COMMON GROUND COMMON FUTURE

HOW ECOAGRICULTURE CAN HELP FEED THE WORLD AND SAVE WILD BIODIVERSITY

By Jeffrey A. McNeely and Sara J. Scherr

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PREFACE

Today, humanity faces a serious challenge. Much of the Earth's biodiversity—the richness of its many species of flora and fauna—is at risk. The areas that are home to the greatest numbers of at-risk species are also home to large numbers of rural people, many of them desperately poor. Local agriculture, as the chief provider of food and livelihoods to these people, must expand to meet rapidly growing world demand, keep up with burgeoning populations, and prevent hunger. Yet agriculture, as currently practiced, is a chief cause of the destruction of valuable habitats, pushing species towards extinction. Agriculture cannot be curtailed, but if policies are not changed, large numbers of endangered species of all types will be lost in the next fifty years.

There are solutions. Around the world, farmers, scientists, and environmentalists are finding methods to conserve habitats and preserve species while boosting food production and improving the incomes of the poor. These innovations are based on the belief—borne out by empirical evidence—that humans and wild species can share common ground and prosper in a common future. Productive farming and effective conservation can occur on the same land through sound science and policy. It is to those innovators, whose stories are told here, that this report is dedicated.

This report was commissioned by Future Harvest, an initiative of 16 food and environmental research centres around the world that work to promote food security, protect the environment, and eliminate poverty. Future Harvest commissions scientific studies on agriculture and its relationship to the environment, economic growth, peace, public health, and world population.

The full study on which this report is based was commissioned from IUCN-The World Conservation Union by Future Harvest as part of its research programme to examine the relationship between agriculture and the environment. This report, and the full study from which it is drawn, mark the beginning of an international effort to raise awareness about the importance of improving food production in order to preserve the environment upon which all life on Earth depends. Working with IUCN and other partners, Future Harvest will bring the results of this study to scientists, policymakers, farmers, and the general public through outreach efforts that include seminars, international meetings, and educational materials. The full study, *Common Ground, Common Future: Ecoagriculture Strategies to Help Feed the World and Save Wild Biodiversity,* by Jeff McNeely and Sara Scherr, will be published during the next year. ■

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] 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.[2]

Farming to feed the growing human population is one of the chief causes of extinction. In much of the tropics and other parts of the world where people share the land with wild plants and animals, agriculture, as currently practiced, represents a profound threat to wild biodiversity. 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. Population in tropical wilderness areas is, on average, growing at an annual rate of 3.1 percent—over twice the world's average rate of growth.[3] Millions of hectares of forests and natural vegetation have been cleared for agricultural use and for harvesting timber and wood fuels. The misuse of pesticides and fertilisers often poisons water and soil, and pollutes coastal areas. Agriculture also fragments the landscape, breaking wild species populations into smaller units that are more vulnerable to extinction. Farmers have generally sought to eliminate wild species from their lands in order to reduce the negative effects of pests, predators, and weeds.

In an effort to protect wild animal and plant species from the threats posed by human development and agriculture, many nations have created protected areas that limit activities such as hunting and farming. Globally, protected areas cover nearly 10 percent of the Earth's land surface.[4] However, research shows that these reserves alone are not sufficient to protect wild biodiversity. Protected areas inevitably lose species when surrounded by landscapes that bring invasive alien species, pollution, and development pressure. According to projections based on accepted ecological principles, if only the currently protected land areas remain as wildlife habitat, between 30 and 50 percent of the species will still be lost, because the reserves do not contain populations large enough to maintain the species.[5]

Environmentalists concerned about wild biodiversity and agriculturalists focused on producing food have often worked at cross-purposes. Environmentalists seek to protect wildlife by expanding protected areas and reducing the intensity of input use in farming. Agriculturalists strive to increase agricultural production in order to meet growing market demand and, in developing countries, to provide livelihoods and protect people from starvation and malnutrition. In order to accomplish all these important goals, both sides will have to recognize that endangered species, essential farmlands, and desperately poor humans often occupy the same ground.

Almost half of the areas currently protected for biodiversity are in regions where agriculture is a major land use, and food production will need to increase in coming decades to keep up with population growth and increasing demand.[6] In fact, some experts predict that the world's demand for food will grow by 50 to 60 percent by 2030.[7] 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. Instead of working to alleviate hunger or increase sustainability, agricultural policies and research have often focused on designing high-productivity systems to produce surpluses for export, with little or no regard for resulting pollution or habitat destruction that threaten wild species. 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.

(continued)

"ECOAGRICULTURE" CAN HELP PRODUCE MORE FOOD AND PROTECT WILD BIODIVERSITY

This report analyses the links between agriculture and biodiversity. It highlights the findings of a major new study that—for the first time—brings together successful methods from around the world that are being used to increase food production and save wild species. These innovative farming and land management techniques are elements of what the authors see as a new type of agriculture: "ecoagriculture." These success stories—brought together from six continents—demonstrate that, while agriculture now presents the greatest threat to species diversity, improvements in agriculture through research can reverse this trend and enable agriculture to help conserve wild biodiversity.

The study from which this report was drawn breaks exciting ground with new information on the relationships between agriculture and biodiversity, farming methods for environmentally sensitive areas, and ways that environmentalists and agriculturalists can work together to manage farms and wildlife areas. Most of the methods can be used by poor as well as rich farmers and will, in many cases, actually raise their incomes. The study documents several dozen cases of ecoagriculture systems from diverse farming systems around the world, of which 18 are summarized below.

This report identifies six key ecoagriculture strategies that can help farmers grow the food they need—without destroying the habitats of the wild species that live on or near their land.

Strategy 1: Reduce habitat destruction by increasing agricultural productivity and sustainability on lands already being farmed
Strategy 2: Enhance wildlife habitat on farms and establish farmland corridors that link uncultivated spaces
Strategy 3: Establish protected areas near farming areas, ranch lands, and fisheries
Strategy 4: Mimic natural habitats by integrating productive perennial plants
Strategy 5: Use farming methods that reduce pollution
Strategy 6: Modify resource management practices to enhance habitat quality in and around farmlands

The research compiled here shows that there are ways to manage the coexistence of wildlife and agriculture and that previously unrecognised synergies can lead to increased food productivity and conservation gains. Much remains to be done to study, perfect, and disseminate ecoagriculture strategies. These next steps include research, public education, the development of markets, the creation of incentives, implementation of local projects, and investment in ecoagriculture by governments, international development agencies, civil society, and the private sector.

Throughout history, humans have shown a tremendous capacity to adapt to changing conditions. While today's wild biodiversity is under unprecedented pressure from humans and the ever-increasing numbers of people who will need more food, promising strategies used in various parts of the world show that ecoagriculture can be productive and profitable while protecting biodiversity. The research described in this report can help the people and endangered species that share common ground to also share a common future. While the principles of ecoagriculture are widely relevant around the world, this report focuses special attention on impoverished areas of the biodiversity-rich tropics. ■

WILD BIODIVERSITY AT RISK AROUND THE WORLD

Biodiversity is important wherever it is found. Biodiversity helps maintain the essential balance of the Earth's atmosphere, protects watersheds, renews soil, and recycles nutrients. In areas with little biodiversity, such as deserts, the relatively few species that survive are each particularly important for the people who live there.

***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.*[8]

***AGRICULTURE** here refers to the wide variety of ways that natural ecosystems are modified to provide goods and services for people through the nurturing of domesticated species of plants and animals, including modern and traditional farming, ranching, aquaculture, fishing, and forestry.*

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.[9] 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.

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 (see map 1 at end of this report).

THE "THIRD WAVE" OF SPECIES EXTINCTIONS IS NOW UNDERWAY

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.[12] The third wave of extinctions is much more recent.

Expansion of people into new areas caused the first two waves of extinctions. In the few millennia after humans first arrived on the Australian continent some 50,000 years ago, the continent lost 86 percent of its marsupial mammals, plus some egg-laying mammals and large lizards. Similarly, in the thousand years after human hunters migrated into North America 12,000 years ago, the continent lost at least 57 species of large mammals—73 percent of all large mammals on the continent. These included horses and camels, giant

NO SUCH THING AS PRISTINE

"Natural" or "wild" biodiversity does not mean "pristine," or untouched by humans. People have profoundly affected virtually all ecosystems. Nearly all tropical forests have been cleared for crops at least once—and probably several times—over the past 10,000 years.[13] Many of the dominant tree species in tropical rainforests were protected or planted when the land was cleared.[14] The difference today is the speed and scale of destruction.

sloths, glyptodonts (animals that resembled giant armadillos), mammoths, and mastodons. Europe suffered roughly comparable losses.

The second wave of extinctions—notable for the loss of bird species—was associated with human settlements of oceanic islands within the past 3,000 years. Nearly all of the diverse and often extraordinary flightless bird species of New Zealand were lost by the mid-1700s, a result of over-hunting and the introduction of pigs, dogs, and rats. More than half a million skeletons of the huge flightless birds known as moas have been found in ancient Maori settlements in New Zealand. Similar processes occurred in Madagascar, Cyprus, the Azores, the Caribbean, and Polynesia, where more than 1,000 bird species—more than 10 percent of the birds then alive on Earth—became extinct after people first arrived on these islands.[15]

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. These species include nearly 24 percent of mammals, 12 percent of birds, and almost 14 percent of plants.[16] Many experts believe that biodiversity is more threatened now than at any time since the extinction of the dinosaurs 65 million years ago.[17]

CLEARING FORESTS TO CREATE FARMLAND CAUSES MOST EXTINCTIONS TODAY

The destruction of habitat is the primary cause of the current wave of extinctions. 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 damage to land already cleared 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. However, the rate of extinctions increases more quickly as habitat areas continue to decline. Thus, if forest clearing continues at 1990s rates, the forests will lose many of their remaining species by the middle of the 21st century.[18]

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.[19] 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.[20]

With agricultural expansion, highly diverse forests and other natural habitats are converted into much simpler pastures or cropping systems. 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 crops and pastures. 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.[21]

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

WILD SPECIES AID AGRICULTURE

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.

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.[22]

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.[23] 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.[24]

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. Later, 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 ALSO HARM WILD SPECIES

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.[25] 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.[26] Excessive growth of aquatic plant life resulting from overly abundant nutrients (known as "eutrophication") can destroy wetland ecosystems. 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.[27] Even larger dead zones are reported in the Baltic and Black seas.[28]

In 1990, world sales of pesticides amounted to US$50 billion. Many of these pesticides have made a significant contribution to crop yields. For example, it is estimated that global wheat losses to pests are half what they would be without any pesticide use.[29] 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.[30] Pesticide residues can disrupt the nature of aquatic freshwater and coastal ecosystems, including coral reefs, mangrove forests, and seagrass beds. ■

BATS, BEES, AND OTHER POLLINATORS: CRITICAL TO AGRICULTURE, THREATENED BY POLLUTION

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.[31] 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.[32]

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.[33]

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.[34] In 19 of the world's 25 biodiversity hotspots, population is growing more rapidly than in the world as a whole.[35] 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.[36]

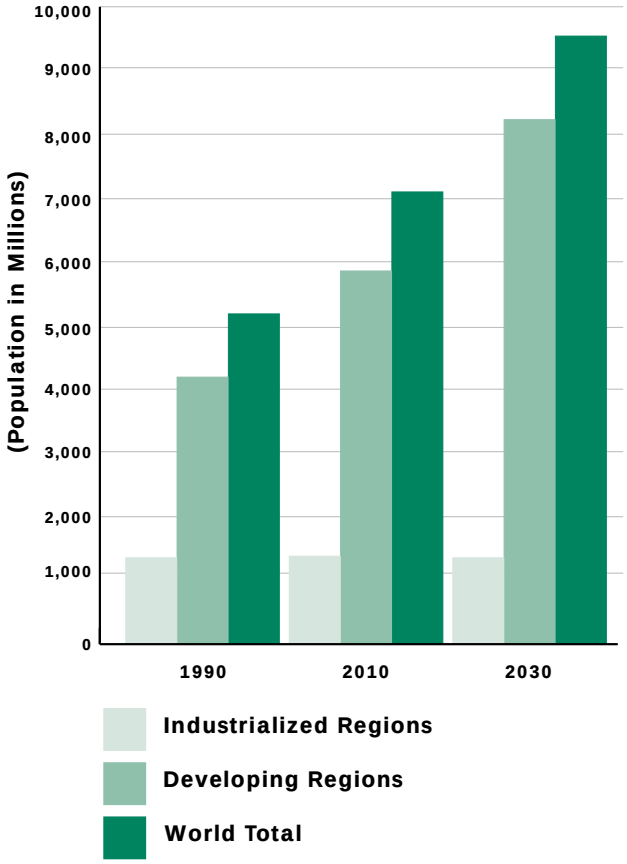
In 19 of the world's 25 biodiversity hotspots, population is growing more rapidly than in the world as a whole.

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.[37] Some 300 million people live in forested areas and another 200 million live around them, most of them poor.[38] 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.[39]

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 nearly 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.[40]

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.[41] 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.[42]

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 annually in Africa—not enough to keep up with population growth.[43] 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. ■



The world's population will grow fastest in the developing world, home to many of the world's richest areas of biodiversity (Lutz, W., C. Prinz, and J. Langgassmer. 1993. World population projections and possible ecological feedbacks. POPNET 12: 1–11; United Nations, 1994 estimate).

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. Agriculture must be promoted to feed people in tropical nations for three main reasons:

First, while tropical farmlands are not always economically competitive with heavily subsidized temperate farms (especially maize and wheat farms), they do have great productive potential for many crop types, including rice, coffee, cocoa, oils, fruits, and spices that are valued in international markets.

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.[44]

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.[45]

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.[46] Of the 17,229 major reserves, 45 percent (encompassing nearly a fifth of total globally protected areas) are themselves heavily used for agriculture.[47] Map 2 at the end of this report shows that many more protected areas are situated within regions of agricultural production. The challenge to protect these areas effectively, in the face of future demands for food and rural livelihoods, seems daunting.

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.[48] 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. ■

LAND OF THE LIVING DEAD: BIODIVERSITY CHANGES IN A SINGAPORE FOREST RESERVE

The fact that nature reserves alone cannot protect wild biodiversity is clearly shown in the experience of the Singapore Botanic Garden, founded in 1859. This small, protected fragment of lowland tropical rainforest has lost 50 percent of its 448 recorded plant species over the 100 years since it was surveyed in the 1880s. Worse, half of the tree species present in the most recent survey were represented by only one or two individuals. Those species may not be reproducing and, in fact, may be among the "living dead"—living out the last generation before extinction.[49] Other species extant but not reproducing include the Javan rhinoceros, the golden Vizcacha rat, and the Hawaiian po'ouli black-masked honeycreeper.[50]

ECOAGRICULTURE: MEETING 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.

ECOAGRICULTURE refers to land-use systems managed for both agricultural production and wild biodiversity conservation.

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 on biodiversity—to find better farming technologies and natural resource management practices, better institutions, and better policies, so that the farmers' trade-offs are less stark.[51] 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, conservationists, and policymakers manage landscapes with both food production and species conservation as essential values, dramatic progress can be made on both fronts. Managing entire ecosystems or entire landscapes with a unified strategy to feed people and protect wild inhabitants simultaneously can be a cost-effective approach to biodiversity conservation.

ECOAGRICULTURE CAN 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. The study on which this report is based documents several dozen cases of ecoagriculture practices in diverse farming systems around the world, 18 of which are summarized in this report.

In these cases, we have identified six successful ecoagriculture strategies, which follow herein.

STRATEGY 1: REDUCE HABITAT DESTRUCTION BY INCREASING AGRICULTURAL PRODUCTIVITY AND SUSTAINABILITY ON LANDS ALREADY BEING FARMED

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.[52]

MOST SPECIES-RICH COUNTRIES: MAMMALS

Country	No. of species
1. Indonesia	515
2. Mexico	449
3. Brazil	428
4. Dem. Rep. of Congo	409
5. China	394
6. Peru	361
7. Colombia	359
8. India	350
9. Uganda	311
10. Tanzania	310

McNeely, Jeffrey A., et al. 1990. Conserving the World's Biological Diversity. *Washington: IUCN, World Resources Institute, Conservation International, World Wildlife Fund-U.S., and World Bank.*

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 photograph 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 over 20 years.[53]

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.[54]

Saving Brazil's Atlantic Forest through improved dairy farming

Brazil's Atlantic Forest, a unique type of humid subtropical 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.[55]

AGRICULTURAL LANDS INCLUDE MANY NON-CULTIVATED AREAS THAT ARE POTENTIAL HABITAT FOR WILD BIODIVERSITY. THESE INCLUDE THE FOLLOWING:

- **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**

STRATEGY 2: ENHANCE WILDLIFE HABITAT ON FARMS AND ESTABLISH FARMLAND CORRIDORS THAT LINK UNCULTIVATED SPACES

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.

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.[56]

MOST SPECIES-RICH COUNTRIES: FLOWERING PLANTS

Countries	No. of Species
1. Brazil	55,000
2. Colombia	45,000
3. China	27,000
4. Mexico	25,000
5. Australia	23,000
6. S. Africa	21,000
7. Indonesia	20,000
8. Venezuela	20,000
9. Peru	20,000
10. Russian Fed.	20,000

McNeely et al., 1990

Creating wild bird habitat on farms 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.[57] In Britain, the 600,000 hectare set-aside has become the third largest land-use type in the lowlands, after grass and cereals.[58]

STRATEGY 3: ESTABLISH PROTECTED AREAS NEAR FARMING AREAS, RANCH LAND, AND FISHERIES

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. The relationship between the park and its neighbours needed to change.

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.[59]

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 a Landcare group, 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 Landcare groups are working in partnership with government, non-governmental organizations, and corporations to address soil, water, and biodiversity degradation through cooperative ecosystem management.[60]

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 after the creation of the no-take zones, species diversity and abundance 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.[61] 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 around the reserve.[62] The model has now spread through the Philippines and Indonesia.

STRATEGY 4: MIMIC NATURAL HABITATS BY INTEGRATING PRODUCTIVE PERENNIAL PLANTS

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.[63]

MOST SPECIES-RICH COUNTRIES: AMPHIBIANS

Countries	No. of Species
1. Brazil	516
2. Colombia	407
3. Ecuador	358
4. Mexico	282
5. Indonesia	270
6. China	265
7. Peru	251
8. Dem. Rep. of Congo	216
9. USA	205
10. Venezuela/Australia	197

McNeely et al., 1990

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.[64] 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.[65]

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.[66]

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.[67] Other researchers and non-government organizations have actively promoted marketing that provides a financial premium to shade coffee growers.

STRATEGY 5: USE FARMING METHODS THAT REDUCE 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.[68] 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 aquatic 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 mixing 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.[69]

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 have 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.[70]

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 in the Philippines 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.[71] The natural vegetative strips also provide important habitat for wild flora and small fauna.[72] Further research showed how to enrich 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 6: MODIFY FARM RESOURCE MANAGEMENT PRACTICES TO ENHANCE HABITAT QUALITY IN AND AROUND FARMLANDS

Improvements in the way that farmers manage their natural resources can allow many different wild species to flourish, 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 that by flooding their fields during the fallow season, their farms can become habitat for many species of endangered songbirds, ducks, and cranes without reducing profits. Flooded 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 have 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.[73]

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 does not interfere with preserving 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.[74]

ORGANIC FARMING AND ECOAGRICULTURE

Organic farming is a type of ecoagriculture that relies on the Earth's own natural resources to grow and process food. Organic practices include cultural and biological pest management and prohibit use of synthetic chemicals in crop production and antibiotics or hormones in livestock production. The primary benefits of organic farming for wild biodiversity are the decreased release of agro-chemical pollutants and improved soil husbandry. Though organic agriculture was previously considered "low yield", advances in research and farming practice have led to large and sustainable yield increases in some systems, even without agrochemicals. While organic farming is an important ecoagriculture approach, it is not the only one. In many cases, farms where agrochemicals are used can still protect precious habitat through careful management (such as using filter strips to prevent excess nutrients from entering waterways), supplemented with other strategies, such as increased crop diversity or establishment of wildlife corridors. In impoverished soils, such as many found in Africa, some chemical fertiliser is often needed in combination with organic nutrients to build up soil organic matter for sustainable production. Strategic, but limited, use of non-persistent pesticides is part of many integrated pest management systems.

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 by 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. Over the past decade, researchers have developed short-duration fallows that reduce farmers' needs for fertilisers and produce a range of valuable products, such as wood for building poles and fuel. 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.[75] In western Kenya several thousand farmers increased yields 21 percent by using one-season shrub fallows that gave better economic returns than continuous cropping.[76] ■

ECOAGRICULTURE CAN HELP FEED THE WORLD'S PEOPLE AND PROTECT BIODIVERSITY

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. A major constraint to progress 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.

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, public policy, and public education. 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, ecoagriculture 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, researchers, and conservationists 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 conservationists 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. Markets can be developed for food products that are grown through ecoagriculture, so farmers will be motivated to take up biodiver-

sity-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. This would ensure that the most economically beneficial development occurs and benefits all stakeholders. 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 may 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.[77]

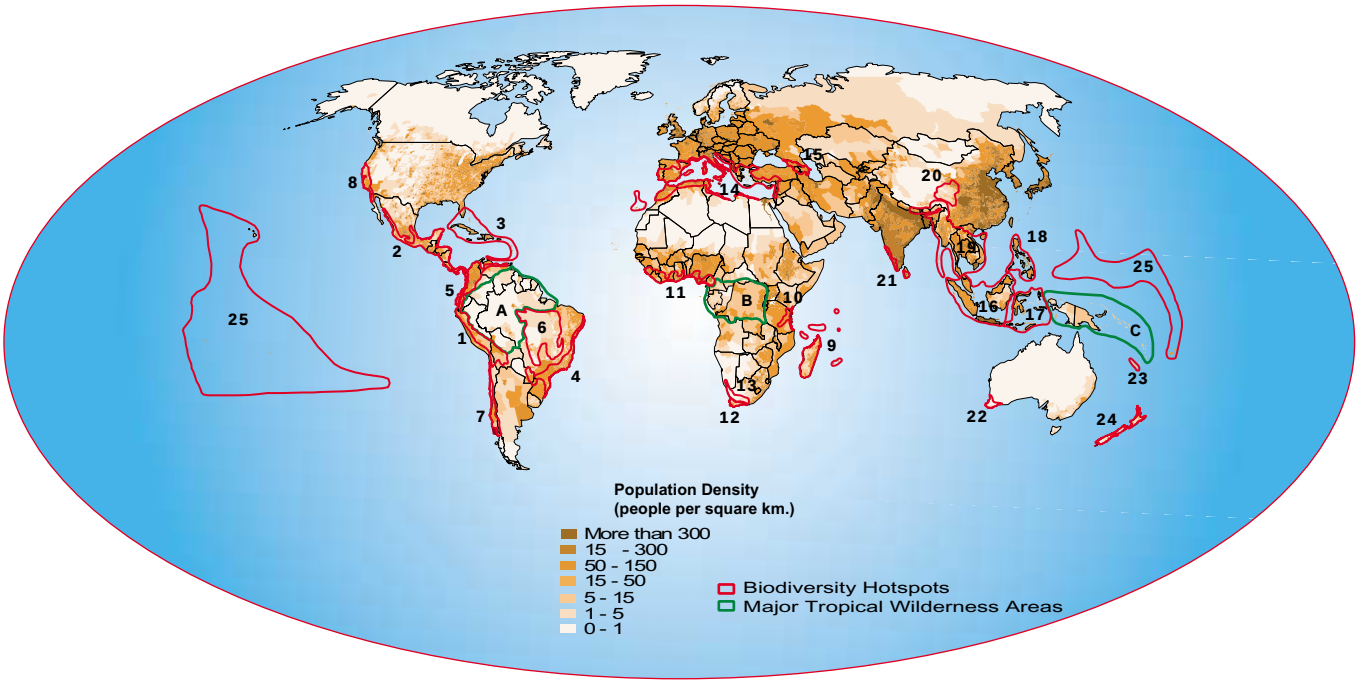
Governments, international development agencies, civil society, and the private sector should make investments in ecoagriculture. In relation to their agricultural production, developed countries spend five times as much as developing countries on agricultural research and development.[78] International 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. For example, experts estimate that every dollar invested by the United States in international wheat research from 1960 to 1993 returned up to 200 times that amount to US farmers and consumers, for a total of up to US$13.4 billion.[79]

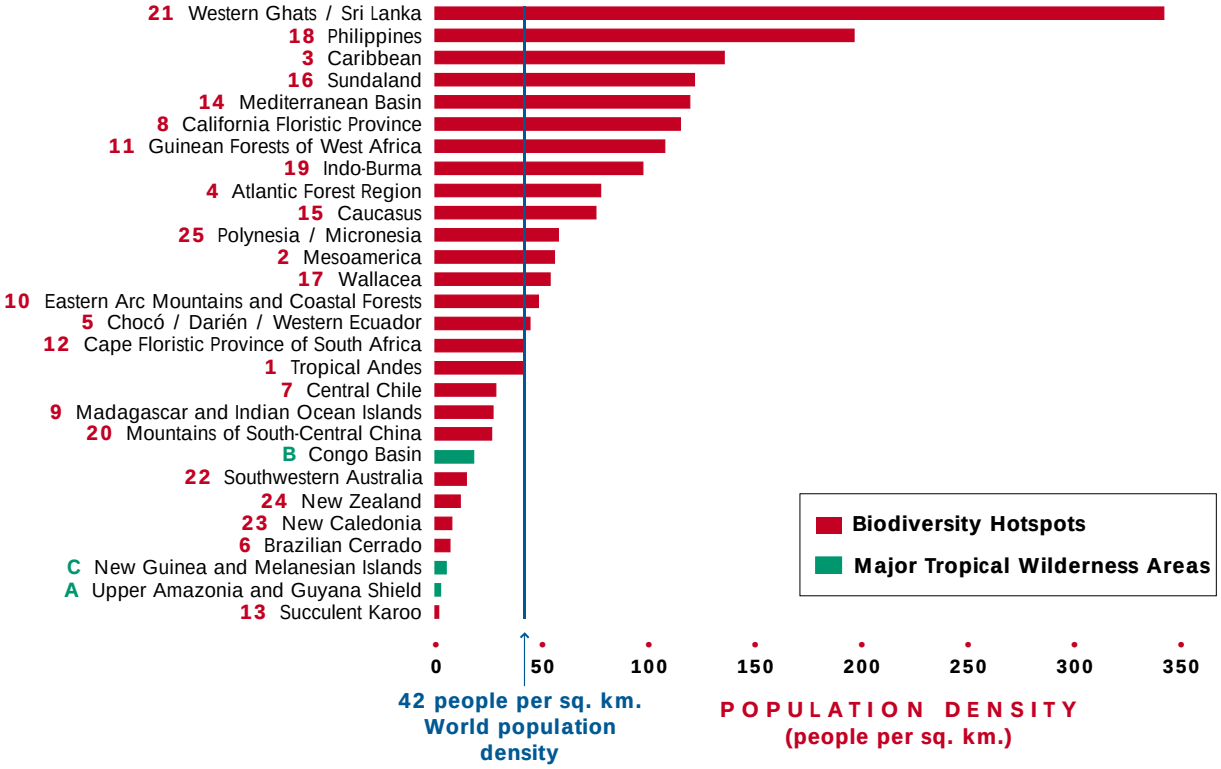
Over the long term, with considerable research and experimentation, most agriculture could become ecoagriculture in both developed and developing countries, for farmers rich and poor. For the immediate future, ecoagriculture should be promoted where it is needed most urgently. Ecoagriculture should be 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.

Throughout history, humans have shown a tremendous capacity to adapt to changing conditions. While today's wild biodiversity is under unprecedented pressure from humans—whose ever-increasing numbers of people will need and demand more food—promising strategies used in various parts of the world show that ecoagriculture can be productive and profitable while protecting biodiversity. The research described in this report can show the way to significant innovations in resource management and agriculture—enabling people and wild species to prosper far into the future. ■

MAP 1—GLOBAL BIODIVERSITY HOTSPOTS

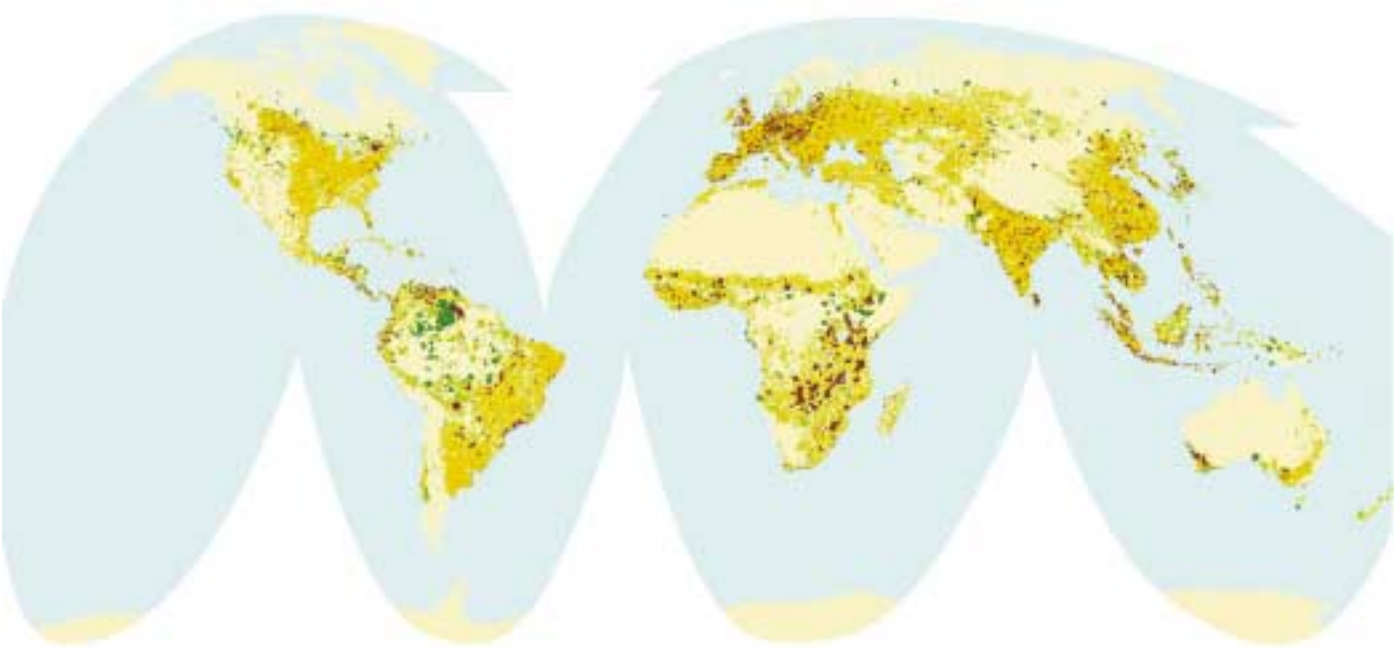
Humans and wild species share the same land in many areas where biodiversity is richest—and most at risk. Agriculture is the biggest cause of species extinctions today. Ecoagriculture is one of the greatest hopes for preserving biodiversity for the future (Cincotta, Richard P., and Robert Engelman. 2000. *Nature's Place: Human Population and the Future of Biological Diversity.* Washington: Courtesy of Population Action International).





MAP 2—GEOGRAPHIC RELATION BETWEEN PROTECTED AREAS AND AGRICULTURAL LAND

Nearly half of the areas currently protected for biodiversity are themselves heavily used for agriculture, and many of them are located in regions where agriculture is a major land use. Neither fencing off wildlife nor restricting farming can save the world's threatened species from extinction (Wood, Stanley, Kate Sebastian, and Sara J. Scherr. 2000. *Pilot Analysis of Global Ecosystems: Agroecosystems.* Washington: International Food Policy Research Institute and the World Resources Institute).



Agricultural share of protected area (percent)

- **1-5**
- **5-30**
- **30-100**
- **Within the extent of agriculture**
- **Outside the extent of agriculture**

NOTES: The extent of agriculture estimate from Pilot Analysis of Global Ecosystems (PAGE) (Wood et al., 2000) includes areas with greater than 30 percent agriculture, based on a reinterpretation of GLCCD, 1998 and USGS EDC, 1999, plus additional irrigated areas based on Doell and Siebert, 1999. The protected areas within the extent of agriculture were derived from *Protected Areas Database* (WCMC, 1999). For protected areas represented only by points, a circular buffer was generated corresponding to the size of the protected area. The share of protected areas that is agricultural was calculated for each protected area using the PAGE agricultural extent.

PROJECTION: Interrupted Goode's Homolosine

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