The Importance of Biodiversity in Agricultural Systems

In ecology and conservation biology, biodiversity is a well-known concept - one that most of us learn in high school. It is not, however, so commonly associated with agriculture. Biodiversity is apparent in the variety of plants and animals farmers raise, but less obvious are the countless soil biota, pollinators, and natural enemies of pests and diseases that support agricultural production. When we look at an agricultural system as an ecosystem with particular niches, biodiversity is an important part of the structure and function of that ecosystem and its ability to sustain itself while under farmer management. In this paper, I will examine how farmers manage three aspects of agrobiodiversity – genetic, planned, and associated – with specific examples interwoven throughout of ecosystem services provided as well as threats and challenges to increasing biodiversity in farming systems.

The term agrobiodiversity describes the particular structure and function of diversity in agricultural systems. The goal of a farm, in contrast to natural ecosystems, is to produce a harvestable product, whether that be a yearly vegetable crop, bicentennial hardwood, or daily dairy milk. The removal of nutrient-rich biomass from an agroecosystem requires management and off-farm inputs to ensure continued yields. Agricultural intensification has greatly decreased biodiversity on farms, and monocultural systems are extremely vulnerable to disturbances of disease, pests, and weather (Jarvis et al. 2007). Some of these issues can, however, be minimized by increasing biodiversity. Biodiversity also provides important ecosystem services, such as carbon sequestration, watershed protection, and nutrient cycling (Jarvis et al. 2007).

Genetic Diversity

Genetic diversity in both plants and animals is of particular importance for continued adaptation to changing environments and selection according to farmers’ needs. Genetic diversity can be conserved in situ or ex situ; on the farm, or off the farm (Esquinas-Alcázar 2005). Ex situ conservation means that seeds are stored but not cultivated, and as such cannot continually adapt and change – this method does not as yet include livestock, and cannot even begin to encompass the many different varieties and crops that exist (Esquinas-Alcázar 2005). Conserving genetic diversity on the farm means conserving local landraces and allowing adaptation to occur over generations so that plants are well-suited to the land and the selective pressures in a given geographic region (Jarvis et al.).

Measuring and recording genetic diversity is important for assessing changes and shifts in genetic diversity over time. Names may be used as an indicator for the number of varieties with distinct traits, but they are not a consistent indicator globally. In identifying varieties, farmers may or may not distinguish between different landraces; Sadiki et al. documented across countries that farmers’ identification of crops could range from generic bean to location-specific names and traits (2007). Genetic diversity is more technically measured in terms of different phenotypes, the number of alleles at a gene locus, the distribution of alleles, and the extent of difference between them and
their phenotypic expression (Hodgkin 2007). The greater the genetic diversity within a species in a given region, the greater the species’ ability to adapt to its particular environment.

Adaptation to a local environment occurs through migration, recombination, mutation, and through natural and farmer selection processes. Recombination is most effective at producing diversity in crops that are cross-pollinated, such as maize and pearl millet. Rice, wheat, and barley are self-pollinators and thus recombination will not produce as much phenotypic change. Some plants, like bananas, cassava, and potatoes, are clonally propagated and so very little genetic change can occur except through mutations (Hodgkin et al. 2007). Genetically modified seed as well as hybrid seed cannot be collected by the farmers to plant the following season, and so there is not potential for such varieties to adapt to local conditions unless breeders do so before selling the seed.

In countries where traditional agriculture still exists, many farmers save their seeds. In Nepal, for example, only 3% of rice seed was purchased from the certified seed sector in 1999-2000 (Hodgkin et al. 2007). Farmers get their seed from their own farms or from friends, relatives, neighbors, and local markets, or they may save their own seeds. This allows natural selection specific to the region and farmer selection to occur.

From crops that survive natural selection, farmers select for seed based generally on the size and quality of seed rather than the entire plant stand (Hodgkin et al. 2007). Maize growers save the best unhusked ears for seed, husking them later. In Mesoamerica, the distal and basal ends of the ear are not used; interestingly, there can actually be significant genetic difference between seeds on an ear because of pollen competition (Hodgkin et al. 2007). Farmers sometimes encounter pest and disease problems storing their seed, which pose difficulties for planting more seed, but also could be positive selection pressures for those seeds with greater tolerance or resistance to a particular disease or pest.

Conserving genetic diversity native to a place or region is a dynamic process, requiring farmer wisdom and knowledge (Jarvis et al. 2007). Some research programs are incorporating Participatory Plant Breeding approaches in which farmers and breeders work together to select traits in a breeding process. These kinds of approaches hold promise for developing hardy and high-yielding varieties, but also require intensive time involvement on behalf of farmers. Farmers could not work part time jobs while participating in such a breeding program (Hodgkin 2007).

Planned Biodiversity

In addition to genetic diversity within a single crop species, the diversity of species and ecosystems occurring in a region can also provide important ecosystem services as well. Farmers can plan and manage biodiversity by choosing to incorporate several different crops as well as habitat for beneficial insects. Models such as agroforestry emphasize the farm as a complex ecosystem in dynamic equilibrium. Farmers can also allow, maintain, or restore wild ecosystems that promote species richness. These natural ecosystems can provide carbon sequestration, nutrient cycling, and water protection.

For example, planting a several different crop species in polyculture is shown to have yield benefits in some cases. In a three-year field study in Iowa, a polyculture of perennial grains and legumes overyielded in comparison with monoculture controls of each crop on its own (Picasso et al. 2011). Potential exists for greater productivity at 4-5 years because the crops will be well established. One of the issues in polycultures,
However, is that selection pressure will occur as crops compete for nutrients, sunlight, and water. But polycultures can also be complementary; plants with differing root depths are able to take up water and nutrients from different levels in the soil, thus minimizing competition and supporting a wider variety of soil biota (Picasso et al. 2011). More research is needed to determine the management practices, as well as indicators of how polycultures affect particular ecosystem services.

**Associated Biodiversity**

Associated biodiversity describes the effects of countless soil organisms, pollinators, and beneficial organisms guarding plants against pests, diseases, and weeds (Jarvis et al. 2007). Earthworms, soil microorganisms, and bacteria combined with plant and tree roots provide nutrient cycling as well as maintenance and creation of soil structure (Brown 2007). One gram of soil can contain thousands of species of bacteria (Brown et al. 2007). Pollinators, which need habitat in wild or planned areas, contribute to the genetic diversity of cross-pollinated crops (Jarvis et al. 2007). Beneficial organisms also require habitat but can help decrease the need for pesticides (Russell and Bessin 2008).

To give a brief but illustrative example, the wasp *Trichogramma ostriniae* is used as a biological control for the European corn borer (because the wasp, native to China, is a natural predator of the *Asian* corn borer). The corn borer is a moth that, in its caterpillar stage, damages seeds and fruits of corn and solanaceous (nightshade) plants, including peppers, eggplants, potatoes, and tomatoes (Russell and Bessin 2008). The wasp is an egg parasitoid that is born in and feeds off of the in the eggs of the corn borer. In a two-year field study, Russell and Bessin tested the effects of the predatory wasp on pepper plants infested with the corn borer. They also included habitat modification by interplanting buckwheat as a way to attract other beneficials and provide food for the wasp. Without habitat, the wasp cannot survive. They found that the number of damaged fruits decreased with the addition of the wasp (Russell and Bessin 2008). Because insect pests have distinct stages of life from egg, pupa, larvae, to adults, the presence of several natural predators that attack the pest at different life stages is important in the success of biological controls (Jarvis et al. 2007).

The primary issue in using the *ostriniae* wasp is that it is not native to the Americas, and the introduction of a non-native species can pose significant challenges to native wasps and other organisms. Indeed, many of the pests and diseases attacking crops in the Americas are not native (Russell and Bessin 2008). As such, there may not be existing, native, biological predators to these non-native threats.

**Future Areas of Study**

Future areas of study in agrobiodiversity are many, but especially needed in regards to management practices for farmers seeking to integrate different kinds of integrated systems. In addition, the positive results of many studies on multifunctional farming strategies are often overlooked because of the small scale of studies and the challenge of identifying and measuring ecological effects (Jarvis et al. 2007). Alternative experimental models must be identified. Large-scale agricultural studies require economic resources, political will, and the potential for research to have economic value to farmers. But ecological benefits are not bought and sold on a market; they are not figured into prices of inputs or products that farmers buy and sell (Jarvis et al. 2007). Research is also needed to give a more comprehensive understanding of the relationship
between ecosystem services and biodiversity, as well as identifying the functions of biodiversity that are irreplaceable.

**Conclusion**

Biodiversity is an essential characteristic of most natural ecosystems, and provides many essential ecosystem services. Agricultural systems ought to reflect this structure with careful management of agrobiodiversity and preservation of natural ecosystems. Genetic diversity increases the potential for plants to be well suited to their environment and adapt to changes. Planned biodiversity can be managed by farmers for the benefits of complementarity and ecosystem services. Associated biodiversity of soil organisms, pollinators, and beneficials can serve as built-in regulatory systems. Ultimately, breeders’ and farmers’ choices have interregional and intergenerational consequences when it comes to agrobiodiversity. The value of ecological services and environmental benefits of biodiversity, while not reflected in market prices, is a public good worth conserving.

**Literature Cited**


