Common Ground, Common Future: Using Ecoagriculture To Raise Food Production And Conserve Wild Biodiversity

Sara J. Scherr*

and Jeffrey A. McNeely**

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* Senior Policy Analyst, Forest Trends and Adjunct Professor, Agricultural and Resource Economics Department, 2200 Symons Hall, University of Maryland, College Park, MD 20742, Tel: (703) 758-2548; (202) 298-3004; Fax: (202) 298-3014; sscherr@arec.umd.edu, sscherr@forest-trends.org

** Chief Scientist, IUCN-The World Conservation Union, Gland, Switzerland, Tel: Fax: jam@hq.iucn.org

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Abstract

The world's biodiversity—the richness of its many species of plants, animals, birds and insects—is on the brink of a mass extinction comparable to the disappearance of the dinosaurs 65 million years ago. Globally, agricultural expansion and intensification are among the leading causes of habitat and species loss. Almost half of the world's major protected areas are themselves heavily used for agriculture, and many of the rest are "islands" in a sea of farmland. Malnutrition is pervasive among people living in at least 16 of the 25 biodiversity "hotspots" where wildlife is most at risk, even as population growth is increasing local demand for food. New forms of agriculture—"ecoagriculture"—are needed that both raise farm production and incomes, and increase wild biodiversity. Ecoagriculture builds on the concept of "ecosystem management", by increasing wildlife habitat in non-farmed patches in agricultural landscapes, and enhancing the habitat quality of productive farmlands themselves. A global study has identified a range of ecoagriculture strategies, and well-documented examples of such farming systems that resulted from new scientific research, farmer-conservationist cooperation and innovation, and policy action. Actions are proposed to promote ecoagriculture on a scale sufficient to make a significant contribution both to conserve global biodiversity and reduce rural poverty.

Introduction

Today, the world is poised on the brink of the largest wave of extinctions since the disappearance of the dinosaurs 65 million years ago.[1] Farming to feed the growing human population-- including modern and traditional farming, ranching, aquaculture, fishing, and forestry-- is one of the chief causes of extinction. More than 1.1 billion people now live within the world's 25 biodiversity "hotspots," areas described by ecologists as the most threatened species-rich regions on Earth. Although globally, protected areas cover nearly 10 percent of the Earth's land surface,[2] these reserves alone are not sufficient to protect wild biodiversity. Protected areas inevitably lose species when surrounded by landscapes that bring alien invasive species, pollution, and development pressure.

Experts predict that the world's demand for food will grow by 50 to 60 percent by 2030.[3] Moreover, nearly half of the world's most threatened species-rich areas contain human populations plagued by extreme malnutrition, with one-fifth or more of local populations undernourished. Unless agricultural practices are improved—among smallholders and large-scale agribusiness alike—habitats and species will continue to disappear at an alarming rate. Unless agricultural production in the tropics increases, poverty will deepen. The challenge is to protect wild species and conserve habitat while *increasing* agricultural production. This paper reviews these challenges and proposes a new approach—*ecoagriculture*—that pursues these joint objectives.

Wild Biodiversity at Risk

Biodiversity refers to the variability of life on Earth, the living species of animals, plants, and microorganisms; the genes they contain; and the ecosystems they help form.[4] Biodiversity helps maintain the essential balance of the Earth's atmosphere, protects watersheds, renews soil, and recycles nutrients.

Relatively few species live in extreme environments, such as sand dunes, hot springs, and deep oceans. Tundra and open seas also have relatively low numbers of species. Higher concentrations of species reside in grasslands and coniferous forests of temperate latitudes; and even more survive in tropical savannas, marshes, and swamps; rivers and lakes; ocean tidal zones; and nutrient-rich marine shoals. The largest concentrations of biological diversity are found in the rainforests of the tropics.

Comprising only 2.3 percent of the entire surface of the Earth, lowland and mountainous tropical rainforests probably hold more than 50 percent of all species.[5] The warm tropics are also home to nearly 60 percent of the world's poorest people. Increasing global demand for products from the tropics and growing human populations in these areas pose the greatest threats to wild biodiversity.

Since pre-historic times, humans have caused three major waves of species extinctions. The first wave resulted primarily from over-hunting as people moved into new regions, such as the Americas and Australia, for the first time. The second wave of extinctions was associated with human settlements of oceanic islands within the past 3,000 years.[6] The third wave of extinctions has been building over the past 400 years and is underway today. Unlike the early waves, it is affecting species of all evolutionary forms and sizes, in every region of the world, and in every kind of habitat. The current wave is not yet catastrophic—just 1 percent of birds and 1.8 percent of mammals have become extinct thus far. But far higher numbers are poised at the precipice of extinction, comprising what might be considered "the living dead." These species include nearly 24 percent of mammals, 12 percent of birds, and almost 14 percent of plants.[7] Many experts believe that biodiversity is more threatened now than at any time since the extinction of the dinosaurs 65 million years ago.[8] Some experts calculate that if present trends continue, at least 25 percent of the world's wild plants and animals could be extinct or vastly reduced in number by the middle of this century, with further losses coming at an accelerating pace.[9]

The 25 most threatened species-rich regions were coined "biodiversity hotspots" by the conservationist Norman Myers. Working with Conservation International, Myers identified hotspots based on the number of endemic species—species found nowhere else—and the degree of threat to the area and its species. Within the 25 hotspots live more than 1.1 billion people—more than 20 percent of the world's population.[10] In the three major tropical wilderness areas that are still relatively sparsely populated (the Upper Amazonia and Guyana Shield in South America; the Congo River Basin in Africa; and the New Guinea-Melanesia complex of islands in the South Pacific), the population is growing at 3.1 percent—double the rate of the rest of the world.[11] These areas could soon become hotspots, if population growth continues at its current rate. Even in areas with little biodiversity, such as deserts, the relatively few species that survive are each particularly important for the people who live there.

The destruction of biodiversity by agriculture creates a vicious cycle that actually undermines agriculture, because wild species are essential to agricultural productivity. Insects and other animals help plants reproduce, contribute to soil fertility, and regulate pest populations. Trees and plants help ensure clean water resources and control floods. Many domestic animals feed on wild plants and grasses for at least part of the year. Wild microorganisms just underground break down organic matter; build soil; help move air, water, and nutrients within soil; and destroy pests. Many plants require pollen from other individuals to set seeds and regenerate. Bats, wild bees, and other insects are the principal pollinators of fruit trees and major staple food crops. These crops include potato, cassava, yams, sweet potato, taro, beans, coffee, and coconut.[12] Declines in populations of wild bees and other pollinators caused by pollution and habitat loss now threaten both the yields of major food crops and the survival of wild plant species. Due to an epidemic of mites, a quarter of North America's wild and domestic honeybees have disappeared since 1988, with a cost to American farmers of US$5.7 billion per year.[13]

Agricultural Causes of Biodiversity Loss

Agricultural land-clearing and habitat pollution are the most important causes of biodiversity loss.

Land-clearing

The loss and fragmentation of native habitats caused by agricultural development and conversion of agricultural lands into urban sprawl are widely recognized as the most serious modern threats to the conservation of biodiversity.[14] Habitat loss and degradation is the most pervasive threat to species, affecting 89 percent of all threatened birds, 83 percent of threatened mammals, and 91 percent of threatened plants.[15]

Over the last four centuries, about half of all tropical forests—home to as much as two-thirds of terrestrial species—have been cleared for agriculture and other human activities. Conversion of land from forest to farm resulted from both industrial farming and logging by large corporations and subsistence farming by poor families. Experts predict the extent of clearing will ultimately eliminate 15 percent of the species contained in the forests. Some of these species have already disappeared, while others will be lost over the next generation.[16]

Some habitat types have been converted much more extensively to agriculture than others. Nearly half of the entire global area of temperate broadleaf and mixed forests and tropical and sub-tropical dry and monsoon broadleaf forests have been converted to agriculture. More than a third of temperate grasslands and savannas are occupied by agriculture, as are more than a quarter of tropical and sub-tropical conifer forests and mangroves.[17]

While the global trend in crop land use appears to be roughly constant—with abandoned or fallow lands roughly equalling new agricultural fields—some parts of the world with high concentrations of biodiversity are suffering egregious losses of species due to the rapid conversion of habitats to agricultural uses. In Southeast Asia, cropland has increased by some 11 million hectares from the early 1980s to the early 1990s, with most cropland claimed from land that was previously forest. Since 1972, more than 500,000 square kilometres of Amazon rainforest—some 13 percent of the entire Amazon region—has been converted to crops and pastures.[18]

Land conversion can split up large habitat systems into separated fragments in which populations are too small to sustain themselves. In addition, the need for large amounts of water to irrigate farmlands—more than 70 percent of all fresh water used globally—often leads to the draining of species-rich wetlands and rivers.[19] In more than half of the nearly 1,000 Wetlands of International Importance listed under the Ramsar Convention, agriculture is considered to be a major cause of change to wetlands.[20]

Farmers over the centuries have made a conscious effort to reduce wild biodiversity, fearing pests, diseases, dangers to livestock, and competition with crops for water, nutrients, and space. To be a "good" farmer meant clearing the wild. Clearing of natural vegetation and creating uniform fields was further encouraged by mechanization and the management cost savings from monocultures.

Run-off of chemical pesticides, fertilisers, and livestock waste

In large areas of the developing world, low-intensity farming systems use little chemical fertilisers and pesticides. In many cases, crop yields are much lower than they could be, causing unnecessary conversion of more and more habitat to farmland. By contrast, in both developed and many developing countries, surplus staple foods, high-value fruits and vegetables, and export crops are produced using intensive farming systems. There, the overuse of fertilisers and pesticides—whose run-off poisons land, water, plants, and animals—is a significant problem.

Globally, application of chemical fertilisers has increased from 14 million tons in 1950 to 137 million tons in 1998.[21] Availability of this low-cost nutrient source for crops is one of the key factors behind historically high growth in crop yields across the world. Meanwhile, the explosive growth in intensive livestock operations in industrialized countries and near big cities in developing countries has led to large accumulations of organic waste materials such as used bedding straw and manure.

Unfortunately, excessive nutrients from inorganic fertilisers and animal waste often flow into lakes, rivers, and coastal zones, where they can cause serious harm to wild biodiversity. For example, in 1,785 bodies of water in 39 states of the United States, livestock waste has been identified as the principal pollutant.[22] Excessive growth of aquatic plant life resulting from overly abundant nutrients (known as "eutrophication") can turn wetlands into wastelands. The resulting long-term increase of aquatic plant life can deplete oxygen over large areas and dramatically alter ecosystems, leading to species extinctions and stress on fisheries. One oxygen-depleted "dead zone" near the outlet of the Mississippi River in the United States covers 18,000 square kilometres, an area larger than Kuwait.[23] Even larger dead zones are reported in the Baltic and Black seas.[24]

In 1990, world sales of pesticides amounted to US$50 billion. Many of these pesticides have made a significant contribution to crop yields.[25] Unfortunately, many pesticides have had a disastrous impact on biodiversity, both through direct ingestion of poisonous chemicals by individual animals and through pollution of freshwater and coastal habitats.[26] Pesticide residues can disrupt the nature of aquatic freshwater and coastal ecosystems, including coral reefs, mangrove forests, and seagrass beds.

More People Means More Agriculture in Many Threatened Regions

Global population continues to grow, especially in developing nations. The global population in 2000 was approximately 6 billion, up from under 1.4 billion in 1900. By the year 2020, global population is likely to reach around 7.7 billion, with well over 80 percent of this growth occurring in developing countries. More people will need more food. The poor spend a high proportion of their incomes on food—somewhere between 50 to 80 cents of every dollar. In addition, as incomes rise around the world, people add protein-rich meat and fish to their diets, which compounds the problem. These foods, as well as other agricultural products bought by high-income consumers, such as cocoa, flowers and vegetables, and raw materials for industrial products, require more natural resources, labour, and land to produce. As a result, some experts predict that the world's people will demand 50 to 60 percent more food by 2030.[27]

The largest population increase will take place in the biodiversity-rich countries of the tropics. More than 70 percent of the world's extreme poor (those who live on less than US$1 a day) live in rural areas.[28] In 19 of the world's 25 biodiversity hotspots, population is growing more rapidly than in the world as a whole.[29] Population in the relatively sparsely populated tropical wilderness areas is, on average, growing at an annual rate of 3.1 percent—over twice the world's average rate of growth. The hotspots are also rapidly urbanizing. Currently, 146 major cities are located in or directly adjacent to a hotspot. Of those cities, 62 have more than 1 million inhabitants.[30] In 19 of the world's 25 biodiversity hotspots, population is growing more rapidly than in the world as a whole.

Rural poverty is concentrated in many of the areas of richest or most threatened biodiversity, especially in the warm tropics. Of the 955 million poor people living in rural areas of developing countries in the mid-1990s, an estimated 630 million lived on marginal agricultural, forested, and arid lands.[31] Some 300 million people live in forested areas and another 200 million live around them, most of them poor.[32] Indigenous ethnic groups, often among the most impoverished and marginalized groups, frequently live on lands where extensive wild biodiversity remains. The rural poor will require additional land to meet their food needs, to grow crops and raise livestock to sell, and for settlements and infrastructure. Most will continue to rely on agriculture as their livelihood.

Of the 1.2 billion people worldwide who earn a dollar a day or less, 75 percent work and live in rural areas; projections suggest that over 60 percent will continue to do so in 2025.[33]

Many of the poor are malnourished. In 1990, nearly half of all children living in the warm, semi-arid tropics and sub-tropics were malnourished, as were more than a third of those in the warm sub-humid and humid tropics. A quarter of children in the cool tropics and sub-tropics with summer rainfall suffer from malnutrition, as do less than a fifth in the humid sub-tropics. Globally, 59 percent of all malnourished children in the developing world reside in the warm tropics, 27 percent in the warm sub-tropics, and 15 percent in the cool tropics and sub-tropics.[34]

At least 16 of the 25 biodiversity hotspots are located in areas with very high malnutrition; they encompass fully one quarter of all the undernourished people in the developing world.[35] Countries that include biodiversity hotspots and in which more than a fifth of their total population is undernourished include: India, Nepal, Thailand, Laos, Cambodia, the Philippines, Papua New Guinea, Democratic Republic of Congo, Republic of Congo, Kenya, Madagascar, Namibia, Cameroon, Bolivia, Haiti, Dominican Republic, Honduras, and Nicaragua. Under-nutrition rates in several large countries—including Mexico, Guatemala, Brazil, Peru, Ecuador, China, Indonesia, and Vietnam—are much higher in the vicinity of biodiversity hot spots than for the country as a whole.[36]

Instead of working to alleviate local hunger or increase sustainability, agricultural policies and research have often been focused on narrow commercial interests. The agricultural systems on which the rural poor most depend have often received the least attention from governments and researchers. In the 1990s, many developing countries cut public spending on agriculture, as donors pressed for smaller government. As a result, during 1990-96, agriculture grew less than 3 percent annually in low-income countries (excluding India and China) and 2 percent in Africa—not enough to keep up with population growth.[37] At the same time, increased concentration of wealth has meant that fighting obesity and other problems of excess food consumption is now a preoccupation in Western countries and among urban elites in developing countries.

Ecotourism and Protected Areas Alone Cannot Save Wild Biodiversity

There are those who argue that tropical countries with rich biodiversity should stop trying to use agriculture as the primary means to feed and employ people. They point out the ecological challenges of farming in the tropics and recommend instead relying on food imports and ecotourism. But this view ignores some basic facts:

First, while tropical farmlands are not always economically competitive with heavily subsidized temperate grain farms, they do have great productive potential and can win out on the international market for many crop types, including rice, coffee, cocoa, oils, fruits, and spices.

Second, most countries in the developing world cannot afford to purchase much of their food from the international market. While agricultural trade has grown dramatically in recent decades, the share of food that is traded—10 percent—has remained relatively constant since 1960. Most food is grown and consumed within national borders, and this is likely to remain the case in most countries.[38]

Third, agriculture is the chief employer and creator of wealth in these areas. For many of the poorest, biodiversity-rich countries, non-agricultural economic options do not appear to be able to generate enough food or income, or to employ enough people to alleviate widespread poverty in the short and medium term. Agriculture is the "engine of growth" for poorer countries. Research in Africa, for example, has shown that despite the growing importance of non-farm activity, prosperity depends on economic linkages with farming. In West Africa, because of multiplier effects, adding US$1 of new farm income resulted in a total increase of household income ranging from US$1.96 in Niger to US$2.88 in Burkina Faso.[39]

At the same time, it is unrealistic to expect isolated protected areas to carry the full responsibility for conserving wild biodiversity. Globally, some 44,197 protected areas cover 13,279,127 square kilometres—nearly 10 percent of the Earth's land surface.[40] Of the 17,229 major reserves, 45 percent (encompassing nearly a fifth of total globally protected areas) are themselves heavily used for agriculture.[41] Many more protected areas are situated within regions of agricultural production. he challenge to protect these areas effectively, in the face of future demands for food and rural livelihoods, seems daunting. Yet if only the existing protected land areas were to continue as wildlife habitat, about 30 to 50 percent of the species would still be lost, according to projections based on accepted ecological principles. This is because the isolated protected areas do not contain large enough populations to maintain the species.[42] Protected areas can become islands of dying biodiversity. Many animals need the ability to migrate seasonally or travel between separated populations in order to avoid extinction. Limited reserve areas cannot fulfil this need, and the lands that would be needed for the massive expansion of protected areas that would be required to avoid high extinction rates are already being used to feed local people and fuel local economies.

The Challenge

As currently practiced in much of the world, agriculture represents a profound threat to wild biodiversity. Yet growing human populations and increasing demand for agricultural products mean that agricultural output must necessarily expand, especially in the tropics, for at least several more decades until the human population begins to stabilize.

Under existing technical, economic, and policy conditions, many rural farmers, especially those in intensive farming systems, face a difficult trade-off between agricultural production and biodiversity. If they want to protect a little more biodiversity, they must sacrifice a lot of production; if they want a little more production, they must sacrifice a lot of biodiversity. The challenge is to expand the amount of food that can be produced on a continuing basis without negative effects—to find better farming technologies and natural resource management practices, better institutions, and better policies, so that the farmers' trade-offs are less stark.[43] Among poor agricultural producers in the developing countries, a lack of advanced technologies often leads to biodiversity loss—more land and resources are used for agriculture than would be needed using more sustainable and productive techniques. In more highly capitalized farming, it is often an excess of modern techniques—methods that create too much pollution or compact the soil—that leads to the loss of biodiversity.

Ecosystems must be managed as a whole with protected areas as reservoirs of wild biodiversity within a "matrix" of land managed to protect its habitat value, while also providing food and income to people. Because agriculture—including annual crops, tree plantations, grazing lands, and forestry—is such a dominant user of land, and because its potential influence on wild biodiversity is so extensive, it needs to have a much higher profile in biodiversity planning. When farmers, environmentalists, and policymakers manage landscapes with both food production and species conservation as essential values, dramatic progress can be made on both fronts.

Ecoagriculture Strategies Save Wild Species While Increasing Agricultural Production

Effective approaches to preserving biodiversity recognize the realities of life in developing nations. Rapid population growth means more hungry mouths to feed. Consumer demand for higher-value foods, as incomes grow, offers real livelihood opportunities for poor farmers. Even farmers who appreciate biodiversity will do what they must to grow enough food to provide for their families, and some will seek to maximize short-term profits even if long-term environmental costs are high. It is thus imperative that biodiversity be saved without sacrificing agricultural production. In fact, the real challenge is to protect wild species and conserve habitat while *increasing* agricultural production and farmer incomes—what we call "ecoagriculture." Innovators around the world are meeting the challenge through successful ecoagriculture strategies, with measurable benefits to farmers and wild biodiversity. Obviously, the potential to integrate different types of wildlife into agricultural landscapes will vary according to the type of farming system. We have identified six successful ecoagriculture strategies, which are described below, each with several examples:

Strategy 1: Create biodiversity reserves that also benefit local farming communities

Creating more protected areas within agricultural regions can keep marginal lands out of production and create habitats where wild species populations can grow. Farmers will support these reserves especially where wild species, such as pollinator bees, have beneficial effects for the productivity of the remaining farms in the area, where they can benefit economically from the reserves, or where they recognize the value of environmental services such as watershed protection.

→ *Protecting rhinos and tigers: Nepalese farmers become conservationists*

In the early 1990s, many of the 275,000 people in the villages around Nepal's Royal Chitwan National Park were hostile to the conservation efforts there. The park is home to the endangered rhinoceros (population around 450) and tiger (now estimated at 107). Every year, the rhinos and tigers caused three to five human deaths, large numbers of cattle losses, and significant damage to crops. Meanwhile, poor villagers wanted to harvest some of the park's resources. In 1993, pioneering legislation created a buffer zone of wild land around the park and dedicated 30 to 50 percent of park revenues for investment in local villages. Local villagers began a community-run elephant-back safari project in the buffer zones, making the area one of most popular tourist destinations in Nepal, attracting 83,000 visitors per year. The park and safari revenues help preserve the park, manage community forests, and improve the lives of local villagers. In its first six months of operation, the safari project provided money to refurbish three schools and a health clinic. Buffer zone forests have also helped to protect villagers from floods and provide shelter against rhinos raiding their crops. Villagers are benefiting from jobs in the buffer zone, and the populations of many wild species are increasing.[44]

→ *Creating new spaces for wild animals in Australia*

In Australia, farming in many sensitive areas has destroyed habitat and degraded soil and water. Working together in Landcare groups, farmers in one community have been able to produce more wheat and feed more sheep—while creating new wild spaces. The farmers have planted over 35,000 trees and have fenced a large area of their land as protected areas to conserve wild animals. Two marsupial species have been reintroduced to the area—the threatened brush-tailed bettong and the endangered Bridle nail-tailed wallaby. To date, around 4,500 active community groups are working in partnership with government, non-governmental organizations, and corporations to address soil, water, and biodiversity degradation through cooperative ecosystem management.[45]

→ *Helping both fish and fishers with marine reserves in the Philippines*

In the Philippines, over-exploitation of coral reef fisheries has become a major problem. In order to help the fisheries recover, one community created three "no-take" reserves where fishing was banned completely. Each protected area has a fishery breeding sanctuary and a surrounding buffer area for ecologically sound fishing. In the first three years since the creation of the no-take zones, species diversity and abundance have significantly increased for many families of fish, especially the favourite targets of fishers. Species diversity increases ranged from 20 to 40 percent, while increases in the numbers of all food fishes ranged from 42 to 293 percent over the three sites. The fishers themselves, initially sceptical, were happy with the results, as total fish yields increased significantly in the areas around the reserves.[46] A survey of 100 "no-take" reserves around the world with complete bans on fishing found average increases of 91 percent in the number of fish, 31 percent in the size of fish, and 23 percent in the number of fish species present.[47] The model has now spread through the Philippines and Indonesia.

Strategy 2: Develop habitat networks in non-farmed areas

The many unused spaces in farmlands can provide habitat for migratory animals or connect species populations in different protected areas, increasing the likelihood of species survival. Even species that do not require large territories can find nesting areas, food, and protective cover in these spaces.

Non-cultivated areas that are potential habitat for wild biodiversity:
Riverbanks and natural waterways
Irrigation canals
Farm, road, and other drainage ways
Uncultivated strips within crop fields
Windbreaks
Border plantings or live fences between plots
Little used or low-productivity croplands and grasslands
Farm or community woodlots
Farm, community, government, or private natural woodlands or forest
Private industrial plantations
Homesteads
Roadsides
Public or private recreational parks
Special sites conserved for cultural value to indigenous people

→ *Planting windbreaks to connect forest patches in Costa Rica*

In a wet, mountainous region of northeast Costa Rica, wild parakeets damaged farmers' coffee trees, and high winds limited dairy productivity and increased calf mortality. In 1989, the Conservation League of Monteverde worked with farmers in 19 communities to create 150 hectares of windbreaks by planting a mix of indigenous and exotic tree species. The windbreaks have increased the herd-carrying capacity of the pastures and have resulted in higher coffee and milk yields. Damage to coffee from wild parakeets has been reduced, because the parakeets prefer the fruit of *colpachi*, one of the species used in the windbreaks. The windbreaks serve as important biological corridors connecting remnant forest patches in the area. One study found seeds of 174 different plant species in the windbreaks. Birds dispersed 95 times more seeds (mainly wild tree species) in the windbreaks than in the surrounding pastures.[48]

→ *Creating wild bird habitat on farms in Britain*

In Britain, farmers have come to the rescue of endangered wildlife with the help of payments for environmental services offered by European governments to farmers who create habitat for wild species on their farms. Under one effective approach, farmers plant specially designed seed mixtures to create wild bird habitat in small strips and plots distributed strategically around the farms. This provides valuable winter-feeding and nesting habitat for farmland birds.[49] In Britain, the 600,000 hectare set-aside has become the third largest land-use type in the lowlands, after grass and cereals.[50]

Strategy 3: Reduce (or reverse) conversion of wild lands to agriculture by increasing farm productivity

Natural habitats are sometimes converted to agricultural uses simply to take advantage of new market opportunities. But often conversion takes place when existing farms cannot produce enough food to meet subsistence demands, when not enough local jobs are available, or when degradation from unsustainable farming practices leads to land abandonment. Two-thirds of the rural population in developing countries live and farm in lower quality "marginal" lands. If productivity can be increased in the more productive areas of these farms, pressure could be eased on marginal lands, which otherwise can be quickly degraded and become useless for both farming and wildlife. Under some circumstances (not all), increasing productivity on lands already being farmed can help prevent farmers from destroying natural habitats in search of better cropland.[51]

→ *Replacing slash-and-burn techniques with higher yield methods in Honduras*

As rural population has grown and croplands have degraded in the hillsides of central Honduras, farmers have cleared large areas of pine forest habitat each year as they seek more land for low-productivity crop production. The loss of forest habitat has sharply reduced wild populations of deer, agouti, raccoon, and squirrels (which have traditionally provided an important source of animal protein for local diets), and other native fauna and flora have declined sharply. Working with local farmers, scientists introduced improved varieties of coffee and vegetables, as well as new methods of fertilizing, irrigating, rotating, and mixing crops that significantly boosted crop yields and employment on the farmers' enhanced land. Higher cash incomes from vegetables and coffee enabled farmers to purchase fertiliser to replenish soil nutrients both in their commercial fields and in fields growing subsistence staple food crops, thus nearly doubling maize yields on permanent fields. This allowed them to abandon marginal fallowed fields, which reverted to forest. Aerial photographic analysis shows that the net area under forest cover remained largely stable in communities that implemented the improved practices. In contrast, communities using traditional methods saw forest cover decline by at least 13 percent and, in some cases, by as much as 20 percent.[52]

→ *Increasing lowland rice yields to reduce hillside farming in the Philippines*

In the Philippine province of Palawan, rising numbers of people have required more food than traditional farming could provide. Population growth has been 4.6 percent per year. Because the best lands for farming—lowland farms that receive their water from rainfall—were already under cultivation, farming expanded into environmentally sensitive areas, promoting acute upland deforestation in areas where farm yields are marginal. To increase agricultural production, the Philippine National Irrigation Administration constructed numerous small-scale communal irrigation systems and upgraded others to supply the lowland farms with a regular supply of water. The lowland farms were then able to produce more food, while employing many workers who had previously been involved in lower-paying upland farming and forest product extraction (such as hunting, charcoal making, and resin collection) in the environmentally sensitive upcountry. As a result, annual forest clearing by upland households declined by 48 percent.[53]

→ *Saving Brazil's Atlantic Forest through improved dairy farming*

Brazil's Atlantic Forest, a unique type of humid sub-tropical forest, is one of the most threatened habitats in the world. The forest is home to lion tamarin monkeys found nowhere else, as well as hundreds of endemic bird species and a rich flora including rare orchids and bromeliads. As a result of five centuries of population growth, land-clearing, and uncontrolled fire used in pasture "management," only 7 percent of the original forest cover remains. Today, small-scale dairy farming is one of the most important economic activities in the area, but the practice has put farmers at odds with conservationists because the cattle require ever-expanding areas of low-quality pasture. Since the mid-1990s, the non-governmental organization Pro-Natura has provided technical assistance to poor dairy farmers to improve farm productivity and incomes. In exchange, the farmers have committed to reforest and regenerate part of their land. Pro-Natura helped farmers to invest in genetic improvement of their dairy herds, use mineral supplements, improve fodder, and produce silage. As a result, participating farmers saw their milk yields triple and their incomes double. The improved pastures were able to feed more cattle, so the area in pasture could be reduced. More than 60 hectares of pasture on 16 farms have already been converted back to forest, and many additional pastures are now candidates for reforestation. In addition, over 50,000 tree seedlings raised by Pro-Natura and municipal governments have been planted on farms and in rural communities.[54]

Strategy 4: Minimize agricultural pollution

In intensive farming systems, pesticides and fertilisers have led to great gains in farm output—but overuse and mismanagement can lead to run-off of chemical by-products and livestock waste that poison water and land. Innovative solutions have been developed to reduce pollution while still controlling pests and enhancing production. Examples include:

→ *Using "buffer strips" to stop pollution in the Chesapeake Bay*

The Chesapeake Bay is one of the richest natural fisheries in the world. Over the past century, pollution—about a third of which comes from agriculture—has led to dramatic declines in fishing harvests, health problems for wildlife and humans, and extinctions of local wildlife. In 1992, the state of Maryland committed to restore the Chesapeake to its former health and productivity. To help heal the bay, farmers along the shore began using "buffer strips"—land allowed to grow wild around their farms—to filter out surplus fertiliser and livestock waste from water that runs off their fields. The strips also provide habitat for many species of wild flora and water birds. By 1995, almost half of Maryland farmers used buffer strips.[55] As a result of these and other innovations, point-source emissions of phosphorus were cut by 56 percent from 1985, while emissions of nitrogen were cut by 35 percent. Many threatened wildlife species have begun to recover.

→ *Reducing the need for chemical pesticides in China*

The rice fields of East Asia have some of world's highest levels of pesticide use. Pesticide pollution has wiped out many species in and around irrigated rice fields and affected the entire food chain, from microorganisms to insects to frogs and other species, even causing the virtual disappearance of vultures and some hawks from many parts of Asia. In Yunnan Province in southern China, farmers have reduced the need for pesticides by using more diverse rice varieties to control rice blast disease. An unusual research trial involving thousands of farmers found that planting more than one variety of rice helped prevent the spread of the disease throughout the entire crop and increased rice yields by 89 percent. Because the rice blast declined by 94 percent, the fields of rice need less costly chemicals and are friendlier to wild biodiversity. In 2000, 42,500 hectares of rice fields were being planted with this method, and 10 other provinces in China are beginning to test the technique.[56]

→ *Reducing pesticide overuse through public education in Vietnam*

Farmers in Vietnam were applying more pesticide to their fields than was necessary to control pests, creating pollution that harmed local habitats. Research led to new recommendations for farmers to reduce pesticide use without sacrificing yields. Disseminated by radio dramas and leaflets, the recommendations have spread to about 92 percent of the Mekong Delta's 2.3 million farm households. Within five years, insecticide applications decreased 72 percent, and rice production increased 27 percent. Reducing pesticide use benefits the many species of frogs and fish that also inhabit the rice fields, the people who depend on these species as a source of protein, and the farmers who wish to increase the profitability of their rice.[57]

→ *Reducing erosion with "natural vegetative strips" in the Philippines*

In the Philippines, erosion is a major problem for farms on hilly lands. Contour hedgerow systems have been widely promoted to reduce erosion and produce organic matter for soil improvement, but Filipino farmers were unwilling to take on the expense of planting these land- and labour-intensive hedgerows. Researchers in the Philippines found that "natural vegetative strips"—rows left uncultivated during contour ploughing so that natural vegetation could grow there—were not only far less expensive, but also controlled erosion nearly as effectively as planted hedgerows.[58] The natural vegetative strips also provide important habitat for wild flora and small fauna.[59] Further research enriched the natural vegetative strips with high-value fruit trees from which farmers could earn cash income. Since natural vegetative strips were first introduced, thousands of farmers have adopted this low-cost technology in the densely populated, steep farmlands of northern Mindanao.

Strategy 5: Modify management of soil, water and vegetation resources

Improvements in the way that farmers manage their natural resources can allow many different wild species to find homes within and around farms with no reductions—and sometimes with increases—in crop yields. Good logging practices can prevent much of the damage caused to forests and increase long-term production. Reduced tillage can lower farming costs while protecting the microorganisms that live in the soil. Improved irrigation efficiency can make more water available for wetlands. Methods can be adapted to labour or capital-intensive farming systems.

→ *Providing habitat for songbirds in flooded fields in California*

In the Sacramento and San Joaquin Valleys of California, the conversion of wetlands to rice fields destroyed the habitats of many species of birds. Now, rice farmers have discovered how their farms can become habitat for many species of endangered songbirds, ducks, and cranes without reducing profits. Rice fields are also serving as habitat for millions of migratory birds, such as Canadian geese, that live in fields during part of their annual migration. Researchers found that fallow rice fields provide habitat nearly as good as natural wetlands for finding food. Because there are few predators in the rice fields, the rice farms actually may be a safer habitat for waterbirds. Some rice farms are now being managed jointly with restored natural wetlands to provide year-round wildlife habitats. The system also accomplishes the growers' objectives of decomposing waste straw and controlling weeds and diseases.[60]

→ *Preserving wetlands through traditional irrigation in Zimbabwe*

In Zimbabwe and other parts of Africa, irrigating fields with conventional systems is prohibitively expensive and drains tons of water from rivers and wetlands that are home to many wild species of plants, animals, and fish. Farmers have developed a promising alternative: irrigated gardens in shallow, seasonally waterlogged depressions called "dambos". They fence a plot and hand-dig water channels between the beds. Researchers studying dambos in Zimbabwe found that yields per unit of land and water were approximately twice as high as in mechanical irrigation systems. They were also much less expensive than formal irrigation systems. Dambo fields often retain some native vegetation and often contain a wide variety of crop species. Cultivation on the dambo with indigenous methods is environmentally sustainable. It does not dry up the dambo, mine the groundwater, or reduce downstream flows, and it helps preserve wetland habitats rich in biodiversity. Approximately 15,000 to 20,000 hectares of dambo gardens are already under productive cultivation in Zimbabwe, and the potential is for up to 80,000 hectares, mainly in the poorer communal areas. Similar wetland landforms are found in Malawi, South Africa, Rwanda, Sierra Leone, and Nigeria.[61]

→ *Providing space for wild species by rotating fields out of production in Kenya and Zambia*

In Africa, farmers in search of increased crop yields have often been encouraged or forced by land scarcity to give up traditional farming methods that support more biodiversity. Traditional fallows—fields left aside from production and allowed to grow wild for a year or longer—have been disappearing in Africa and around the world. Researchers have worked with farmers to develop improved fallows, in which fast-growing trees or shrubs are planted in fallow fields. These increase farm productivity and food security by reducing the need for purchased fertilisers and improving soils with low organic matter. Improved fallows also support a far wider range of wild species than continuous annual planting. Shrub and tree canopies provide protected nesting areas and protection for birds and small mammals. Researchers have developed short-duration fallows that reduce farmers' needs for fertilisers and produce a range of valuable products, such as timber wood. The practice has spread rapidly, even on small farms. In eastern Zambia, 3,000 farmers began to use improved, two-year tree fallows that nearly tripled annual net farm income from maize, their most important crop.[62] In western Kenya several thousand farmers increased yields 21 percent by using one-season shrub fallows that gave better economic returns than continuous cropping.[63]

Strategy 6: Modify farming systems to mimic natural ecosystems

As agriculture has expanded into wild lands, complex natural habitats have been simplified, eliminating many native plants and animals. Farm and forest landscapes can be "designed" to produce food, while providing habitat that is similar in both form and function to wild habitats, mixing perennial and annual crops in ways that conserve natural water systems and provide the types of habitat preferred by wild species.[64]

→ *Trees in pastures help forest birds in Central America*

Interspersing trees in pastures has provided a boon to both farmers and wild species. On more than 9 million hectares of pasture lands in Central America, scattered trees provide shade to cattle, as well as timber, firewood, and fence posts to farmers. In addition, the trees retain rich communities of plants that would otherwise not be present in the agricultural landscape. A study of trees in pastures on 24 farms in Costa Rica found that primary forest trees accounted for 57 percent of all species and a third of all individuals.[65] The trees provide food for migratory birds, such as three-wattled bellbirds, resplendent quetzals, and keel-billed toucans, as they migrate from the Monteverde Reserve down to the Pacific lowlands, as well as to bats and other animals that live on or near the farms.[66]

→ *Creating "agroforests" to provide profits to farmers and homes to wild species in Indonesia*

In Indonesia, the need to preserve wild species in its forests has been in conflict with the economic need to produce food and farm income. Local people have developed a solution: the creation of "agroforests". Agroforests are complex, multi-storey mixtures of planted trees, shrubs, and food crops widely found in the humid tropics that resemble the structure of natural rainforests. About 4 million hectares of agroforests are found today in Indonesia. Agroforests are sustainable, profitable to farmers, and economically important in Indonesia and worldwide. Rubber from agroforests (a quarter of the world's natural rubber) is valued at US$1.9 billion. While reducing the economic pressure on protected forest reserves, agroforests also support significant biodiversity. Rubber agroforests, for example, may contain 250 to 300 plant species other than rubber trees.[67]

→ *Making biodiversity-friendly coffee plantations profitable in Central America*

Shade coffee plantations, in which coffee plants grow in the shade of a wide variety of native tropical trees, are close to moist tropical forests in their species diversity. However, coffee breeds that grow in direct sunlight have been widely promoted and adopted because they have higher yields—despite costing nearly 50 percent more to produce, using more agricultural chemicals, and reducing the usable lifespan of plantations. In Central America, wild animals and plants have lost habitat as trees have been cleared to grow fields of sun coffee bushes. Researchers looking for ways to help shade coffee plantations compete have found that adding a fast-growing native tree species, *Cordia alliodora*, has minimal impact on coffee yields and can be harvested for profitable timber.[68] Other researchers and non-government organizations have actively promoted marketing that provides a financial premium to shade coffee growers.

Policies to Promote Ecoagriculture

The challenge of future landscape management is to simultaneously help preserve wild species, increase the productivity of the land, and empower the rural poor. As the examples of innovators show, ecoagriculture can help to meet this challenge. Successes have been made possible by creative, on-the-ground experimentation and by major advances in science, in areas such as ecology, genetics, agronomy, microbiology, wildlife biology, remote sensing, ecosystem modeling, and inexpensive resource monitoring methods. The ecoagriculture innovations presented in this report resulted from integrating agricultural and ecological research with local farming practices. Interestingly, many of these positive results were achieved serendipitously. The main concerns of innovators (at least initially) were to improve agricultural productivity or sustainability, rather than conserve wild biodiversity. Programs that intentionally pursue these goals together should be capable of achieving even more significant benefits, and achieve these more quickly.

The successful spread of ecoagriculture still has many barriers to overcome. Too few farmers, environmentalists, governments, and non-governmental organizations are aware of the need for ecoagriculture, or of the existence of methods that fulfil that need. As scientific understanding deepens, researchers will find more general principles to aid in the design of new land management systems that produce more food while protecting biodiversity. However, agricultural research institutions have not pursued biodiversity preservation aggressively, preoccupied as they are with the many conventional production challenges that still face the agricultural sector. Universities and other institutions doing ecological research have remained focused on non-agricultural ecosystems. Many government policies and market mechanisms reward farming techniques that create too much waste, use too many harmful chemicals, and use more land than is needed. A global effort is needed to mobilize research and innovation. Ecoagriculture can be encouraged through concrete steps in research, technology development and dissemination, and public policy.

Research and technology development

A major constraint is the lack of production technologies, conservation practices, and resource management systems that can achieve more biodiversity-friendly agriculture while still maintaining desired production levels. In many cases, fundamental information is lacking about ecological interactions between agricultural and wild species that would allow for the design of better systems.

Research can continue to shed new light on the complex relationships between wild biodiversity and agriculture. Using advanced ecological and agricultural methods, as well as on-farm research, ecoagricultural techniques should be sought to help preserve wild species, increase the productivity of the land, and empower farmers, including the rural poor, to be good stewards of the land. Universities, governments, and non-governmental organizations can develop and test new ecoagriculture practices to determine specific solutions to the differing challenges in developing and industrialized nations. This effort will include the search for new crop breeds, fertilisers, and pest controls, as well as new farm and landscape management techniques that can boost agricultural yields while allowing more wild species to survive on and around farms and fisheries. Practical, usable solutions can be found when farmers and researchers work in close cooperation.

Public education can make farmers, environmentalists, and policymakers aware of best practices and encourage ecoagriculture. An important first step will be to bring environmentalists and agriculturalists together to learn more about the interrelationship of wild biodiversity and agriculture and to develop strategies for promoting scientific research and public policies that advance ecoagriculture. Extension programs in developing countries can help organize local people to work together to manage their landscapes and ecosystems for both biodiversity and production goals.

Financial incentives for ecoagriculture

Ecoagriculture systems and practices should be designed so that they are not only profitable for farmers, but *more* profitable than conventional practices. New markets can also be developed for food products that are grown through ecoagriculture, so farmers will be further motivated to take up biodiversity-friendly methods. Markets for sustainably grown products—like the certified "Salmon Safe" label currently in use in the Pacific Northwest of the USA, certified organic produce, certified wood, or "conservation beef"—can be expanded. "Emissions markets" can be created to control agricultural pollutants such as fertiliser, pesticides, and livestock waste run-off. In these markets, legal permission to pollute is traded as a controlled commodity, leading those who can most cheaply curtail pollution to do so in order to sell their permits at a profit to those who face the highest costs to improve their practices. Agroecotourism can be developed, following on the lines of popular educational tours of organic farms now given in Italy. Sustainable development investment portfolios can be created to support ecoagriculture ventures. Transferable development rights can be established to limit total development in a biodiversity-rich area, while allowing landowners to trade development rights with each other. Special efforts are needed to ensure that poorer producers can participate in these markets and that their land and resource rights—including informal rights—are respected.

Payments to farmers should be made where biodiversity is particularly high risk, to provide an incentive for them to adopt ecoagriculture. In some cases, biodiversity-friendly farming simply does not yet produce enough income for local people to afford major land use changes. But the value of protected habitat to other users in the region or to the global community may indeed be much greater than its agricultural use. When this is the case, payments for environmental services can be used to compensate local people for practising ecoagriculture or removing tracts of land from agricultural production for management as wildlife habitat. Tax credits or deductions may be given based on certification of "biodiversity-rich systems." In Chiapas, Mexico, for example, farmers are given assistance payments to shift from unsustainable, low-income land use patterns—mainly extensive fallow systems that involve regular forest clearing—to sustainable forestry, agroforestry, and agricultural systems that support more biodiversity, while sequestering carbon from the atmosphere to reduce global warming. The payments come from revenues derived from an international greenhouse gas mitigation agreement with the International Federation of Automobiles, which is committed to offsetting the carbon emissions resulting from sponsored car races.[69]

Investing in Ecoagriculture

Governments, international development agencies, civil society, and the private sector should make investments in ecoagriculture. In relation to their agricultural production, developed countries spend five times as much as developing countries on agricultural research and development.[70] International aid to developing-country agriculture has declined dramatically for 10 to 15 years. Reversing these trends, and focusing some of the investment in ecoagriculture, would benefit both developing and developed countries.

Over the long term, with considerable research and experimentation, most agriculture could become ecoagriculture in both developed and developing countries, for farmers rich and poor. For the immediate future, ecoagriculture should be promoted where it is needed most urgently. Ecoagriculture should be further developed and instituted quickly in important centres of wild biodiversity in the tropics, around wildlife reserves where agricultural systems are under greatest threat of degradation, and in poor farming areas where people are especially dependent upon wild biodiversity for their livelihoods.

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