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STRATEGIES TO ENHANCE WILD BIODIVERSITY IN AGRICULTURAL LANDS

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1. For some time, we have known ways to make agriculture more biodiversity-friendly -- but not how to do so while also increasing yields and farmer income. Even a decade ago, most such practices were adapted from low yield traditional farming systems, or required market price premiums for farming to remain profitable. Some observers still criticize "environmentally-friendly" agriculture for constraining yields and thus indirectly harming biodiversity by requiring the clearing of new lands to meet demand for food (Trewavas 2001). Fortunately, a growing number of innovative researchers, farmers and community planners working together have begun to tackle the agriculture-income-wild biodiversity challenge. We call this new approach "ecoagriculture" – agroecosystems in which landscapes managed for both the production of food and the conservation of wild biodiversity (McNeely and Scherr, in press).

2. This paper describes the genesis and key principles of ecoagriculture. We will describe key strategies to achieve productive ecoagrosystems, and illustrate them with case studies from diverse farming systems around the world. Our examples illustrate that such systems can be practical on a wider scale, socially and economically acceptable to farmers, and relevant in the dynamic economic environments within which farmers must operate. In all of the cases, wild biodiversity increased and farmer incomes and livelihoods improved; in most cases (all of those in developing countries) agricultural product supply also increased. While the long-term viability of these particular "win-win-win" cases has yet to be confirmed, and the geographic extent of many is still limited, they suggest real potential for developing a biodiversity-friendly agriculture that also reduces poverty and meets the challenge of growing food demand. The potential to apply advanced tools and methods of agricultural and environmental science to the challenges of ecoagriculture is huge, but largely unexploited. We are still in the early phases of the "learning curve", and much more research is needed to understand how to rebuild biodiversity in ways compatible with food security and rural development.

The Ecosystem Approach

3. The conceptual framework for ecoagriculture arises from the "ecosystem approach", as developed under the Convention on Biodiversity. The ecosystem approach recognizes that ecosystems must be managed as a whole, with protected areas serving as reservoirs of wild biodiversity in a "matrix" of land that is managed to enhance its habitat value, while also providing a range of benefits to people, from food supply and income to environmental services. Biodiversity protection in an ecosystem management framework calls for a coordinated strategy that clarifies

objectives, goals and investment strategies for protected areas and other land uses that influence wildlife protection. It encourages protected areas to be integrated fully within key planning frameworks, including land use and development plans, national biodiversity strategies and action plans, and strategic plans for relevant sectors (including agriculture, forestry, fisheries, tourism, energy, transport, and even the military). Within this integrated strategy, agricultural lands need to be managed as part of the matrix surrounding protected reserves, while the protected areas are managed as part of the matrix surrounding agricultural lands. Critical habitat features for wild biodiversity are maintained **(Box 1).**

Box 1. Habitat Features Critical for Wild Biodiversity

- Nesting sites
- Protective cover from predators
- Clean water and water
- Access to breeding territory (migratory tracks unimpeded)
- Access to food sources in all seasons (varied habitats)
- Predator-prey balance
- Presence of symbiotes, pollinators and other interdependent species

4. Related terms that are used by some environmental planners include “bioregional planning”, “ecoregion-based conservation”, “the ecosystem approach”, “an ecosystem-based approach”, “integrated conservation and development projects” (ICDP), “biosphere reserves”, “landscape ecology”, and “integrated coastal zone management”; all are based on more comprehensive approaches to resource management. The idea that conservation problems should be addressed in whole ecological or landscape units based on integrated biological, physical, and socio-economic assessments stretches back at least into the 1960s, but it could be argued that this has been the *de facto* approach of stable rural communities throughout history.

5. While significant multiple use is challenging within a small area, over a larger bioregion, various parts of the landscape can be allocated to different dominant land uses, with all land uses contributing to the overall objectives of ecosystem management. Ecosystem management provides a comprehensive framework for bringing together a wide range of different approaches to conservation, helping to integrate or coordinate the various sectors with an interest in biodiversity. The scope of ecosystem management efforts may include activities across the entire land and waterscape, crossing ownership, political, and even international boundaries. Conserving a species of rare or threatened plant involves conserving other parts of its ecosystem, including pollinators, seed dispersers and other organisms that play significant roles in the lifecycle of the plant or animal. Ecosystem analysis can help decision makers consider options for landscape-scale developments**.** The ecosystem approach implies: intersectoral cooperation; decentralization of management to the lowest level appropriate; equitable distribution of benefits; use of adaptive management policies that can deal with uncertainties and are modified in the light of experience and changing conditions; and a multi-disciplinary approach that takes into account scientific, social, and economic issues (Slocombe 1991; Grumbine 1994; and Miller 1996).

6.Our understanding of ecosystem functioning remains very incomplete. For example, we do not know how much biodiversity can be lost from an ecosystem before essential services (such as nutrient cycling) begin to be affected. Some ecologists argue that the health and stability of ecosystems are correlated with biodiversity, so reducing diversity may compromise the integrity of the system. Others contend that ecosystem properties are determined by the functional traits of dominant species, or the composition of functional groups. This implies that at least some species may be redundant. A more balanced view is that while ecosystem processes may reflect the activities of a few dominant species, systems with greater diversity are more likely to contain the most productive species. System resilience is evolutionarily reinforced through the multiple interactions and feedback loops that characterize more complex foodwebs (Levin 1999). Sensible ecosystem management, therefore, calls for conserving all of the elements of the system, recognizing that the incompleteness of our knowledge makes it risky to lose any of the pieces. Managing ecosystems and landscapes with a unified strategy to save most of their inhabitants, can be a cost-effective approach to biodiversity conservation. It addresses the worry that a simple focus on managing populations of particular species of interest will cause us to fall farther and farther behind in the overall effort to conserve biodiversity, as funding is unlikely to ever be sufficient to address the individual needs of every species. Models based on new understanding of ecological relationships can help inform ecosystem management.

Co-existing with Wildlife

7. Our emphasis in this paper is on ways to increase populations of wildlife in the midst of agricultural regions. It is important, however, to note that peaceful co-existence is not always the result. Important conflicts may arise. Increased wild bird populations (e.g., parrots) may consume standing crops or infect poultry with disease. Some wild animals may behave as predators on domestic livestock (e.g., wolves or lions). Some herbivores may raid crops, such as elephants, wild pigs, or rhinos; and some aggressive native or non-native plants may infest farm fields (e.g., weeds such as *Imperata* or *Lantana*). Some species feed on stored crops (eg. rats, mice). Other wildlife may represent a potential threat to human life and health (e.g., poisonous snakes, tigers). Indeed, concerns about such threats led to many of the original decisions by farmers or whole communities to clear native vegetation and remove potential wildlife habitat. Farmer resistance to increasing wildlife populations can be considerable, even among individuals with a strong philosophical commitment to environmental values. Even so, "ecoagriculture" implies active co-management of both agricultural production and wildlife.

8. Ecological research over the past few decades has shown that strategic interventions can often significantly reduce the number of actual conflicts with resident or visiting wildlife. Some wild predators actually serve to control agricultural pests, and are thus beneficial to farmers. Measures that have been implemented successfully in various parts of the world include: modifications in livestock husbandry (everthing from lambing and kidding in sheds to putting bells on their sheep); fencing (species-specific requirements); guarding animals (such as donkeys in sheep and goat flocks); repellents and frightening devices; or maintaining wild populations of snakes or owls to control rats (USDA 1994). Near large wildlife reserves, digging trenches has proven effective in discouraging elephants and rhinos. (see, for example, the Internet Center for Wildlife Damage Management at www.ianr.unl.edu/wildlife/solutions/handbook). Some types of weeds can be controlled with modified grazing regimes, and bird and insect pests has been successfully controlled by establishing plants that provide alternative feed and water sources. Some pests can be controlled by managing pest-predator populations. Selective destruction or removal of problem animals can be

done. Considerable research is required to devise and document the efficacy of wildlife control methods for specific species and ecoagrosystems.

9.Recognition of potential problems is an important part of ecosystem planning, and monitoring of farm-wildlife interactions to enable corrective measures to be taken is an essential parts of the ecosystem management process. Especially promising ways to enhance agriculture-wildlife coexistence are strategies whereby local farming populations benefit directly from the presence of wildlife in their landscapes, through sharing of ecotourism revenues, direct harvesting of wild products, public assistance with wildlife control measures, or payments for biodiversity services provided (Kiss 1990). Where conflicts are unavoidable, mechanisms must be put in place to compensate farmers fairly for their losses (Tisdell 1999).

MAKING SPACE FOR WILDLIFE IN AGRICULTURAL LANDSCAPES

10. Agriculture is often seen as incompatible with wild biodiversity, but several strategies are available to make more space for wildlife in agricultural landscapes. Under some conditions, increasing agricultural productivity on existing farmlands will reduce the expansion of farming onto new lands, or even encourage the contraction of production areas. Meanwhile, in and around existing farmlands it is often possible to identify spaces that can be maintained as protected areas, either as larger reserves, or as habitat networks in production areas. This section suggests several strategies for improving the relationship between agriculture and wild biodiversity, based on practical experience from around the world.

Strategy I: Reduce Land Conversion by Increasing Productivity

11. Agricultural land conversion is a leading threat to wild biodiversity. Pressure for agricultural expansion often results from incentives to expand profitable production systems. But in many cases, the pressure results from stagnant agricultural productivity in the face of rising market and population pressures, lack of agricultural employment that induces the landless to seek unexploited lands, and degradation from unsustainable intensification in lower quality lands that leads to land abandonment. Increases in agricultural productivity and sustainability may help to slow or reverse these latter processes

12. We have compiled three documented cases where increases in agricultural productivity led to a contraction in agricultural lands, and reversion to wild vegetation.. All of these took place in farming systems in marginal lands that relied on short fallows. Intensification of production on the best (irrigated, or more fertile) lands permitted farmers to withdraw from (or slow expansion into) more extensively managed fallow areas. A fourth case describes how assistance to improve their dairy farm productivity enabled farmers to convert some of their pastures back to forest.

Example 1.1. Introduction of cassava in northern Zambia reduces deforestation

13. Most of northern Zambia is open miombo woodland. Most of the nutrients in these soils are leached and acid, not suited for continuous grain cultivation. Using low input systems, farmers can only cultivate them one out of every four years. With medium and high input levels this rises to two and three out of every four years, respectively. The rest of the time farmers must leave the land in

fallow to restore its nutrients, organic mater and soil structure, and control weeds, pests and diseases. Early in the last century, the *chitemene* shifting cultivation system dominated most of northern Zambia. In this system, farmers chop down a large area of trees, pile the trunks onto a smaller area and burn them. Then they grow crops in the ash for a few years. The fire releases the nutrients in the woody biomass and makes them available for crops and provides a seedbed free of weeds. The heat also affects the soil structure, leaving a fine seedbed for finger millet (*Eleusine coracana*), the first crop. In more populated areas, fallow periods were too short for woodland to regenerate, so the forests were gradually replaced by grasslands, and farmers used a modified grass mound system. Grass turf was incorporated into the mounds; finger millet and beans were planted on the spread out mounds after the organic matter decomposed. Uncontrolled fires were common and affected the regrowth of woody vegetation and species composition.

14. In the first half of the 20th century, the British introduced cassava (*Manihot spp.)*, a starchy root crop, to northern Zambia, with the objectives of controlling deforestation and permitting the land to support more than the 2.2-2.5 persons per square kilometer carrying capacity of the chitemene system. Cassava cultivation was labor intensive and greatly improved food security. Farmers typically planted cassava on ridges or mounds as the main crop in "cassava gardens," often alongside other crops during the first year. Although farmers initially resisted the new crop, they discovered its advantages and it eventually became most people's main staple, producing good yields even in poor soils where most other crops failed. Household models suggest that cassava boosted the carrying capacity two to six times relative to the chitemene system, and that households could meet their food requirements with 40 percent less labor input, giving them much larger surpluses for sale. The introduction of cassava reduced deforestation by increasing land productivity in a context where farmers mainly sought to meet their subsistence requirements (Holden 2001).

Example 1.2. Increasing lowland rice yields reduce extensive hillside farming in the Philippines

15. Population growth in the Philippine frontier province of Palawan has been particularly high (4.6 percent per year), and as a result agriculture there has expanded into marginal and environmentally sensitive areas, promoting acute upland deforestation. The area's main staple is rice and its main cash crop is maize; farm size averages 2.6 to 5.1 ha. To intensify and raise agricultural production, the Philippine National Irrigation Administration constructed or upgraded a number of small-scale communal irrigation systems in Palawan. These are in the lowlands, but most are adjacent to inhabited upland forest areas.

16. Household surveys show that irrigation allowed farmers to increase cropping intensity to 1.9 crops per year, whereas on rainfed farms it was only 1.2. They used less family labor and less total labor during each cropping season, but more hired labor. By raising the opportunity cost of labor, intensification of lowland irrigated cropping induced upland farmers to participate less in lower-paying forest-clearing and forest product extraction (hunting, charcoal making, resin collection). After the irrigation systems were installed in the lowlands, annual forest clearing by upland households declined by 48 percent. After the introduction of lowland irrigation, average wage income rose nearly three-fold among upland households that engaged in off-farm work. These positive impacts resulted in part from the fact that the upland area is physically adjacent to the lowland irrigated area, reducing the cost of working off-farm. Also, there was relatively little

investment in labor-saving technology among lowland farmers, which would have partially reversed the employment gains (Shively and Martinez 2001).

Example 1.3. Regenerating native pine forest habitat in Honduras through improved crop technology

17. The central region of Honduras covers about 8,900 square kilometers, of which over 90 percent is rugged hillsides. All was originally forested; about half of the area today is covered by native pine forest, with scattered deciduous forest stands. Significant deforestation occurred prior to the mid-1970s, due to over-logging and frontier agricultural settlement. Since then, commercial logging has been sharply controlled. However, conversion of forest to farmland has continued as a result of a 2.3 percent annual rural population growth, agricultural demand from the even faster-growing capital city nearby, and widespread erosion and nutrient depletion in steep fields used for low-value staple food crops. As a result of loss of forest habitat, wild populations of deer, agouti, raccoon, various squirrels (which have traditionally provided an important source of animal protein for local diets), as well as other native fauna and flora have declined sharply.

18. But a different pattern of land use change has emerged in some of the region's communities, as a result of research and extension by National Coffee Program of Honduras and by the local Pan-American Agricultural School of Zamorano. In the 1980s the Zamorano School identified a wide range of fruit and vegetable varieties suitable for local steepland conditions, and developed integrated nutrient and pest management strategies and sprinkler irrigation and conservation practices. The Coffee Program encouraged coffee-growing communities to intensify production of basic grains, to free up farmland to expand shade coffee area, and plant higher-yielding coffee to replace traditional varieties. In the late 1980s and early 1990s, communities occupying a third of the area of the Central Region adopted and adapted these new technologies. Higher cash incomes from vegetables and coffee enabled farmers to purchase fertilizers to replenish soil nutrients both in their commercial fields and in 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 stable during this period in the coffee-growing communities and declined only slightly in the horticultural communities. This contrasts with at least 13 percent, and in some cases as high as 20 percent, forest cover decline in the basic grains communities. Unlike the extensive farming communities, these did not report a decline in wild game over the period; indeed, their reliance on hunting for game declined (Pender, Scherr and Durón 1999; Scherr 2000).

Example 1.4. Saving Brazil's Atlantic Forest through Improved Dairy Farming

19. Brazil's Atlantic Forest, a unique type of humid sub-tropical forest, is one of the most threatened in the world. Special biodiversity values include the presence of endemic lion tamarin monkeys, hundreds of endemic birds and a rich flora, particularly of rare orchids and bromeliads. Only 7 percent of the original forest cover remains—the result of five centuries of population growth, land-clearing for coffee and livestock (and subsequent degradation), and uncontrolled fire used in pasture "management". Dairy farming is one of the most important economic activities of the rural areas today, but has very low productivity, requiring ever-expanding areas of low-quality pasture.

20. An NGO called Pro-Natura began a project in the early 1990's to work with dairy farmers living around one of the largest remnants of protected Atlantic Forest in the state of Rio de Janeiro: the Desengano State Park, with support from White Martins/Praxair SA. They made a deal with the farmers: they would provide technical assistance to improve dairy farm productivity and incomes; in exchange, the farmers would commit to reforest and regenerate part of their land, and maintain it as a conservation easement. Pro-Natura helped farmers to invest in genetic improvement of their dairy herds, use of mineral supplements, improve fodder and produce silage. As a result, milk yields of participating farmers tripled, and incomes rose by over 100 percent. The improved pastures were sufficient to meet their forage needs, so the area in pasture could be reduced. Over 60 hectares of pasture on 16 farms in northern Rio de Janeiro have so far been converted back to forest, serving as a buffer zone for the protected forest areas, and many additional pastures are now candidates for reforestation, including parts of the Capelinha settlement of the landless peoples movement MST, a former sugarcane plantation. Farmers and local communities supported the reforestation in part for their other ecosystem services, especially water flow regulation and erosion control. Over 50,000 seedlings raised in two tree nurseries managed jointly by Pro-Natura and municipal governments, have been planted on farms and in rural communities (References: www.pronatura.org; Pro-Natura International Newsletter; Reports to Summit and Ford Foundations).

Strategy II: Expand Wild Biodiversity Reserves

21.Large protected areas are likely to remain a central feature of ecosystem management for biodiversity. Large mammals, birds, and trees require large territories for effective reproduction, as do "interior species", i.e., those that do not flourish on the edges or in fragments of habitat, but are dependent on extensive areas of closed-canopy forests. Some conservationists have established the goal of maintaining at least 10 percent of each major habitat type in fully protected reserves; this figure has already been exceeded in some habitat types. A recent study of 93 parks in 22 countries found that 83 percent had been largely successful in controlling encroachment, especially land clearing. In over 60 percent of the parks studied, hunting and grazing pressures were better controlled than in surrounding areas (Bruner *et al*. 2001).

22.Under many circumstances, it will be fully justifiable to take or keep land out of agricultural production in order to establish protected areas. It especially makes sense to establish such sites where the support of local agricultural populations can most easily be obtained. This is likely to be in conditions where:

- the site clearly helps to make farming more productive or sustainable (e.g., by protecting valued pollinators);
- the reserve helps to protect locally-valued environmental services (e.g., good water quality);
- the site offers attractive alternative livelihood options (e.g., by enhancing fishing income or attracting tourists);
- farmers are adequately compensated for the loss of land or helped to make the transition to an equally attractive livelihood option (e.g., with payments for biodiversity services); or
- local communities themselves value the aesthetic, cultural, or recreational aspects of the habitat or of particular species (e.g., to protect sacred groves from development by outsiders).

23. Most protected areas have been established in and around lower-intensity rainfed agricultural systems, where land values and productive potential were relatively low. Even in these areas,

however, their "value" for local people may still be significant, and without local people's "buy-in" to the site boundaries, it has been difficult to ensure those boundaries. Biodiversity conservation initiatives are increasingly being targeted at lands with much higher value for agriculture. In such cases, a much clearer analysis of tradeoffs is needed, and evidence of potential benefits of conservation for the surrounding farmers must be rigorously produced. Otherwise, mechanisms must be found to fairly compensate local people for giving up valuable resources. The main challenge of this strategy is the high politicl and organizational costs to establish and maintain protected areas.

24. Other areas may be protected for *in situ* conservation of genetic diversity. Crop genetic improvement, either by conventional breeding or biotechnology, depends upon access to germplasm that contains promising or desirable traits. The greater the range of genetic resources available, the greater the probability of being successful in that search. Some traits may be found in previously bred lines, but often, particularly for traits such as pest and disease resistance, they are to be found in wild relatives. While large *ex situ* genebanks play an important role in conserving such germplasm, *in situ* conservation allows species to continue to co-evolve in relation to their natural environment and their pests. *In situ* genetic conservation efforts for wild relatives of domesticated crops have sometimes also been linked to establishment of protected areas including working farms (Amaral, Persley and Platais 2001). The basic principle behind a genetic reserve is to conserve sufficient genetic diversity to enable the species to continue evolving, with sufficient research capacity available to enable the resources to be utilized. Gadgil *et al.*, (1996) developed landscape-based conservation plans for several important taxa of plants. Reserves currently exist for maize in Mexico, wheat in Israel, and a country-wide program funded by the Global Environment Fund (GEF) in Turkey (Hodgkin and Arora 2001). India has established a "gene sanctuary" in the Garo Hills for wild relatives of citrus and further sanctuaries are planned for banana, sugarcane, rice and mango (Hoyt 1992). The Chatkal Mountain Biosphere Reserve in Kirgizstan conserves important wild relatives of walnuts, apples, pears, and prunes. These programs seek to preserve farming areas and nearby wildlands, usually with some restrictions on management and harvest to protect wild biodiversity.

25. Communities sometimes take the lead in establishing wildlife reserves. Tonda Wildlife Management Area in Papua New Guinea contains a unique savanna interspersed with riverine gallery forest that provides a globally significant wintering ground for migratory species of waterfowl. It covers 590,000 hectares under customary tenure, with about 1200 inhabitants distributed among 16 villages. It was established in 1975 at the request of the customary landowners for the conservation and controlled utilization of wildlife and other natural resources. The population is mobile and shifting cultivation remains an important part of the local economy, operating on a fallow period of 15-30 years. Customary land owners are allowed to hunt freely, but have agreed that the region between the Bensbach and Morehead Rivers will be closed to hunting, and no vehicles or boats can be used for hunting for anywhere within the site (Alcorn 1993). In Indonesia, "community conservation agreements" have been developed to give rights of use to local communities for buffer zone areas and allow them to prevent outsiders from opening new lands within Sumatra's Kerinci National Park. Villagers are encouraged to grow indigenous tree species after harvesting existing tree crops within the national park; they are also granted 20-year rights of use to the land in order to slow further encroachment (Barber *et al.* 1995).

26. Below we describe three examples in which local farmers have actively cooperated in protected area management, or in some cases initiated establishment of protected areas, in ways that appear to have benefited both wild biodiversity and the community.

Example 2.1. Buffer zones to protect rhinos and tigers in a national park in Nepal

27. Royal Chitwan National Park is located on Nepal's border with India, along the flood plains of the Rapti, Reu and Narayani rivers. It covers 93,200 hectares and its ecological value is greatly extended by the adjacent Parsa Wildlife Reserve (49,900 hectares). The alluvial terraces laid down by the flood plains provide a very productive habitat for grazing mammals, most notably the Indian rhinoceros (population around 450) and several species of deer which provide prey for Nepal's healthiest tiger population (now estimated at 107). The riverine/tall grass habitat there is more extensive than that reported anywhere else in Asia. The 1991 census recorded 275,000 people in 36 Village Development Committees settled around the park's vicinity, and conflicts between the park and local people are a major management problem (Lemkuhl *et al*. 1988). Three to five people are killed each year by rhinos and tigers, domestic cattle may constitute up to 30 percent of tiger kills in settled areas on the periphery of the park, rhinos can significantly damage rice and other crops, and local villagers cast covetous eyes on the park's rich resources (Mishra 1982). People living in the buffer zones around Royal Chitwan National Park may derive up to 80 percent of their needs for firewood and fodder from the forest. The resulting competition between humans and rhinos, tigers, and other large mammals, causes significant conservation problems.

28. Pioneering legislation in 1993 empowered the Government of Nepal to declare areas surrounding Chitwan as a buffer zone, and for local User Group Committees to use 30-50 percent of park revenues for managing community forests, income generation activities, community development work, and so on (Sharma and Wells 1997). A community-based ecotourism project, under the auspices of the Baghmara User Group Committee, was granted land management rights by the Government of Nepal in 1995. In the locally managed forests, the Baghmara Group constructed nature trails for elephant-back safaris and a wildlife viewing tower where tourists can stay overnight. Within the first six months of operation, nearly 8,000 tourists visited the Bagmara wildlife viewing area and generated nearly US$200,000 in revenues, providing money to enable the Baghmara Group to refurbish three schools and a health clinic. Half of annual income will go to support Royal Chitwan National Park and about 5 percent will be retained by the Baghmara Group. An area that had been largely deforested and supported little wildlife prior to this conservation investment has now become one of the most popular tourist destinations in Nepal (83,000 visitors per year), based on elephant-back tours into the riverine grasslands to view rhinos and other species of mammals, birds, and reptiles. Village forests to the north of Chitwan help to protect villagers from Rapti river floods and provide a shelter against rhinos raiding their crops. Some 1240 ha have been given by the Forest Department to the local forest user groups. Villagers receive income of 10,000 rupees per elephant per year ($200) plus $3 per trip. The income has enabled them to build biogas plants and smokeless stoves, provide training to local women's groups, and carry out numerous other activities that reduce human pressure on the park. The local villagers are now convinced that rhinos are a critical tourism attraction and they claim to do whatever they can to support conservation (McNeely 1999).

Example 2.2. Agricultural gene sanctuaries protect wild biodiversity in Turkey

29. Agriculture was born over ten thousand years ago in the Fertile Crescent, which encompasses modern-day southeastern Anatolia, the Asian part of Turkey. Today, more than 8,700 species of vascular plants are found in Turkey, about 30 percent endemic. In the early 1990s a project -- funded under the auspices of the Global Environment Facility (GEF) -- was established to conserve plant genetic resources in their natural habitats, i.e. *in situ*. *In situ* conservation maintains interactions between plants and their natural pests, predators and environmental conditions, and is thus crucial to efforts to provide resistance to new pest and pathogen mutations as they arise. The GEF project in Turkey was the first of its kind in the world to protect multiple wild crop relatives -- both woody and non-woody -- using an integrated, multi-species, multi-site approach.

30. A key feature of the project was the establishment of Gene Management Zones (GMZs) based on ecogeographic surveys and inventories of state-owned land. Protected areas with specific management requirements adapted to individual plant species and environmental conditions, GMZs serve as reserves for one or more endangered or economically important plant species, and are large enough to encompass considerable genetic variation within populations. The GMZ concept was first used in California in the 1960s, but is a new concept to most of the rest of the world. Based on findings on genetic diversity, project planners designated 22 GMZ. Kazdagi National Park was home to 10 GMZs covering five target species, including wild plum, chestnut, Turkey red pine, Anatolian black pine and Kazdagi fir. Seven GMZ were designated at Ceylanpinar State Farm, containing five species of wild wheat relatives. The Bolkar Mountains contained 5 GMZs covering Anatolian black pine, Turkey red pine, two types of Taurus fir and Taurus cedar. A vital element of GMZ management is local community participation, to preserve local people's access to the GMZ, by finding ways to accommodate traditional activities associated with local livelihoods. Grazing in many cases can continue, with some modifications. During some parts of the year, grazing animals actually enhance a GMZ's desired vegetation pattern by shattering the seed and trampling it into the soil for germination the following year ("natural seeding"). Similarly, the local practice of harvesting chestnuts was incorporated into the management plan for the GMZs for this target species. Lessons learned over the course of the project are informing the development a large GEF biodiversity project in Turkey and other projects elsewhere (Diversity 2000).

Example 2.3. Marine reserves help both fish and fishermen in the Philippines

31. Fisheries scientists have learned that by banning fishing completely in certain areas, the overall fish catch in adjacent areas can increase. 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. Those increases occurred within two years of starting the protection scheme. The beneficial effects spilled over into areas where fishing was still permitted. In St. Lucia, for example, a third of the country's fishing grounds were designated no-take areas in 1995. Within three years, commercially important fish stocks had doubled in the seas adjacent to those reserves. A benefit of the reserve approach is that rules are simpler to enforce than with traditional regulations, as inexpensive global positioning systems can be used to monitor compliance (*The Economist*, February 24, 2001, p.83).

32. This concept has been applied in community-level marine source management in several island villages in the Philippines, where over-exploitation of coral reef fisheries has become a major problem. In 1985, Marine Management Committees (MMC) were formed to design new coral reef protection and management schemes that reflected the interest of local people. As marine reserves began to

function and illegal fishermen were repelled, community support for the MMCs has increased. Apart from village-based patrolling of the coral reefs, activities included growing giant clams in the fish sanctuary areas for the community to manage and harvest. Marine reserve guidelines were refined into a legal document adopted by the municipal town councils and MMC members were trained to manage tourism, and establish alternative income schemes such as mat weaving and sea cucumber mariculture. Each of the three protected areas now has a fishery breeding sanctuary and a surrounding buffer area for ecologically sound fishing. Destructive fishing methods, such as using dynamite, cyanide or very small-mesh gillnets, have been effectively banned. Species diversity and abundance have significantly increased for certain families of fish, especially the favorite targets of fishermen; mean percentage increases in species diversity 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. Total fish yield for the fishermen also increased, providing them important economic benefits (Savina and White 1986; McNeely 1988). Recognizing the success of such community initiatives, the government of the Philippines has decentralized and given municipal and city governments responsibility for their marine waters out to 15 kilometers off shore. The MMC model has spread throughout the Philippines and into Indonesia (White and Vogt 2000).

Strategy III: Develop Habitat Networks in Non-farmed Areas

33. In most agricultural landscapes, even those with intensive farming systems, considerable land area is devoted to non-agricultural uses. These include obvious features, like farm wetlands, wood lots, or windbreaks, but also often-ignored sites like schoolyards, temple grounds or graveyards (**Table 1**). There is often more wild biodiversity present than most people realize, and considerable scope to protect or enhance those resources. Thus, a third major strategy to promote biodiversity in agricultural regions is to modify the use of those "in-between" spaces, to provide better ecological conditions for wild biodiversity to thrive.

Table 1: Non-Cultivated Areas in Agricultural Lands: Potential Habitat for Wild Biodiversity

Around water resources:
- Riparian forests and ecosystems
- Natural waterways
- Irrigation canals
- Watershed areas to promote water harvesting
- Farm, road and other drainage ways
- Drainage water used for fish habitat or production
- Stream filter strips (using native and a variety of usable components), to catch sediment and chemical run-off

In and around farm fields:
- Conservation reserve areas taken out of farming
- Uncultivated strips within crop fields as habitat for weeding relatives of crop plants, especially in areas known to be centers of origin or diversity for crop plants
- Windbreaks
- Border plantings or live fences between plots or paddocks, or between farms
- Irrigation bunds
- Vegetative barriers to soil and water movement within crop fields

- Areas taken out of production to control salinity, or abandoned as a result of salinity
- Little used or low-productivity croplands
- Little used or low-productivity grasslands

In and around forest areas:
- Farm or community woodlots
- Farm, community, government or private natural woodlands or forest
- Private industrial plantations

Other sites:
- Homesteads
- Along roadsides
- “Sacred groves” in communal lands, churchyards or graveyards
- Schoolyards
- Agroindustrial or hospital sites
- Agro-ecotourism sites
- Public or private recreational parks
- Special sites conserved for cultural value to indigenous people

34. No matter how carefully they are protected, small reserves will progressively lose their most distinctive species if they are surrounded by a hostile landscape. But if the surrounding matrix is managed with biodiversity in mind, agricultural areas can make a positive contribution to biodiversity. The greatest potential for meeting biodiversity conservation goals is by establishing habitat according to an integrated pattern within and across farms that reflects landscape-scale ecosystem planning. Different types of niches in agricultural landscapes, depending upon their size, shape and location, may support different types of biodiversity. Non-farmed areas can be utilized to provide “patches” of certain types of habitat, or to form “corridors” linking protected areas and enabling species to maintain genetic contact between populations that otherwise would be isolated. This may involve protecting remnant native vegetation or re-establishing wild species, often “keystone” species that provide micro-habitats for associated species. Remnants may include both biological communities that depend on a continuation of traditional land use practices, and survivors of pre-agricultural vegetation. Through various kinds of linkages with the surrounding landscape, protected areas can avoid becoming fragmented and degraded and become more effective in conserving biodiversity.

35. While we still have much to learn about ecological relationships between wild species and agricultural habitats, some general principles are developing. We know that since many vertebrate and insect species use and require two or three habitats diurnally, seasonally, or in their life cycle, the proximity and access to such habitats is critical (Forman 1995). Networks of natural vegetation are particularly effective for maintaining populations of “edge species,” and for connecting breeding stocks in dispersed protected areas. Such networks could potentially meet a significant part of the habitat needs for many types of species, even without large protected areas nearby. In western Australia researchers found that even modest increases in native vegetation from 7 to 10 percent, strategically located, significantly improved habitat value (C.Binning, pers. comm. 3/01).

36.Even small fragments of native habitat can help migratory animals at sites that provide food and shelter for specific periods of the year. Many migratory species of birds, for example, will find these relatively small areas of habitat sufficient to meet their transitory needs. Recent studies of insect-eating birds in isolated fragments in Brazil have indicated that the rapid establishment of tall secondary forests around small fragments linking them back to more extensive primary forest areas and greatly accelerates the recovery of the avian insectivore community to something close to the pre-isolation situation. Thus small fragments can provide a safety net for a significant number of species and their genetic diversity, and a breathing space for conservationists to plan strategies for preventing the loss of the species concerned. Intervention management can then be focussed on species that are particularly sensitive to fragmentation, such as large carnivores, large trees, and epiphytic orchids. For example, Cowlishaw (1999) concludes that 30 percent of forest primate fauna will be lost even if deforestation is controlled, unless corridors to connect protected areas are established.

37. Simple, low-cost landscape interventions can help biodiversity. Farmers can locate and orient crop production lands, corridors and barriers to minimize species loss and promote dispersion of certain species, or to act as natural barriers to avoid the dispersion of harmful populations. For example, farmers managing fallow-based systems can leave strips of natural vegetation when clearing land for temporary farm fields; where these strips are left along the contour, they also markedly reduce erosion caused by clearing and cultivation on steeper slopes. Especially in extensively managed agricultural systems, natural ecological disturbance patterns (such as fire and floods) can be maintained wherever possible, to play their normal role in biodiversity conservation.

38. Many opportunities are also available to improve habitat in and around farms in more densely populated and intensively cultivated farming areas. Farmers already recognize the potential role of perennial vegetation in “in-between” places to stabilize agricultural production. For example, in heavily populated parts of Burundi, Kenya, and Uganda, where farm size is very small, the number of trees on farms is increasing as farmers recognize their value for fodder, fuelwood, boundary delineation, and food production (Sanchez *et al*. 1996). On small farm holdings, perennials planted around farm fields must be carefully screened to ensure they are compatible with agricultural crops, and that any non-native species do not become invasive and thereby harm the local ecosystems or farm production.

39. Many farmers are interested in wildlife conservation, where it can be done without significant financial loss or livelihood risk. For example, farmers have worked to recover native or endemic species now rare in the landscape, by converting low-value unfarmed areas to native vegetation, or preserving biodiversity-rich wetlands. In ranching systems, landowners and community groups have allocated marginal grazing lands to help conserve wild species. For example, a large-scale row- and field-crop farm in central California incorporated over 50 locally adapted species of native perennial grasses, forbs, sedges, rushes, shrubs and trees into various parts of the farm -- on poor quality lands, roadsides, irrigation canals, natural sloughs, tailwater ponds and hedgerows. The 200 hectare farm has 3 ha of 5-10 meter wide multi-species hedgerows that serve as year-round “habitat highways” for deer, fox, bear, coyotes and many other animals, whose populations have dramatically increased. They act as a web connecting the other native habitat patches, as well as supporting beneficial insects that control pests in adjacent row crops. While the farmer faces additional costs for seed and plant materials, special equipment, and increased transportation due to limited local markets for the native grass seeds, cost savings are achieved from reduced pesticide use, labor and tillage. Field studies demonstrated no meaningful difference in crop yields, and implementing practices in unfarmed areas has caused little or no reduction in the land available for

crops (Anderson *et al.* 1996). In Ontario, Canada, a farm survey found that in 1999 77 percent of farmers felt wildlife was "very or somewhat important as a necessary part of the balance of nature", and farmers had invested a total of almost $8 million in enhancing wildlife habitat (Ontario Soil and Crop Improvement Association 2001).

40. It is often desirable to include in plant mixtures species that produce products that are economically valuable, for cash sale or for household consumption. These can help to meet the livelihood needs of farmers, as well as important environmental functions. While they may modify habitats somewhat, their advantage is in providing financial incentives for farmers to maintain them over the long term. By enriching the natural vegetation growing in between farm fields with nutritious food species, the nutritional status of local people can be improved. Native vegetation established in non-farming areas, such as roadsides or schoolyards, can include food or fuel plants to be harvested by the poor. Even if not all vegetation in these "in-between" sites is native, increasing below and above-ground biodiversity will often be ecologically valuable. Inclusion of exotic species that provide products of value to farmers can encourage participation in biodiversity conservation, and may be considered wherever their establishment represents a net improvement in overall habitat quality and does not threaten to become invasive.

41. Three cases illustrate how wildlife habitat can be created "in-between" agricultural production areas, to the mutual benefit of farmers and wild species. They were developed in diverse farming systems, of varying levels of farming intensity. The first three were developed through NGO and international research institutions, while the latter two are large government programs in industrialized countries. Major wildlife conflicts have not yet been reported in any of the cases.

Example 3.1. Farmland corridors in Costa Rica

42. In 1989, the Conservation League of Monteverde, in a wet, mountainous region of northeast Costa Rica of high natural biodiversity value, initiated tree-planting activities with farmers. The project worked in 19 communities, and helped farmers to establish over 150 ha of windbreaks. The windbreaks, a mix of indigenous and exotic tree species, were designed to protect coffee trees and dairy cows from the negative impacts of high winds. The economic returns from windbreaks to the farmers are very high, even without considering timber products, as wind protection results in higher coffee and milk yields, reduced calf mortality and morbidity, and larger herd-carrying capacity of pastures. Nearby farmers also established windbreaks that allowed the production of high-value horticultural crops in the protected fields. Damage to coffee from wild parakeets has been reduced, because the parakeets prefer the fruit of a native tree known as colpachi, one of the species used in the windbreaks. Furthermore, farmers who received benefits from the windbreaks have been more receptive to efforts to protect the remaining natural forest on their farms (Current 1995).

43. Research has shown that the planted windbreaks serve as effective biological corridors connecting remnant forest patches in the Monteverde area. These corridors are especially useful for the migratory species of songbirds that are an essential part of agroecosystems in North America during their summer breeding season. The windbreaks also dramatically increased the deposition of tree and shrub seeds within the agricultural landscape. A careful study of annual "seed rain" patterns in the windbreaks and adjacent patterns found that seeds deposited in the windbreaks represented 174 species and at least 53 plant families. Trees accounted for a third of all species.

Epiphytes and trees were primarily bird-dispersed, whereas herbs were primarily dispersed by wind, gravity or explosive mechanisms, and shrubs by a combination of mechanisms. These windbreaks were only 3-7 meters in width, yet they increased seed deposition by birds over 95-fold relative to the pastures. They were effective despite consisting of primarily exotic, nonfruit-bearing species that offered no food resources for birds. If native, fruit-producing trees were incorporated into the windbreaks, it is likely they would enhance the incoming seed rain and species richness further (Harvey 2000)

Example 3.2. Soil erosion barriers with native plants in the Philippines

44. Contour hedgerows are rows of perennial shrubs established along the contour that have been promoted on steeplands to reduce erosion and produce organic matter for soil improvement. Most contour hedgerows have used exotic grass or shrub species, requiring special nursery development to provide planting materials and considerable labor for establishment. In the early 1990s, researchers at ICRAF in the Philippines, frustrated at farmers' low adoption of hedgerow technology, began a series of studies to identify the most cost-effective approach to contour planting of perennials. They discovered that natural vegetative strips (NVS) -- contour rows left uncultivated during plowing, so that natural vegetation could grow there -- were not only the least expensive (zero cost for planting materials and establishment), but erosion control was nearly as effective as in planted shrub hedgerow technologies. Studies found rows as far apart as 2 to 4 meters elevation distance served nearly as well for erosion control as more closely-spaced rows, while removing much less area from production (Mercado *et al. 1*997). Further research developed a very low-cost method for laying out initial contour lines, and for enriching the natural vegetative strips with high value fruit trees from which farmers could earn cash income.

45. First introduced to NVS in 1996, thousands of farmers have now adopted this low-cost technology in the densely populated steep farmlands of northern Mindanao, the Philippines (**Figure 16**). The natural vegetative strips are not only valuable for maintaining soil fertility on farms and protecting local watersheds, but they also provide important habitat for wild biodiversity. A study of floral composition and community characteristics of fields with NVS confirmed the high diversity of native plant species, while the presence of untilled areas provided habitat for native fauna (Ramiaramanana 1993). Economically profitable timber and fruit tree species in the NVS further expand their habitat value for wildlife.

Example 3.3. Protecting wetlands on U.S. farms

46. The Convention on Wetlands of International Importance, also known as the Ramsar Convention, has some 115 State Parties who have identified nearly 1000 wetlands for the Ramsar List of Wetlands of International Importance. This set of protected areas covers more than 70 million hectares. Globally, some 25 percent of the Ramsar sites contain agricultural lands within them. In Latin America, half the Ramsar sites contain agricultural land, while in Africa and eastern Europe the figure is about 40 percent. Within Ramsar sites, agricultural lands are expected to be managed in ways that are sustainable and "wise".

47. By engaging farmers surrounding important wetland areas, entire wetland ecosystems can be protected. For example, in various parts of the United States, programs have been devised to engage local farmers voluntarily in wetland protection, by enhancing economic values for recreation,

hunting or fishing, and through a variety of conservation agreements between farmers and state agencies and or conservation organizations. With the 1985 Farm Act, wetlands were no longer to be drained, without jeopardizing a farmer's subsidies, but former rigidities in environmental regulation were relaxed, encouraging farmer participation. These programs permit sustainable local use of wetlands and continuous profitable use of areas around the wetlands. Where fields are converted to wetlands, investments are made to improve agricultural productivity in fields outside wetlands (Frazier 1999; Considine, Roe and Willard 1999). The U.S. Wetlands Reserve Program, established in 1990, has protected over 375,000 hectares, and another 100,000 ha have been proposed for enrollment; in 2000, requests for participation were running five hectares for every one enrolled (Audubon 2000). Between the mid-1970s and 1992, the average rate of wetland conversion for agricultural production plummeted from about 165,000 hectares per year to about 13,000 hectares per year, and it is expected that the U.S. will soon experience a net increase in wetlands on the agricultural landscape (OECD 1997:146-7).

48. The European Union's Common Agricultural Policy has sought to reduce over-production and support farmer iincomes. Financial payments have been made to farmers under the condition that some agricultural land would be set aside, essentially taken out of agriculture. In the UK, the 600,000 hectares of set-aside became the third largest land-use type in the lowlands after grass and cereals (Sotherton 1998). Farmers are required to set aside at least 15-18 percent of the land covered. Set-aside has been most successful in benefiting wildlife habitat and plant diversity where the land has a short history of intensive cropping and the seed supply in the soil can still generate a diverse local flora. In other areas, a selected plant cover for birds or game may be more beneficial. Set-aside provides valuable winter feeding and nesting habitat for farmland birds, and after a cereal crop can provide an overwinter cover of stubble which is very beneficial for certain birds. Particularly important has been the introduction of a non-rotational set-aside scheme which enabled farmers to plant specifically designed seed mixtures to create wild bird habitat, and to plant such mixtures in relatively small strips and plots distributed strategically around the farm, thus avoiding large blocks of set-aside. This has allowed the creation of designed game and wildlife habitats, providing cover in winter and breeding habitat in spring. It appears that small blocks scattered across the farm considerably increase the capacity of set-aside to benefit wildlife (OECD 1997b).

Strategy 4: Modify Resource Management Practices

49. Modifications in the management of soil, water and vegetation can reduce the negative and enhance the positive impacts of agricultural systems on wild biodiversity. Increasing agrobiodiversity -- the diversity and spatial mix of crop, tree and livestock components on the farm -- can also enhance habitat value. More diverse, management-intensive, site-tailored farming practices may reduce economies of scale, and may increase farmers' monitoring costs. It thus tends to be more feasible for smaller-scale, resident producers, and for producers in highly heterogeneous areas, where variable farm management across diverse landscape niches is necessary anyway. On the other hand, some management practices like minimum tillage are cost-reducing for large-scale farmers, and scattered trees in pasture are largely scale-neutral.

50. Habitat quality of farmlands can often be improved by changing water, soil and plant resource management in ways that have neutral or even positive effects on agricultural production. There is great scope for increasing use efficiency of both rainwater and irrigation water in agriculture, thus

making more water available for wetlands and wildlife. Better management of drainage water in irrigation systems can prevent salinization of soils and water, and resulting radical changes in habitat quality. Water conservation measures can help to slow the velocity of water moving across the surface, encouraging better percolation through the soils and availability of water for non-crop plants.

51. Soil micro-organisms include macrofauna (earthworms, termites and ants), decomposers, pests and pathogens (fungi, mesofauna, bacteria, nematodes), and microsymbionts (nitrogen-fixers, mycorrhizas). These are pivotal to sustainable agriculture, through their roles in making soil nutrients available to crops through breakdown of organic matter and nitrogen fixation, suppressing soil-borne diseases and pests, detoxification of waste materials and maintaining good soil structure. They also constitute a high proportion of all wild biodiversity. By modifying the frequency and intensity of tillage practices, preventing soil erosion, and maintaining soil organic matter, habitat for these microorganisms can be enhanced, with beneficial effects on crops.

52. Natural vegetation in farmlands can be better managed for both habitat quality and production. Throughout much of the tropics, inorganic fertilizers and pesticides are insufficient for sustainable agricultural production, even where both are available and used in an ecologically sensitive way. To maintain high organic matter requires additional organic biomass application. To control pests, lands must be left out of production -- that is, left in fallow -- for at least short periods. But as agriculture has intensified around the world, traditional medium- and long-term fallows are disappearing. It used to be common wisdom that fallows would have no role in the permanent agriculture of the future. Over the past decade, however, researchers working together with farmers have developed short-duration, improved woody fallows for many tropical agroecosystems. Because they reduce farmers' cash costs for purchase of fertilizers and produce a range of valuable products for household use or sale, the practice has spread rapidly, even on small farms. Short fallows, using trees, shrubs or herbaceous plants, can enhance wild biodiversity by reducing agro-chemical pollution and providing suitable habitat. Fallow systems provide mosaics of spatially interacting fallow and cropped plots (van Noordwijk 1999); these can be an important part of broader land use mosaics to enhance wild biodiversity. To provide the benefits of a fallow, functional or structural biodiversity seems more important than species richness, because of their effect on nutrient recycling and retention, risk reduction with climatic variability or pests, and economic outputs from the fallows themselves (Buresh and Cooper 1999).

53. Careful fire management in shifting cultivation and grazing systems can ensure that timing and scale of fires are appropriate to the ecosystem, and ensure that livestock grazing and feeding systems are improved more generally (de Haan, Steinfeld, and Blackburn 1999). Potentially invasive species of plants can be prevented from establishing, and controlled where they have become a problem. Weeds can be better managed through shade, soil cover, and other means that avoid use of herbicides that can have negative impacts on biodiversity. Biodiversity-friendly measures such as intercropping, crop rotations, cover crops and green manures are widely used, even in large commercial systems. For example, large-scale commercial wine-grape plantations in both the North and South are using a mixture of cover crops between rows of vines, that are mowed and incorporated into the soil several times a year (Thrupp 1998), thereby benefiting both biodiversity and the crop. A study of the northeast region of the U.S. has shown that numbers of wild turkeys, Canadian geese, deer, raccoons, skunks and possums have increased where farmers leave more crop residues in autumn and winter, as well as (Mac *et al*. 1998). Improved forest

management and logging practices (reducing the proportion of area logged or intensity of timber harvest, avoiding use of heavy machines, protecting high-biodiversity habitat niches) can greatly reduce habitat damage and wildlife losses, relative to conventional forestry systems (Putz *et al*. 2000).

54. In many tropical drylands, livestock play a central role in local livelihoods, both for cultural reasons and because crop yields are so precarious in that environment. The establishment of large wildlife reserves in traditional grazing areas, with sharp restrictions on local rights to graze and to destroy wildlife threatening their cattle, has caused conflict and exacerbated poverty. In response, new paradigms have been developed for co-managing domestic livestock and wildlife (Bourn and Blench 1999; IFAD 2001; Kiss 1990). Research has shown that livestock and wildlife exploit different (but overlapping) ecological niches in time and space, and have evolved different physiological and behavioral strategies to reduce competition. Predation and infrastructure damage from large wild mammals can be limited through improved physical protection. Some experts now advocate mixed livestock raising and harvesting of wild herbivores as the most economic use of low-rainfall rangelands, thus maintaining the full natural biodiversity (Western and Pearl 1989). While maintaining income and use values from livestock, the new strategies also benefit pastoralists economically by integrating wildlife into their livelihood strategies, earning income from eco-tourism, safari hunting, park revenue sharing, cash compensation for the risks of wildlife damage, sale of rangeland products to tourists. For example, the CAMPFIRE community-based wildlife management program in Zimbabwe has increased incomes in communal areas by an estimated 15-25 percent (Butler 1995), though household level income increases may be less. Research in Ghana, Kenya, Zimbabwe, and Namibia showed significantly higher economic rates of return on wildlife ranching than from cattle, though the income from tourism, trophy hunting, and wild meat is subject to market saturation (Bojos 1996).

55. By introducing non-competitive, non-predatory species with complementary food needs, polyculture systems in aquaculture can raise productivity, reduce effluents and diversify output. In China, for example, four types of carp are produced in the same pond to take advantage of food resources in this unique ecosystem: silver carp (that feed by filtering phytoplankton), grass carp (that feed on plant-eating macrophytes), common carp (an omnivorous bottom feeder) and bighead carp (that feed by filtering zooplankton) (Naylor *et al.* 2000).

56. Deliberately diversifying farming systems by planting a wider range of crop species and cultivars, for example as a mosaic of small plots or in fully integrated agroforestry systems, can result in much greater wild biodiversity as various forms of wildlife move in to occupy the expanded ecological niches. Underutilized niches on the farm can be filled with economically valuable indigenous species. It is estimated that 20 percent of the world's farmers rely on mixed polyculture systems. Small-scale farmers in various parts of Africa have ingeniously used agrobiodiversity to control land degradation, maintain yields with minimum external inputs, and exploit their variable environment (Tengberg and Stocking 2001). Even where economic forces continue to strongly favor farm specialization, it is often possible to intercrop minor species strategically on the farm, in particular native species that do not compete with economic crops.

57. Mixing species may benefit crops. In the Philippines, for example, simple intercrops of maize and peanuts help to control the maize-stem borer. A spider which as an adult feeds on (and thus

controls) the stem borer caterpillars, feed while young on springtails found in the leaf littler under the peanut plants. The mechanism of control may be more subtle. Aromatic odors from the intercropping of cabbages and tomatoes repel the diamondback moth; and the shading effect of mung bean or sweet potato grown with maize reduces weed growth (Conway 1997). It may also be possible to increase the diversity of animals on farms by domesticating selected game species, using native vegetation for feed. These may provide a more reliable protein source for local people, especially where common domestic species are poorly adapted to local ecologies (National Research Council 1983; 1991).

58. Three cases of improved resource management resulting in biodiversity benefits are highlighted here. While they are drawn from very different agricultural systems, a common element is that the innovations beneficial to wild biodiversity were introduced primarily to increase crop, livestock or forest production or profitability. The biodiversity benefits were collateral, and might reasonably be expected to increase with greater investment and attention.

Example 4.1. Managing flooded rice fields for wildlife habitat

59. Flooded fields apparently provide foraging habitat equivalent to semi-natural wetlands and, because of reduced predation threat, may be a safer habitat for waterbirds. Thus if managed appropriately one of the world's dominant forms of agriculture can provide valuable waterbird habitat. For example, flooded rice fields in California are used by numerous aquatic birds during winter. This habitat functions like more natural wetlands, so increased flooding may help replace the extensive wetlands that occurred in the region prior to agricultural development (Elphick 2000). Researchers compared the habitat value of flooded rice fields and semi-natural wetlands for several species of aquatic bird. The availability of invertebrate species used by birds for food did not differ among habitats. Semi-natural wetlands had less rice grain but more seeds from other plants than the two rice habitats. Predators passed over a feeding area less often in flooded fields than in unflooded fields or semi-natural wetlands, but birds fed more often in flooded fields.

60. Such results are relevant in many parts of the world. In the Sacramento and San Joaquin Valleys of California, farmers working together in the Valley Care program have instituted minor management changes in flooded rice production that have greatly increased their value for tropical migrant shorebirds and waterfowls. These methods were pioneered by Ducks Unlimited, a conservation and hunters' organization. After rice is harvested, rice stubble and straw are rolled and crushed, and then flooded over the winter as an alternative to burning it. The system accomplishes the grower's objective of decomposing waste straw and controlling weeds and diseases, while providing winter habitat and food for waterbirds. Rolling rice straw is economical in comparison with alternative agronomic methods that do not have the same wildlife benefits, and also eliminates air pollution due to burning, which is now tightly regulated. Some restored natural wetlands are being managed jointly with agricultural lands to provide year-round wildlife habitat. Species benefiting are not only waterfowl (like ducks) but also wading birds, shorebirds and cranes. Shorebirds include dunlins (*Calidris alpina*), dowitchers (*Limnodromus scolopaceus*), killdeers (*Charadrius vociferus*), and other sandpipers. Ducks included northern pintails (*Anas acuta*), American widgeons (*A. americana*) and even mallards (*A. platyrhynchos*) and northern shovelers (*A. clypeata*). Snow geese and Ross' geese were also common (Paine, Bias and Kempka 1996). The rice cropping system in the upper coast of Texas creates a heterogeneous mosaic of flood rice wetlands, grazed fallow lands, and ploughed fields, that has dramatically increased use by

migratory birds like the lesser snow geese, the greater white-fronted geese and Canada geese. Over 20 million waterfowl and geese winter on the upper Texas coast, with the bulk of these using freshwater wetlands associated with rice agriculture (Lacher *et al*. 1999).

Example 4.2. Dambo irrigation compatible with wetland preservation

61. Despite widespread low rainfall and drought, less than 15 percent of Africa's irrigation potential has been exploited. This is largely due to problems with financial resources and management effectiveness in existing systems, and concerns about environmental sustainability, as well as high costs for infrastructure development for conventional irrigation and lack of managerial capacity for large systems. Instead of relying on "conventional" (and especially large-scale) irrigation, small-scale irrigation systems under farmer management -- which already comprise an estimated 47 percent of irrigated area in sub-Saharan Africa – is generally more suitable. Dambo irrigation offers particular promise. Dambos are defined as shallow, seasonally waterlogged depressions at or near the head of a drainage network. Wetland landforms like dambos are found in Zimbabwe ('bani'), Malawi and South Africa ('vlei'), Rwanda ('marai'), Sierra Leone ('boli') and Nigeria ('fadama'). Dambo farmers fence a plot and dig a series of water channels between beds, often with a shallow well in one part of the plot. Water is applied through sub-irrigation from water in the root zone, with buckets, hoses and watering cans for supplemental application. Investment is low, making dambos more affordable than conventional irrigation, and return on investment is high. Zimbabwe has 1.28 million hectares of dambo landform (3.6 percent of the total land area); approximately 15-20,000 hectares of dambo gardens are under productive cultivation, and potential for sustainable production is up to 80,000 hectares, mainly in communal areas. However, concerns about erosion and downstream water flows led to 1970s legislation banning dambo cultivation. Though often circumvented, these laws have restricted research, extension and credit for these systems.

62. Researchers studying dambos in Zimbabwe found that yields per unit land and per unit water were approximately twice as high as in formal irrigation systems. Hydrologic measurements show that cultivation on the dambo with indigenous methods (i.e. no deep drains or mechanical pumps) is environmentally sustainable: it does not dry up the dambo, mine the groundwater or reduce downstream flows. This is because gardens do not consume much more water than native vegetation on the dambos, and the water that is not used by the crops flows through to other fields or to a stream at the bottom. Indeed, dambo cultivation is less damaging, in terms of erosion and water releases (because of dense dambo fencing) than dryland cultivation of the watershed above the dambo (Rukuni *et al*. 1994). Impacts on habitat and wildlife appear relatively benign: dambo fields often retain some native vegetation, high crop diversity in small plots, and live fencing of diverse native species, and they alleviate pressure from livestock grazing and compaction. Few dambos are fully cultivated. Dryland cultivation is the main alternative production system of communal smallholders, but is only a tenth as productive as the dambos; thus dambo production can relieve pressure on upland resources, including wildlife habitat (Meinzen-Dick and Makombe 1999). Responding to evidence of the economic contributions and benign environmental effects of dambos, policymakers in southern Africa are re-thinking the potential for "wise use" of dambos.

Example 4.3. Regenerating native forests in India through Joint Forest Management

63. Following Indian Independence in 1947, forest policy emphasized nationalization and commercial utilization of the country's national forests, which account for nearly 23 percent of the

nation's land area. The national government, however, was unable to manage these resources effectively, instead expanding exotic tree species plantations, to supply fast-growing demand. By the 1980s, less than half of this "forest" land had good tree cover, and subsistence forest products had become scarce. In response to this degradation, thousands of communities, primarily in eastern India's tribal forest tracts, took action to protect their degrading forests. They organized hamlet-based forest protection groups who halted cutting and grazing, often initiating rapid regeneration of the natural forests. Researchers and NGOs, recognizing the potential of natural forest regeneration, began to support these village initiatives by developing methods to accelerate natural regeneration (e.g., to encourage seed germination) and manage product extraction sustainably. After a new National Forest Policy was passed in 1988 that identified the need to motivate forest communities to develop and protect their forests, several states allocated partial public forest management authority to forest communities. The National Joint Forest Management resolution in 1990 supported the rights and responsibilities of forest communities (Poffenberger and McGean 1996).

64. Today, an estimated 30,000 village-level committees are protecting and regenerating 10 million hectares of forests (Bahuguna 2000). Village forests are managed to provide a flow of subsistence products like fuelwood, medicines, fodder and condiments, and some income from commercial timber sales. Their biodiversity value is enhanced many-fold relative to their previous degraded state, while biodiversity is also enhanced in adjacent areas because environmental services of forests are recovering. The extent of habitat improvement for many types of wildlife may be greater than that provided by many of India's official protected areas.

POLICIES TO PROMOTE BIODIVERSITY-FRIENDLY AGRICULTURE

65. The previous discussion demonstrated the importance of developing new approaches to improve the relationship between ariculture and wild biodiversity. Experience has shown that new policy and institutional approaches are also essential to making this transition. This section discusses some of the most promising policy innovations that are being developed and tested around the world to support ecoagriculture.

Property Rights for Biodiversity Protection

66. Establishment of clear legal property rights is important for wild biodiversity conservation, to establish the legitimacy of conservation areas and actions. Of particular concern are recognizing local farmers' rights in protected area designation and management, protection of indigenous rights in biodiversity-rich areas, integration of biodiversity considerations into water rights regimes, and rights over wild genetic resources.

Recognizing farmers' rights in protected area designation and management

67. The first generation of protected areas for biodiversity were largely established on public lands or under eminent domain by national government agencies. In many cases, these lands had been actively used, or claimed under customary rights, by local farmers. Losses suffered by local people were particularly important in shifting cultivation systems where fallow lands were presumed to be "unused", and for common lands important for extractive activities. Recognition of this issue has led to the incorporation of safeguards to protect local land and usufruct rights, many of which are

now reflected in the various international environment conditions, including the CBD. Mechanisms for protection and compensation of losses due to protected area status designation are now also part of national legislation in many countries.

68. Formal authority over natural resource management has been devolved to local levels in a number of developing countries over the past decade, such as Bolivia, Zimbabwe, and the Philippines. This reform should make it easier for local people to play a role in designing and managing protected areas. But even where the enabling policy framework exists, the devolution processes poses some immediate problems, given the weaknesses of local authorities. In many countries, local administrators and elected officials have little training in biodiversity and natural resource management, and limited resources at their disposal, while some customary resource managers may be disempowered (Place and Waruhiu 2000). Efforts to strengthen local governance of natural resources can help to protect farmers' rights in natural resource policy.

Indigenous land rights for biodiversity conservation

69. A high proportion of remaining wild biodiversity is found in areas of traditional indigenous settlement where indigenous resource management systems are still functioning. For example, 30 percent of the remaining natural forest in Mexico – and that with the greatest biodiversity -- is on lands controlled by indigenous people (Scherr, White and Kaimowitz 2001). However, in many developing countries, as a result of colonial rule, nationalization of natural resources at independence, or the establishment of protected areas, indigenous claims to natural resources have been denied. In the process, traditional rules regulating resource access have lost their legitimacy, invariably leading to over-exploitation of resources. Even where land tenure for agriculture is secure (through titling or usufruct rights to individuals or communities), indigenous people have often lost rights to manage natural resources.

70. Many recent initiatives have been successful in establishing indigenous people's rights to manage protected areas, to conserve both biodiversity and compatible agricultural systems. Some 80 percent of Latin America's natural forest is now under indigenous control (White and Martin 2001). India's Joint Forest Management policies were discussed in section 5. In Nicaragua, the Miskito people have formed their own NGO to manage the Miskito Coast Protected Area, overseen by a commission including government, regional, NGO and community representatives (Barzetti 1993). In the Philippines, a local NGO established by the Ikalahan Tribe is managing the 14,730 hectare Kalahan reserve in Luesan. They are implementing an integrated program of community forest management and the extraction of non-timber forest products leading to production of jams and jellies from forest fruits, extraction of essential oils, collection and cultivation of flowers and mushrooms, and manufacture of furniture. As early as 1975, the South Pacific Conference on National Parks and Reserves recommended that governments "provide machinery to enable the indigenous people involved to bring their land under protection as national parks or reserves without relinquishing ownership of land, or those rights in it which would not be in conflict with the purposes for which the land was reserved".

71. In Papua New Guinea, the government has established "Wildlife Management Areas" where local communities co-manage resources. Management Committees have instituted measures such as establishing royalties for the taking of game and fish by outsiders; hunting technique restrictions; prohibiting collection of crocodile eggs; fishing technique restrictions, and restrictions on logging

(Eaton 1985). Australia's Uluru National Park (132,566 hectares), a World Heritage site containing the renowned Ayres Rock is jointly managed by the Anangu Aboriginal traditional owners and the Australian National Parks and Wildlife Service using a combination of traditional knowledge and modern techniques.

Water rights for biodiversity protection

72. Complex sets of ground, surface and irrigation system water rights in agricultural areas govern access by farmers for irrigation and for livestock, by industrialists for processing needs, and by settlements and cities to provide domestic water supplies. Only recently has water been legally reserved in some parts of the world to preserve wildlife habitat. State law in California, for example, prohibits water transfers that would have an unreasonable impact on fish, wildlife or other instream uses. The US Endangered Species Act prohibits water transfers that could harm or harass listed species or cause a significant loss of their habitat. In Mexico, the water law of 1992 requires that quality of water required in the discharge be specified in the granting of water rights, and the responsible national agency can restrict water use in the event of damage to ecosystems, overexploitation of aquifers and other environmental impacts. Environmental protection under market mechanisms appears to be no more difficult than under administrative allocation of water (Rosegrant and Gazmuri 1995). Increasingly, processes being developed for negotiating water rights among diverse stakeholders in a catchment or irrigation district include negotiators representing the interests of biodiversity conservation (Meinzen-Dick and Bruns 2000).

Property rights for genetic resources

73. The rising dominance of private companies rather than public sector research institutions in genetic improvement of agricultural species, and the promising commercial prospects for genetically modified organisms (GMOs) in agriculture and other sectors, have ushered in a period of intense debate and conflict about “property rights” for genetic resources. Who “owns” a gene? Who should benefit from the commercial application of that gene? Will patenting of genetic improvements restrict farmers and local people from using and distributing the native plants or indigenously-developed varieties that were the original source of the gene? Should farmers be compensated financially for past or current *in situ* conservation of genetic material from valuable domesticated or wild plants and their wild relatives? The ultimate legal frameworks that are established internationally and nationally to govern these rights will have a profound effect on farmer, agribusiness, environmentalist and research incentives to maintain, control and access biodiversity.

74. With entry into force of the Convention on Biological Diversity (CBD) in 1993, bioprospecting and transfer of benefits arising from the use of genetic resources have become much more complicated. Today's bioprospector must meet the CBD's Article 15 requirements for prior informed consent, access on mutually agreed terms, and the fair and equitable sharing of benefits. They must also address issues of intellectual property rights and technology transfer; obtain appropriate permits to collect, enter land, and export and import materials; satisfy phytosanitary (for plants) and CITES requirements; and ultimately meet regulatory requirements for product safety standards. Thus bioprospecting depends for its success on the shared and realistic expectations of the partners and their ability to meet each other's needs. The Philippines has already introduced restrictive legislation governing access to genetic resources, while access and benefit-sharing measures have been concluded or are under

development in Australia, Fiji, India, Indonesia, Malaysia, Philippines, Thailand, and elsewhere (ten Kate and Laird 1997). In 1994, the Future Harvest International Research Centers formalized their status as trustees, rather than owners, of the *ex situ* germplasm collections they hold by signing legally binding agreements with the United Nations Food and Agriculture Organization. The collection must remain in the public domain and genetic resources should remain available without restriction to all users. A new standard Material Transfer Agreement binds recipients of germplasm held or developed by the Centers to the terms of the FAO agreements (IPGRI 1999).

Pay Farmers for Biodiversity Conservation

75. In many cases, the potential income and other values from ecoagriculture are insufficient for local people to justify adoption. But the value of protected habitat to other users in the region or downstream (for biodiversity or other environmental services), or to the global community, may indeed be much greater than its agricultural use. Examples might be the value of reduced sedimentation for downstream fisheries, reduced salinization on downstream habitat, reduced water pollution on downstream populations' drinking water, increased carbon sequestration reducing global warming, or rare species for concerned conservationists. New approaches to pay farmers and farming communities for these biodiversity and natural habitat values are being developed all around the world.

Tax relief for farmers maintaining biodiversity

76. Tax policy has been widely used in developed countries to promote biodiversity conservation. Differential land taxes are sometimes applied, with biodiversity-conserving uses taxed at the lowest rate or exempt from taxes. In sensitive agricultural landscapes important for wild biodiversity protection, policymakers may also provide income tax deductions or tax credits for farmers who establish and manage "biodiversity-rich systems". These can be defined in terms of protecting natural habitats in and around the farm (for example, riparian zones, native forest remnants, native grasslands), or managing biodiversity-friendly production systems (for example, non-use of pesticides known to harm endangered species, or use of shaded coffee ensuring bird habitat). Periodic certification is needed to confirm eligibility.

Paying farmers to maintain protected areas

77. Farmers and other rural landholders who manage their land and resources to provide environmental services -- like biodiversity -- produce real environmental services of value to their local, national and/or global community. The concept of payments for environmental services implies that farmers should be compensated directly for providing this service. A variety of approaches have been used and are being developed to reward farmers financially for their biodiversity conservation services.

78. Some conservation programs purchase "permanent conservation easements" from farmers, involving purchase of all future rights to develop the land for farming or other purposes, although the property itself remains in the name of the owner. The farmer is compensated for the loss of the future stream of economic benefits that might have come from that piece of land, through a lump sump payment or more often payment of an annuity. To date, these have been used most widely in the developed countries, but are also increasingly being used in developing country projects

supported by private conservation organizations or conservation trust funds. Under some circumstances, direct payments may offer a lower-cost and more targeted alternative to investing to promote more sustainable production systems (Ferraro and Simpson 2000). Several such instruments have been used for biodiversity protection in the state of Minas Gerais, Brazil (Bernardes 1999). A landmark agreement was recently reached between six environmental organizations and a small community in Mexico, by which the community will receive $250,000 over 15 years to preserve the nesting habitat of the western thick-billed parrot (*Rhynchopsitta pachyrhyncha*) for conserving a 2400 hectare old-growth forest near the Cebadillas village in northern Chihuahua

79. Resource conservation agreements (RCAs) are an incentive-based policy instrument that compensates private land owners for the agricultural and non-agricultural development potential of their land, in exchange for conserving and managing wildlife habitat. At present, this is probably the most widely used instrument to conserve biodiversity in farming areas in the United States and Europe. RCAs can be a cost-effective alternative to public or private purchase of land for establishing protected areas, or paying for permanent conservation easements. For example, an evaluation was done of public costs of managing over 350,000 hectares of existing public lands in subtropical southwest Florida considered to be critical to the survival of the Florida Panther (*Felis concolor*). The cost of RCA's on private lands was found to be roughly equivalent to current expenditures for the public lands reviewed; it was one-half to one-quarter as expensive as the estimated costs of purchasing privately-owned lands or paying for permanent conservation easements to conserve privately-owned panther habitat in the region (Main, Roka, and Noss 1999).

80. In the European Union, over 7 million hectares of land were diverted from cereal and oilseed production under short-term set-aside schemes in 1995-96, including more than 15 percent of agricultural and in the UK, Germany, France, Italy and Spain (European Commission 1999). Fallow land in Europe has increased from around 1 million hectares in the early 1980s to over 4 million hectares by the mid-1990s, providing additional opportunities for wildlife. Farmers in the UK are being encouraged to maintain and restore grass margins, conservation headlands, and uncropped field margins to preserve biodiversity. In the US, the Conservation Reserve Program (CRP) includes nearly 15 million hectares of cropland, most of which has been seeded to grass. But CRP also contains 800,000 ha of land managed for special wildlife practices, over 100,000 ha of wetlands, and 1 million hectares of land planted to trees, all of which benefit wild biodiversity (USDA 1997; OECD 1997a). Tree corridors established between formerly isolated woodlots have reduced the dispersal barriers to wildlife and lowered the degree of landscape fragmentation. A Grassland Reserve Program is being established that would compensate farmers and ranchers for easements of grasslands. An "International Habitat Reserve Program" has been proposed as an international counterpart to the set-aside programs of the OECD.

81. To date, most programs use land use as an indicator of biodiversity value. More specific indicators are needed to reduce conservation and transaction costs, and as a wider range of buyers becomes interested in "purchasing" biodiversity services. State Forests of New South Wales, responsible for managing Australia's largest planted forest estate, has pioneered the development of environmental management services and products to facilitate private investment in forestry projects. They are exploring various options to assign a market value to forests planted and managed primarily for biodiversity services, in particular a "biodiversity credit" (**Box 17**) that could

be sold to interested conservation groups, private companies wishing to enhance their "green" image (State Forests 2000).

Paying farmers for ecoagriculture production

82. Farm conservation payment programs are beginning to move towards more targeted strategies that reward biodiversity outcomes in agricultural systems (strategies 4, 5 and 6 in chapter 7). For example, in the United States, conservation and sustainable farming groups are lobbying for the Conservation Security Act, that would reward farmers for good practices on working lands, on the basis of a "Farm Results Index". Some NGOs are paying farmers on the basis of evidence of wild wolf dens on their farms. The Nature Conservancy has developed a program that allows farmers with small-scale forests to put trees (not the land) in a TNC-managed "forest bank" that is managed sustainability, in return for an annual payment, funded from sustainable management of the bank's timber resources (R. Curtis, pers. comm., February 28, 2001). Various NGOs have helped farmers to set up certified "conservation beef", "conservation pork" and "conservation farming" production that can be marketed for a premium, in exchange for agreement to defined conservation practices. In Europe, most countries have "agri-environment" programs which compensate farmers for biodiversity-enhancing agricultural practices. For example, in the UK government subsidies to organic agriculture amounted to US$36 million in 1999, designed to convert over 60,000 ha to organic production by 1000 farmers. A further US$20 million has been earmarked for this purpose over the next six years (OECD 2000).

83. Some payments also support maintenance or expansion of land under agricultural production where such uses are threatened (by market forces or urban development). Such systems are found primarily in Europe, although efforts to maintain peri-urban agriculture are growing in the U.S. and Canada. In Switzerland, the expansion of "ecological compensation areas", including "extensive" and "low-intensive' pasture, floral meadows and other farmland reserved for ecological purposes, now cover almost 8 percent of agricultural land, and have had a positive effect on species diversity, especially insects and beetles. In Austria around 40,000 ha of meadows of high ecological value were signed up for protection, while the UK has targeted ecologically valuable types of semi-improved grassland for maintenance, through the Environmentally Sensitive Area and the Countryside Stewardship schemes. Canada's Permanent Cover Program has helped the prairie bird population to recovery, by increasing grass and forage production (OECD 1998). One of the advantages of environmental payments, de-linked from commodity programs, is that -- unlike traditional payments to leave land out of production -- they are a form of transfer to farmers that is likely to be approved by the World Trade Organization.

Paying farmers for other environmental services compatible with biodiversity

84. Payments to farmers for carbon, water, salinity control or other environmental services could potentially be combined to generate payments high enough to justify farmer investment in ecoagriculture. Various countries are experimenting with payments to land managers in upper watersheds to provide water quality and flow control to downstream water users for urban consumption or irrigation use. Experience from various parts of the world demonstrates that good natural vegetative cover needed to maintain healthy watersheds to produce a steady and reliable source of water, may also provide good biodiversity protection. For example, 7600 ha of cloud forest in the La Tigra National Park in Honduras provide the capital city of Tegucigalpa with 40 percent of its drinking

water at a cost of about 5 percent of its second largest source. Guatopo National Park in Venezuela provides 20,000 liters per second of high-quality water to Caracas, justifying an expenditure of over US$15 million to buy out timber and farming interests in the area. The value of the hydroelectricity produced by Venezuela's Canaima National Park (3 million ha) is equivalent to 144 million barrels of oil per year, about US$2.5 billion at the current price (Garcia 1984).

85. The Kyoto Protocol of the Convention on Climate Change may allow companies to pay farmers and forest owners for carbon sequestration to offset industrial emissions. Pilot projects and private sector offset initiatives are already underway in many parts of the world. To date, some US$12 million has gone to protected areas as part of carbon offset initiatives, involving Belize, Costa Rica, Paraguay, Peru, Bolivia, Ecuador, Guatemala, and Uganda. Such projects typically involve an energy firm, such as Wisconsin Electric Power Company or American Electric Power, and NGOs, such as The Nature Conservancy, CARE or OXFAM. Financial instruments are being developed that would allow credits for these payments to be traded in secondary and future markets, and thus be included in investment portfolios (Wilson, Moura Costa and Stuart 1999). Some such “flexible mechanism” is likely to be included in an eventual international climate agreement.

Markets for Products from Ecoagriculture

86. The power of the market can not only be destructive of biodiversity. It can also be harnessed to protect biodiversity, through commodity markets for wild products, certified biodiversity-friendly products, and agro-ecotourism.

Market development for products from wild species

87. While hundreds of species have been domesticated, they still represent a small fraction of the potentially useful plants and, to a lesser extent, animal species. Domestication was historically limited by technical difficulties in breeding useful and economically desirable characteristics that would make domestic production worthwhile, and the relative abundance and ease of harvesting wild populations. Both of these limitations have been substantially overturned -- one by modern science and the other by the dramatic decline in wild habitat and populations. There is thus a huge potential for domestication and economic trade in wild species that were heretofore ignored (Leakey 1999). Such developments could help to conserve genetic diversity, reduce pressure on remaining wild populations, and offer opportunities for farmers to diversify and increase their incomes in more environmentally sustainable ways.

88. The development of reliable markets is a multi-faceted challenge. Potential consumers need to learn about the product and its value. If the product is a raw material to be processed, then processors need to learn about processing requirements (for example, sawmills need to modify their equipment for new timber species). Quality standards must be developed so that buyers and sellers can agree a standard price. Pricing information needs to be widely known so that producers and consumers can plan knowledgeably for the future. Institutional and technology research and development are typically needed to reduce marketing costs and promote more diverse production systems. Reliable transport systems are needed, especially for perishable products. Seed, planting stock, or breeding stock of known provenance need to be widely available to producers. The private sector will and should handle the bulk of these roles. The public sector and civil society can play a valuable catalytic role in disseminating information, bringing together key market actors, removing subsidies for competing products, reducing regulatory hurdles for producers and intermediaries, and

supporting the needed research (Scherr and Dewees 1994). In Southeast Asia, markets for locally-grown tree products and benefits to local people from market activities have been improved through green marketing, niche specialization, marketing services by extension programs, and market price information systems (Raintree and Francisco 1994).

"Green markets": Certification for biodiversity

89. Another way to use markets to support biodiversity is to provide a premium for agricultural commodities that are grown in ecoagrosystems. The most important instrument that has been designed to achieve this has been producer certification. The global trade in certified organic agriculture is currently worth over US$21 billion worldwide. In Austria, the European country where organics have become most important, 10 percent of the food consumed is now organic. The World Organic Commodity Exchange (WOCS, www.wocx.net) represents over 2500 organic products, including textiles, furniture, cosmetics, wine, vegetables, fruits, dog food, baby food, ice cream and water. One might wonder about "organic water" but the indication of public interest in such products is high and growing, often mainly in response to human health concerns, but increasingly because for environmental concerns as well.

90. The Rainforest Alliance has established a certification program for coffee plantations that maintain forest cover, limit agrochemical applications, and control soil erosion. Consumers in many parts of the North are interested in supporting better habitats for migratory birds in agricultural lands. Rainfall Alliance-certified coffee from Guatemala is now widely available in the USA, and vendors who sell it emphasize its environmental advantages over standard coffee (Perfecto *et al*. 1996). The Nature Conservancy is developing a product called "conservation beef" for premium beef markets, which certifies that the beef was produced according to high conservation standards (B. Boggs, pers. comm., February 22, 2001).

91. A number of certifying bodies around the world have also begun to guarantee that forests are being managed and harvested in a sustainable manner. Major consumers, such as the Swedish multinational furniture retailer IKEA, are agreeing to use only certified timber. Both manufacturers and consumers in many developed countries have indicated a preference for certified timber products, and even willingness to pay a small price premium (Pearce, Putz and Vanclay 1999). The Forest Stewardship Council, formed by several conservation organizations and retailers in 1993, has certified nearly 20 million hectares globally. Over 600 member companies have joined forest and trade networks around the world, including Home Depot (North America), B&Q (UK) and many others. Several certification programs were recently established in developing countries. Certified forests now account for about 10 percent of the total land under timber concession in Latin America, 5.2 percent in Africa and a mere 1.3 percent in Asia-Pacific region. The FSC is beginning to certify non-timber forest products such as Brazil nuts, the resin base for chewing gum and cork (WWF 2000). In addition to environmental certification criteria, FSC and other schemes require protections for local forest communities and users, and promote production efficiency.

92. Certification of biodiversity impacts may become a consideration in financial markets, as "green" mutual funds seek agroindustries that contribute actively to "sustainable development" (Daily and Walker 2000). Large companies traded on stock exchanges around the world are judged by potential investors according to a variety of criteria. Increasingly, some of those criteria relate to

environmental sustainability; many mutual funds exclusively invest in environment-friendly companies. These companies can achieve a competitive advantage by marketing their products as sustainably produced and packaged, and by advertising their environmental responsibility in managing corporate land, water, and forest resources. With further efforts to educate and animate both investors and the public, their performance as stewards of biodiversity might also be rewarded.

Agroecotourism

93. Interventions to increase wild biodiversity in and around farm fields can enhance the aesthetic, cultural and environmental value of an agricultural landscape. Ecotourism can be promoted to exploit these resources as part of efforts to extend tourist visits to already-established protected areas, or within the farm landscapes alone. Locally grown and processed products based on sustainable agricultural systems and local wild products can be marketed to tourists, and local people can also earn income by providing lodging, board and guide services. Livelihood benefits from ecotourism in developing countries are greatest where resources have very high biodiversity value, where there is good transport infrastructure, and where local people are directly involved in providing goods and services to tourists (Honey 1999).

94. European protected areas often incorporate agricultural lands. Switzerland, a country heavily dependent on tourist revenues, subsidizes farmers in mountain areas to maintain traditional mixed agriculture-wildland landscapes, which are perceived to enhance their value to tourists. Some Italian protected areas have ecotourism activities linked explicitly to organic agriculture, with local farmers serving as guides and locally grown organic products being sold to tourists. In Mt. Etna Park (59,000 hectares), pastures and agriculture occupy about 30 percent of the land. (Compagnoni 2000; Spampinato 2000). In Brandenberg, Germany, 6,980 hectares of organic farms have been established within Schorfheide-Chorin Biosphere Reserve (Voegel 2000). Protected area management here includes developing and testing appropriate management methods for buffer zone agriculture that take better care of the native wildlife, attracting tourists by both wildlife and traditional agriculture. In Slovenia's Triblavski Natural Park and Sneznik Regional Park, organic farming is being evaluated as a possible tool for maintaining the traditional rural landscape and protecting and enhancing wild biodiversity (Slabe 2000). All of these areas are in IUCN Categories V or VI. Some large landholders-- notably Latin America and Eastern and Southern Africa -- allocate at least part of their property for conservation purposes, sometimes incorporating tourism. For example, in Natal Province, South Africa, some 8 percent of lands are in protected areas, but an additional 14 percent is under conservation management by private landowners.

INSTITUTIONS TO SUPPORT ECOAGRICULTURE

95. Good technologies, good laws and supportive markets are not enough. Institutions must be put in place, or adapted, to make ecoagriculture a happen on the ground. From a biodiversity perspective, institutions need to provide ecosystem management, research, monitoring, extension and financing.

Ecosystem planning and management at regional scale

96. Ecosystem management calls for the emergence of new types of land use planning institutions and tools to coordinate public and private investment, regulate zoning, and monitor changes in the condition of biodiversity (McNeely 1999). Many countries have established institutional umbrellas or mechanisms that cater for comprehensive multi-sectoral discussion on biodiversity issues, such the Kenya's National Environmental Secretariat and Ethiopia's Environment Protection Authority/Institute for Biodiversity Conservation and Research. Lead regional institutions include river basin development authorities and forest agencies, and state government planning and environmental agencies. Beyond the local and sub-regional level, regional and global ecosystem planning initiatives can also contribute to the management of shared biodiversity resources, such as the Mekong River Basin Commission for wetlands conservation.

97. Sectoral policies, legal frameworks, and some types of policy instruments to promote biodiversity will typically be developed at the national or state level, ideally with ample consultation and input from stakeholders. However, because so much ecosystem management -- by definition -- must be undertaken within a defined geographic area, policy design and governance must be tailored to local conditions, with local input. The old model of watershed or river basin planning imposed theoretically "optimal" solutions that had little or no buy-in from actual land managers and were, therefore, often ignored in practice. They left little scope for local experimentation with alternative solutions to achieve environmental goals. New approaches provide more flexibility for on-going adaptation of program designs, and more opportunities for partnerships with NGOs, public agencies and the private sector (Barborak 1995). While decision-making draws on the expertise of technical and policy specialists, to estimate the likely outcomes of different options, final policy design will typically reflect a negotiated outcome among different farmer groups, environmental organizations, and other resource user groups (MacKinnon et al 1984). Without a genuine "buy-in" of stakeholders to policy objectives and strategies, implementation will not be effective. New techniques of interactive landscape planning can be invaluable in such cooperative processes. The trend towards decentralization of authority in line agencies could have positive implications for integrating agriculture, forestry and biodiversity, as the sectors would be less compartmentalized and accountability to local stakeholders would be greater (Place and Waruhiu 2000). Recent reviews by The Nature Conservancy of nine community-based land use planning efforts in conservation areas in the USA and Latin America (Chung 1999) and by the Biodiversity Support Program of their projects in various tropical countries (BSP 2000) found a range of successful institutional models. Research organizations have been important actors in catalyzing multi-actor, science-based landscape planning in many parts of the world.

Involving local farmers in ecoagriculture development

> "(N)o nation will have lasting conservation on private lands until landowners are excited about the land and understand that environmentally sound land use is not a limit on personal freedom but rather a positive exercise of skill and insights" (OECD 1997a).

98. It has become clear that to achieve real results on the ground, it is essential to involve local farmers -- including the poor -- in planning and implementing legislative frameworks, property rights, payment systems, markets innovations, and ecosystem planning organizations. Agricultural ecologists have learned to respect the wisdom inherent in much traditional practice, and conservationists increasingly have come to appreciate that throughout history, wild biodiversity has been conserved as part of agroecosystems. The "rule of indigenous environments" states that "where

indigenous peoples have a homeland, biologically rich environments are still found" (Nietschmann 1992). Indeed, many of the lands most critical for biodiversity conservation in the world today are inhabited by indigenous or traditional peoples. They are valuable partners in developing ecoagrosystems.

99. Many innovative approaches have been developed by conservationists in recent years to systematically engage local people in ecosystem management planning (Chung 1999). A phased approach to policy action is often desirable, to allow for positive demonstration effects and to "fine-tune" the instruments. Transparent, on-going monitoring of process and outcomes is essential to maintain momentum and build support. Simple indicators widely understood and easily collected, evaluated and accessed by all participants will often be the most cost-effective. Participatory monitoring can help to engage the interest of local populations in biodiversity, involving schools and civic groups. Guidelines for extraction of economically important products from protected areas can be developed jointly by conservation biologists and local people.

100. Indigenous and local communities can be empowered to build capacity for *in situ* conservation and sustainable use based on their traditional approaches. For example, subsistence Yup'ik hunters in the remote wetlands of the Yukon-Kuskokwim Delta of Alaska have developed new waterfowl conservation practices and attitudes crucial to the survival of several species of Pacific migratory birds. This development resulted not from enforcement of official regulations, but by providing minimum necessary conditions for voluntary conservation to emerge as a cultural practice. These conditions included: (i) a social mechanism that maintains the rules within the community and prevents outsiders from cheating; (ii) the perception by hunters that they can influence the availability of game; (iii) a vested interest in the continued availability of the resource; and (iv) the availability of sufficient overall resources to meet basic needs (Zavaleta 1999).

101. While community involvement in ecoagriculture development is essential, it is no panacea. Many biodiversity problems may be of fairly recent origin as a result of expanding populations, immigration, and levels of consumption, so traditional community-based solutions may not be effective in the new circumstances. Local communities do not always have peaceful relations with neighboring communities; building supporting networks requiring inter-village cooperation is not always easy. The fact that local communities are often well adapted to their local environmental conditions does not automatically mean that they are going to make wise decisions. Deciding how to invest scarce resources in assets that mature over several decades (such as forest trees) or are highly mobile (such as migratory species of waterfowl), is a sophisticated task. Any community faces a challenging set of problems when it tries to govern and manage complex multispecies-multiproduct resource systems whose benefits mature at varying rates and are under pressure from competing groups of humans at every step (Ostrom 1998). The best general approach to this complex of problems appears to be greater commitment from resource management agencies to working with communities, improved community resource management programs, effective enforcement of agreed regulations, continuing research and monitoring, and long-term commitment by both conservation and development NGOs (Wood *et al.* 1995).

Monitoring wildlife in agricultural areas

102. If serious, large-scale programs are to be developed to support ecoagriculture, much more effective monitoring will be necessary. The Pilot Assessment of Global Ecosystems for Agroecosystems concluded that very little of the necessary data to assess the interactions between agriculture and biodiversity is currently being monitored. Currently published national data on land use show only net land use changes, and thus understate the true scale of agricultural conversion. Higher resolution data, both spatially and temporally is needed. The size of many protected areas is known, but not their precise geographic boundaries. Improved road network and landuse/cover data would help to assess the level of habitat fragmentation in agricultural landscapes. Improved data on production systems diversity could be used as a proxy for the potential area and quality of wildlife habitat within agricultural areas. There is currently little data on the abundance of wild flora and fauna in and around agricultural production areas, and on the impacts of specific crop combinations and management changes on wildlife populations (Wood, Sebastian and Scherr 2000).

103. Some of these challenges can be addressed by national agencies, including improvements in the use of remote sensing, the geo-referencing of agricultural census and survey data so these can be linked to environmental data, and the panel survey data on environmental features of farms. But much of the necessary information to guide farmers' and local communities' efforts will require locally based monitoring. For example, the Dunelands Farmers Foundation in the Netherlands, a group of 220 farmers working in and around a dune area in the process of becoming a national park, have developed a "wildlife gauge." This is an instrument to measure nature conservation value at the individual farm level. It provides an objective score of the density and quality of wildlife on a particular farm, quantify the efforts of the individual farmer on behalf of wildlife, stimulate greater awareness among farmers about nature and wildlife on their farms. The gauge may be linked to rewards through the Dutch Subsidy Ruling for On-farm Nature Conservation. The Land Stewardship Council, a private, nonprofit membership-based organization to support sustainable agriculture in the midwestern U.S., has a monitoring "toolkit" for farmers to use with neighbors in assessing wildlife and other environmental variables on their farms. The toolkit was developed by a 26-member interdisciplinary team from universities, public agencies, and farmers, and can be downloaded from the Worldwide Web (Website: www.landstewardshipproject.org; G. Boody, pers. comm., February 20, 2001). Participatory adaptive research projects have also been successfully organized in developing countries, to collect farm information for developing biodiversity-related innovations (L. Sperling, CIAT, pers. comm. March 2001).

104. Efforts are underway, through the Global Invasive Species Programme (GISP), to develop an easily accessible invasive species monitoring data acquisition system that links monitoring data with research results, information on identification, and information on ecology and control of invasive alien species. Under the Convention on Biological Diversity, a new International Pollinators Initiative was created in 1999, to monitor pollinator decline and its impact on pollinator services and to identify restoration requirements to sustain pollinator diversity in agriculture and related systems. FAO has established a European Network on Pollination and a Pollination Work Group has been set up recently in Kenya.

Innovation: Pushing the Research Frontier

105. The development of environmentally sustainable and financially profitable ecoagrosystems that can be integrated into regional ecosystem management is one of the most compelling scientific and technological challenges of this century. At present, the three goals of agricultural growth,

poverty alleviation, and biodiversity conservation are seldom complementary, given existing production systems, landscape organization and political economy. In many cases, we lack even the fundamental information about ecological interactions between agricultural and wild species and about the thresholds for maintaining habitat quality, that would allow us to design better systems. As our understanding deepens, we will find more general principles to aid in the design of new management systems; but still the specific solutions for most places are uniquely defined by their particular configuration of resources, uses and users. Agricultural research needs to identify and promote types of technological change that enhance productivity while simultaneously enhancing, or at least not degrading, the resource base and the biodiversity upon which it ultimately depends.

106. Prolific experimentation is going on, at local and sub-regional scales, from which lessons can be drawn. The research community is "ready for blast-off". But the current scale of work in this area is a small fraction of what will be necessary to make a difference at a global, or even ecoregional, scale. Not only must we answer fundamental questions like those above; we must develop and adapt new technology and ecomanagement practices to the many different types of agroecosystems where threats to wild biodiversity accompany threats to food security. The problems are daunting, but human ingenuity provides us with the means to do far better than we are doing now, in terms of both agricultural productivity and environmental protection. A global effort is needed to mobilize research and innovation on the needed scale, through new partnerships.

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