3

The Central Role of Agricultural Biodiversity:
Trends and Challenges

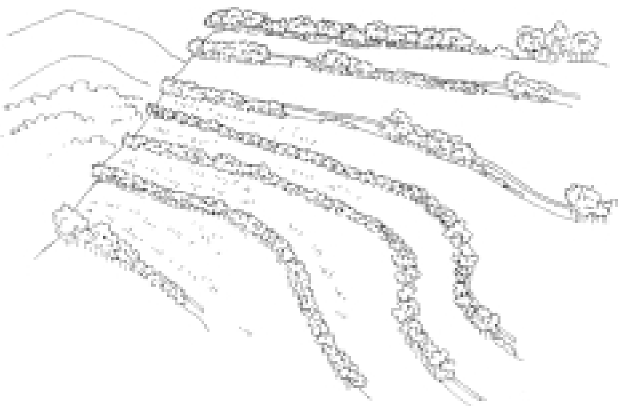
Predominant patterns of agricultural growth have eroded biodiversity in agroecosystems including plant genetic resources, livestock, insects, and soil organisms. This erosion has caused economic losses, jeopardizing productivity and food security, and leading to broader social costs. Equally alarming is the loss of biodiversity in "natural" habitats from the expansion of agricultural production to frontier areas.

> Traditional agroforestry systems commonly contain over 100 annual and perennial plant species per field. Farmers often integrate leguminous trees, fruit trees, trees for fuelwood and types that provide fodder on their coffee farms. The trees also provide habitat for birds and animals that benefits the farms. A shaded coffee plantation in Mexico supports up to 180 species of birds that help control insect pests and disperse seeds.

The conflicts between agriculture and biodiversity are by no means inevitable. With sustainable farming practices and changes in agricultural policies and institutions, they can be overcome. Biodiversity maintenance must be integrated with agricultural practices - a strategy that can have multiple ecological and socioeconomic benefits, particularly to ensure food security. Practices that conserve and enhance agricultural biodiversity are necessary at all levels.

Ethnobotanical studies show that the Tzeltal Mayans of Mexico can recognize more than 1,200 species of plants, while the P'urepechas recognize more than 900 species and Yucatan Mayans some 500. Such knowledge is used to make production decisions.

This paper discusses the ecosystem services provided by agricultural biodiversity, and highlights principles, policies, and practices that enhance diversity in agroecosystems.



N. Vavilov, a renowned Russian botanist carried out systematic plant collection, pioneering research, and conservation of crop diversity starting in the early 20th century. Vavilov developed a theory of the origin of domesticated crops and launched numerous worldwide expeditions to collect crop germplasm. He established an immense seed bank in St. Petersburg which now houses some 380,000 specimens from more than 180 locations in the world. Vavilov also identified major areas of high concentrations of crop diversity around the world, most of which are in developing countries.

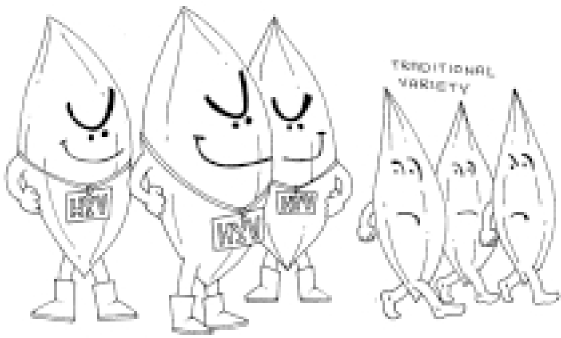
Changing Trends in Agricultural Development and Biodiversity Links

Agricultural Biodiversity Loss: Conflicts and Effects

High yielding varieties (HYVs) - or "miracle seeds" - are now planted on high percentages of agricultural land - 52% for wheat, 54% for rice, and 51% for maize. The use of HYVs has increased production in many regions and sometimes reduced pressure on habitats by curbing the need to farm new lands.

The links between agriculture and biodiversity have changed over time. Increase of agricultural production and productivity, in the last 30 years, stems from both expansion of cultivated area (extensification) and the increased output per unit of land (intensification). It was achieved through technological inputs, improved varieties and the management of biological resources, such as soil and water. Ecosystem services provided by agricultural biodiversity have degraded and therefore undermine ecosystem health.

These general trends in agriculture and biodiversity have been shaped by demographic pressures, including high population growth rates, the migration of people into frontier areas, and imbalances in population distribution. Additional influential forces are the predominant paradigms of industrial agriculture and the Green



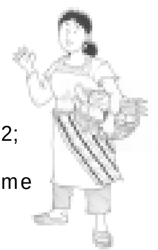
Revolution, beginning in the l960s. These approaches generally emphasize maximizing yield per unit of land, uniform varieties, reduction of multiple cropping, standardized farming systems (particularly generation and promotion of high-yielding varieties), and the use of agrochemicals. Seed and agrochemical companies have also influenced these trends.

Although the predominant patterns of agricultural development in the last several decades have increased yields, they have also significantly reduced the genetic diversity of crop and livestock varieties and agroecosystems, and have led to other kinds of biodiversity losses.

Although people consume approximately 7,000 species of plants, only 150 species are commercially important, and about 103 species account for 90 percent of the world's food crops. Just three crops - rice, wheat, and maize - account for about 60 percent of the calories and 56 percent of the protein people derive from plants.

Livestock is also suffering from genetic erosion. The Food and Agriculture Organization of the United Nations (FAO-UN) figures show that:

- At least one breed of traditional livestock dies out every week in the global context;
- Of the 3,831 breeds of cattle, water buffalo, goats, pigs, sheep, horses and donkeys believed to have existed in this century, 16 % have become extinct and 15 % are rare;
- Some 474 of livestock breeds can be regarded as rare, and about 617 have become extinct since 1892; and
- Over 80 breeds of cattle are found in Africa, and some are being replaced by exotic breeds. These losses weaken breeding programs that could improve hardiness of livestock.



As forms of biodiversity are eroded, food security can also be reduced and economic risks increased. Evidence indicates that such changes can decrease sustainability and productivity in farming systems. Loss of diversity also reduces the resources available for future adaptation.

Increased Vulnerability to Insect Pests and Diseases

Among renowned examples of crop vulnerability to pests and diseases are the potato famine of Ireland during the 19th century, a winegrape blight that wiped out valuable vines in both France and the United States, a virulent disease (Sigatoka) that damaged extensive banana plantations in Central America in recent decades and devastating mold that infested hybrid maize in Zambia.

Genetic homogenization of varieties increases vulnerability to insect pests and diseases, which can devastate a crop, especially on large plantations. History has shown serious economic losses and suffering from relying on monocultural uniform varieties.

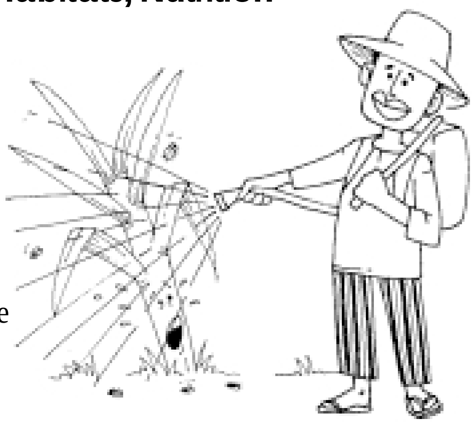
There has also been a serious decline in soil organisms and soil nutrients. Beneficial insects and fungi also suffer from heavy pesticide inputs and uniform stock -- making crops more susceptible to pest problems. These losses, along with fewer types of agroecosystems, also increase risks and can reduce productivity. In addition, many insects and fungi commonly seen as enemies of food production are actually valuable. Some insects benefit farming - for pollination, contributions to biomass, natural nutrient production and cycling, and as natural enemies to insect pests and crop diseases. Mycorrhizae, the fungi that live in symbiosis with plant roots, are essential for nutrient and water uptake.

The global proliferation of modern agricultural systems has eroded the range of insects and fungi, a trend that lowers productivity. Dependence on agrochemicals, and particularly the heavy use or misuse of pesticides, is largely responsible. Agrochemicals generally kill natural enemies and beneficial insects, as well as the "target" pest.

This disruption in the agroecosystem balance can lead to perpetual resurgence of pests and outbreaks of new pests-as well as provoke resistance to pesticides. This disturbing cycle often leads farmers to apply increasing amounts of pesticides or to change products-a strategy that is not only ineffective, but that also further disrupts the ecosystem services and elevates costs. This "pesticide treadmill" has occurred in countless locations. Reliance on monocultural species and the decline of natural habitat around farms also cut beneficial insects out of the agricultural ecosystem.

Additional Losses-Habitats, Nutrition and Knowledge

Agricultural expansion has also reduced the diversity of natural habitats, including tropical forests, grasslands, and wetland areas. Projections of food needs in the coming decades indicate probable further expansion of cropland, which could add to this degradation. Modifying natural systems is necessary to fulfill the food needs of growing populations, but many conventional forms of agricultural development, particularly large-scale conversion of forests or other natural habitats to monocultural farming systems, erode the biodiversity of flora and fauna. Intensive use of



pesticides and fertilizers can also disrupt and erode biodiversity in natural habitats and ecosystem services that surround agricultural areas, particularly when these inputs are used inappropriately.

Other direct effects of reduced diversity of crops and varieties include:

- Decline in the variety of foods adversely affects nutrition;
- High-protein legumes have often been replaced by less nutritious cereals;
- Local knowledge about diversity is lost as uniform industrial agricultural technologies predominate; and
- Institutions and companies in the North have unfair advantages in exploiting the diverse biological resources from the tropics.

> Humanity faces a major challenge to overcome conflicts and build complementarities between agriculture and biodiversity. Meeting this challenge requires addressing root causes of agricultural biodiversity loss, and thus calls for changing practices, paradigms, and policies, as well as commitments by governments and institutions.

Confronting the Causes

Devising effective solutions requires confronting the causes of agricultural biodiversity losses. Proximate causes vary under different conditions, but generally pertain to the use of unsustainable technologies and degrading land-use practices, such as relying on uniform varieties and the heavy use of agrochemicals. Yet more deeply, the roots underlying the erosion of agricultural biodiversity are tied to demographic pressures, disparities in resource distribution, the dominance of industrial agricultural policies and institutions that support and contribute to inappropriate practices, pressures from businesses that promote uniform monocultures and chemicals, the depreciation and devaluation of diversity and accumulated local knowledge, and market and consumer demands for standardized products. Of these driving forces, perhaps the most perplexing are demographic pressures leading to extensification of farming into frontier areas. Changing these patterns requires transforming land-use policies, as well as broader socioeconomic changes that give the rural poor more economic and educational opportunities. These longer-term challenges need concerted attention over time.

Diversity Through Sustainable Agriculture: Principles and Practices

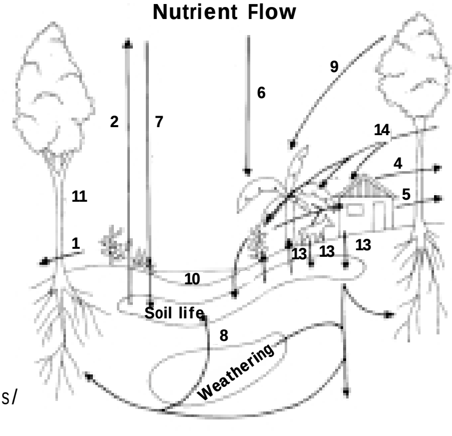
To achieve such transformations for the conservation and enhancement of agricultural biodiversity, the following strategic principles are critical:

1. Application of agroecological principles helps conserve, use and enhance biodiversity on farms and can increase sustainable productivity and intensification, which avoids extensification, thereby reducing pressure on off-farm biodiversity;
2. Participation and empowerment of farmers and indigenous peoples, and protection of their rights, are important means of conserving agricultural biodiversity in research and development;
3. Adaptation of methods to local agroecological and socio-economic conditions, building upon existing successful methods and local knowledge, is essential to link biodiversity and agriculture and to meet livelihood needs;
4. Conservation of plant and animal genetic resources -- especially *in situ* efforts -- help protect biodiversity for current livelihood security as well as future needs and ecosystem functions;
5. Reforming genetic research and breeding programs for agricultural biodiversity enhancement is essential and can also have production benefits; and
6. Creating a supportive policy environment - including eliminating incentives for uniform varieties and for pesticides, and implementing policies for secure tenure and local rights to plant genetic resources - is vital for agricultural biodiversity enhancement and for food security.

Practices for soil fertility/health and nutrient cycling also make use of agricultural biodiversity. Good examples include:

- compost from crop residues, tree litter, and other plant/organic residues;
- intercropping and cover crops, particularly legumes, which add nutrients, fix nitrogen, and "pump" nutrients to the soil surface;
- use of mulch and green manures (through collection and spread of crop residues, litter from surrounding areas, and organic materials, and/or under crop);
- integration of earthworms (vermiculture) or other beneficial organisms and biota into the soil to enhance fertility, organic matter, and nutrient recycling; and
- elimination or reduction of agrochemicals -- especially toxic nematicides -- that destroy diverse soil biota, organic material, and valuable soil organisms.

Nutrient Flow



Possible losses
1 Erosion
2 Volatilization
3 Leaching
4 Export (market/gifts)
5 Removal of wastes

Natural grains
6 Rain
7 N fixation
8 Weathering
9 Sediment/dust
10 Blue-green algae

Management options
11 Woody species
12 Feeding concentrates/ minerals
13 Recycling (via livestock, compost, biogas, slurry, etc.)
14 External inputs

Source: ILEIA. 1992. Farming for the Future: An Introduction to Low-External-Input and Sustainable Agriculture. Netherlands.

These kinds of soil-management practices have proven effective and profitable in a variety of farming systems. Agroforestry illustrates "best practice" of using agricultural biodiversity that also generates multiple benefits. In many contexts, the integration of trees into farming systems is highly efficient, and the trees have multiple functions, such as providing fuel, fodder, shade, nutrients, timber for construction, and aiding soil conservation and water retention. (In West Sumatra, agroforestry gardens occupy 50 to 85 percent of the total agricultural land.) Complex forms of agroforestry exhibit forest-like structures, as well as a remarkable degree of plant and animal diversity, combining conservation and natural resource use.

Agroforestry systems in traditional forms also shelter hundreds of plant species, constituting valuable forms of in situ conservation. Many of the practices noted here serve multiple purposes. For example, intercropping provides pest and soil management as well as enhanced income. For example, an estimated 70-90 percent of beans, and 60 percent of maize in South America are intercropped with other crops. Farmers in many other parts of the world have recognized such diversity as valuable sources of soil nutrients, nutrition, and risk reduction -- essential for livelihoods as well as other economic values.

It is a common misperception that agricultural biodiversity enhancement is feasible only in small-scale farms. In fact, experience shows that large production systems also benefit from incorporating these principles and practices. Crop rotations, intercropping, cover crops, integrated pest management techniques, and green manures are the most common methods being used profitably in larger commercial systems, both in the North and in the South. These situations illustrate sustainable approaches to intensification. Examples are found in tea and coffee plantations in the tropics, and in vineyards and orchards in temperate zones. In most large-scale settings, the change from monocultural to diverse systems and practices entails transition costs, and sometimes trade-offs or profit losses for the first two or three years. However, after the initial transition, producers have found that agroecological changes are profitable as well as ecologically-sound for commercial production and that they present new valuable opportunities.

Using Participatory Approaches

The incorporation of farmers' local knowledge, practices, and experimentation is advantageous in efforts in agricultural biodiversity and sustainable agriculture. Experiences have shown that full involvement of local farming practices in agricultural R&D -- through participation and leadership of local people -- has had beneficial outcomes. It is also important to draw upon farmers' own informal methods of experimenting with unfamiliar cultivars and practices.

In Mexico, for example, researchers worked with the local people to re-create chinampas- multicropped, species-diverse gardens developed from reclaimed lakes which were native to the Tabasco region and part of Mexico's pre-Hispanic tradition. A similar project conducted in Veracruz also incorporated the traditional Asiatic system of mixed farming, mixing chinampas with animal husbandry, and aquaculture. These gardens also made more productive use of local resources, and integrated from plant and animal waste, as fertilizers. Yields of such systems equalled or surpassed these of conventional systems.

In Burkina Faso, on the other hand, a soil-conservation and integrated cropping project in Yatenga province was based largely on an indigenous technology of Dogon farmers in Mali for building rock bunds for preventing water run-off. The project added innovations bunds along contour lines -- and revived an indigenous technique called "zai," which is adding compost to holes in which seeds of millet, sorghum, and peanut are planted. These crops are in a multicropping system.

In such efforts, the full participation of women has significant benefits. As managers of biodiversity in and around farming systems in many areas of the world, women can make important contributions and have a promising role in research, development, and conservation of agricultural biodiversity.

In Rwanda, for example, in a plant-breeding project of CIAT (International Center for Tropical Agriculture), scientists worked with women farmers from the early stages of a project on breeding new varieties of beans to suit local peoples' needs. Together, they identified the characteristics desired to improve beans, run experiments, manage and evaluate trials, and make decisions on the trial results. The experiments resulted in stunning outcomes: the varieties selected and tested by women farmers over four seasons performed better than the scientists' own local mixtures 64-89 per cent of the time. The women's selections also produced substantially more beans, with average production increases as high as 38 percent.

The development of participatory approaches requires deliberate measures, training, and time to change the conventional approaches of agricultural R&D.

Policy and Institutional Changes

Although many institutions are already actively involved, more coordination work is needed at all levels to ensure effective reforms and agricultural biodiversity conservation policies that benefit the public, especially the poor. Policy changes that attack the roots of problems and ensure peoples' rights are needed. Ideas needing further attention include:

- ensuring public participation in the development of agricultural and resource use policies;
- eliminating subsidies and credit policies for high-yielding varieties (HYVs);
- fertilizers, and pesticides to encourage the use of more diverse seed types and farming methods;
- policy support and incentives for effective agroecological methods that make sustainable intensification possible;
- reform of tenure and property systems that affect the use of biological resources to ensure that local people have rights and access to necessary resources;
- regulations and incentives to make seed and agro-chemical industries socially responsible;
- development of markets and business opportunities for diverse organic agricultural products; and
- changing consumer demand to favor diverse varieties instead of uniform products.

> Efforts to conserve and enhance agricultural biodiversity must also address the underlying policies that accelerate its loss. Broader policies and institutional structures focussed on agricultural biodiversity conservation drive practical, field-level changes. Many policy initiatives and institutions have already been established to address these issues.

Building complementarity between agriculture and biodiversity will also require changes in agricultural research and development, land use, and breeding approaches.

Contributed by:
Lori Ann Thrupp
(Email: athrupp@igc.org)

Adapted from: Thrupp, L. 1998. Cultivating Diversity: Agrobiodiversity and Food Security. World Resources Institute, Washington, DC., USA.

Sourcebook produced by **CIP-UPWARD**, in partnership with **GTZ** GmbH, **IDRC** of Canada, **IPGRI** and **SEARICE**.