel are derived from dwindling and ever more expensive fossil fuels. At the same time, climatic extremes are becoming more frequent and intensive agricultural systems show a lower resistance and higher vulnerability to such fluctuations. Fortunately, there are alternatives that enhance resilience and ensure high yields.

Adding large quantities of organic materials is a key strategy to enhance soil quality

Little has been done to enhance the adaptability of industrial agriculture to changing and extreme weather events, except for a focus on "magic bullets" such as genetic modification, with crops that are expected to produce under stressful environments. Almost no work has been conducted on designing management practices that enhance the resilience of monocultures to climate change. But there is ample evidence that agro-ecological designs and practices contribute enormously to this. In fact, many studies reveal that small-scale farmers who follow agro-ecological practices cope with, and even prepare for, climate change, minimising crop failure. Results from various studies suggest that these practices provide a higher resistance to climate events, reduce vulnerability and make farms more sustainable in the long-term.

Based on this evidence, various experts have suggested that reviving traditional management systems, combined with the use of agro-ecologically principles, may represent the only viable and robust path to increasing the productivity, sustainability and resilience of agricultural production. In this paper we explore a number of ways in which these strategies can be implemented through the design and management of agro-ecosystems, allowing farmers to adopt a strategy that, in the end, provides more economic benefits.

Diverse farming systems

Detailed analyses of agricultural performance after extreme climatic events have revealed that resilience to climate disasters is closely linked to the level of on-farm biodiversity. 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 neighbours. A survey of more than 1,800 neighbouring "sustainable" and "conventional" farms in Nicaragua, Honduras and Guatemala, found that the "sustainable" plots had between 20 to 40% more topsoil, greater soil moisture and less erosion, and also experienced lower economic losses than their conventional neighbours. Similarly, those coffee farms in Mexico which exhibit high levels of complexity and plant diversity suffered less damage from Hurricane Stan. And forty days after Hurricane Ike hit Cuba in 2008, researchers found that diversified farms exhibited losses of 50%, compared to 90 or 100% in neighbouring monocultures. Likewise agro-ecologically managed farms showed a faster recovery in their production than monoculture farms.

These are only a few examples that show how complex agro-ecosystems are able to adapt and resist the effects of climate change. Agroforestry systems have been shown to buffer crops from large fluctuations in temperature, thereby keeping the crops closer to their optimum conditions. More shaded coffee systems have shown to protect crops from low precipitation and reduced soil water availability. This is because the overstory reduces soil evaporation and the roots increase soil water infiltration. At the same time, intercropping enables farmers to produce various crops simultaneously and minimise risk. Polycultures exhibit greater yield stability and less productivity declines during drought. A study of the effect of drought (Natarajan and Willey, 1986) on polycultures showed that intercropping is enormously successful. Quite interestingly, the rate of over-yielding actually increased with water stress, showing that the relative differences in productivity between monocultures and polycultures increase with greater stress.

Another example is that of the intensive silvopastoral systems (ISS), which combine fodder shrubs planted at high densities, trees, palms, and pastures. High stocking levels are achieved through rotational grazing, which allows for the natural production of milk and meat in these systems. At the El Hatico farm, in Cauca, Colombia, a five story ISS composed of a layer of grasses, *leucaena* shrubs, medium-sized trees and a canopy of large trees has, over the past 18 years, increased its stocking rates to 4.3 dairy cows/ha and its milk production by 130%, as well as completely eliminating the use of chemical fertilizers. 2009 was the driest year in El Hatico's 40-year record, and the farmers saw a reduction of 25% in pasture biomass, yet the production of fodder remained constant throughout the year, neutralising the negative effects of drought on the whole system. In response to the extreme weather, the farm had to adjust its stocking rates. In spite of this, the farm's milk production for 2009 was the highest on record, with a surprising 10% increase compared to the previous four years. Meanwhile, farmers in other parts of the country reported severe animal weight loss and high mortality rates due to starvation and thirst.

The combined benefits of water regulation, a favourable microclimate, biodiversity, and carbon stocks in such diversified farming systems, not only provide environmental goods and services for producers, but also greater resilience to climate change.

Enhancing soil organic matter

Crop productivity under dry land conditions is largely limited by the availability of water in the soil. The percentage of soil organic matter, or SOM content, is a reliable index of crop productivity in semiarid regions because SOM improves the soil's ability to store and transmit air and water.

Adding large quantities of organic materials on a regular basis is another key strategy used by many ago-ecological farmers. SOM management is at the heart of all efforts to create healthy soils with a high level of biological activity and good physical and chemical characteristics. Increasing the SOM enhances resilience by improving the soil's water retention capacity, enhancing tolerance to drought, improving infiltration, and reducing the loss of soil particles through erosion after intense rains. SOM also improves surface soil aggregation, holding the soil particles tightly, protecting them against rain or windstorms.

REDAGRES

The *Red IberoAmericana de Agroecologia para el Desarrollo de Sistemas Agricolas Resilientes al Cambio Climatico*, REDAGRES, is a network of scientists and researchers spread across 8 countries. Its objectives are to promote the exchange of knowledge and information related to agriculture and climate change. In addition to analysing the impact of climate change on agricultural production, REDAGRES places special emphasis on exploring different adaptation strategies to extreme climatic events, and applying agro-ecological principles to the design and scaling-up of agro-ecosystems that are resilient to climate change.

A few months ago, REDAGRES launched a two year project involving a survey of small-scale farming systems in selected regions of Latin America. The aim is to identify those systems that have withstood climatic events (recently or in the past), and understand their main features. The emerging principles are being shared with family farmers in neighbouring communities and others in the region via field days, cross-visits, short seminars and courses. It is also being used to develop a farmer-friendly manual that will explain how to assess the level of resilience of a farm, and showing what to do to enhance this.

At the same time, organically-rich soils usually contain symbiotic mycorrhizal fungi, such as arbuscular mycorrhizal (AM) fungi, which are a key component of the microbial populations influencing plant growth and soil productivity. AM fungi are important as they improve plant-water interactions, and thus increase resistance to drought. Some specific fungus-plant associations increase drought tolerance and are of great interest for areas affected by water deficits: AM fungi have been reported to increase nutrient uptake in water-stressed plants and to enable plants to use water more efficiently.

Managing soil cover

Protecting the soil from erosion is also a fundamental strategy for enhancing resilience. Cover crop mulching and green manures offer many advantages. Stubble mulching protects the soil surface with residues and inhibits drying of the soil. Mulching can also reduce wind speed by up to 99%, thereby significantly reducing losses due to evaporation. In addition, cover crop and weed residues can improve water penetration and decrease water runoff losses by 2 to 6 fold.

Throughout Central America, CIDDICO, *Vecinos Mundiales* and other NGOs have promoted the use of grain legumes as green manures, an inexpensive source of organic fertilizer and a way of building up organic matter. Hundreds of farmers along the northern coast of Honduras are using velvet bean (*Mucuna pruriens*) with excellent results, including corn yields of about 3,000 kg/ha, more than double than national average. These beans produce nearly 30 tons/ha of biomass per year, adding about 90 to 100 kg of N/ha per year to the soil. The system diminishes drought stress, because the mulch layer left by *Mucuna* helps conserve water in

Legumes fix Nitrogen and provide an additional source of quality fodder

the soil, making nutrients readily available in periods of major crop uptake.

Today, well over 125,000 farmers are using green manures and cover crops in Santa Catarina, Brazil. Hillside family farmers modified the conventional no-till system by leaving plant residues on the soil surface. They noticed a reduction in soil erosion levels, and also experienced lower fluctuations in soil moisture and temperature. Repeated applications of fresh biomass improved the soil quality, minimised erosion and weed growth and improved crop performance. These novel systems rely on mixtures for summer and winter cover cropping which leave a thick residue on which crops like corn, beans, wheat, onions or tomatoes are directly sown or planted, suffering very little weed interference during the growing season. During the 2008-2009 season, when there was a severe drought, conventional maize producers experienced an average yield loss of 50%, reaching productivity levels of 4,500 kilos per hectare. However the producers who had switched to no-till agro-ecological practices experienced a loss of only 20%, confirming the greater resilience of these systems.

Adding social resilience

More diverse plant communities are more resistant to disturbance and more resilient to environmental perturbations derived from extreme climatic events. Undoubtedly, crop diversification represents a viable long-term strategy for farmers experiencing erratic weather. The use of diversification within agricultural production systems can significantly reduce their vulnerability and protect their livelihoods. Farmers that use diversity as a crop management strategy usually add copious amounts of organic matter into their soils, further increasing water retention capacity. Managing cover crops and green manures improves the soil cover, protecting the soil from erosion, but also adds biomass, which in turn contributes to increased levels of SOM.

Such strategies to enhance the ecological resilience of farming systems are essential, but in themselves are not enough to achieve sustainability. Social resilience, defined as the ability of groups or communities to adapt to external social, political, or environmental stresses, must go hand in hand with ecological resilience. To be resilient, rural societies must have the ability to buffer disturbance with agro-ecological methods adopted and disseminated through self-organisation 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 further increase the resilience of agro-ecosystems. The vulnerability of farming communities depends on the development of the natural and social capital that gives farmers and their systems resilience against climatic (and other) shocks. This adaptive capacity resides in a set of social and agro-ecological conditions that influence the ability of individuals or groups, and their farms, to respond to climate change in a resilient manner. This capacity to respond to changes in environmental conditions exists to different degrees within communities but the responses are not always sustainable. The challenge is to identify the responses that are sustainable and to upscale them, enhancing the reactive capacity of communities to deploy agro-ecological mechanisms that allow farmers to resist and recover from climatic events and reducing their vulnerability. Social organisation strategies (solidarity networks, exchange of food, etc.) used by farmers to cope with the difficult circumstances imposed by such events, are thus a key component of resilience.

◆

References

Lin, B.B., I. Perfecto and J. Vandermeer, **Synergies between agricultural intensification and climate change could create surprising vulnerabilities for crops,** *2008, BioScience 58, 847-854.*

Natarajan, M, and R.W. Willey, **The effects of water stress on yields advantages of intercropping systems,** *1996, Field Crops Research 13: 117-131*

Tompkins, E.L and W.N. Adger, **Does adaptive management of natural resources enhance resilience to climate change?** *2004, Ecology and Society 9(2): 10.*

Clara Ines Nicholls is the co-ordinator of REDEAGRES, the *Red IberoAmericana de Agroecología para el Desarrollo de Sistemas Agrícolas Resilientes al Cambio Climático*. *E-mail: nicholls@berkeley.edu.* **Miguel A. Altieri** *(agroeco3@berkeley.edu)* is the president of SOCLA, *Sociedad Científica Latino Americana de Agroecología*.