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Mainstreaming Biodiversity in Agricultural Development

Toward Good Practice

Global Overlays Program

Stefano Pagiola and John Kellenberg
with Lars Vidaeus and Jitendra Srivastava

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The World Bank
Washington, D.C.

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Stefano Pagiola is an economist in the World Bank Environment Department. John Kellenberg is a consultant to the department. Lars Vidaeus is chief of the Global Environmental Unit, and Jitendra Srivastava is the Principal Agriculturalist in the Agriculture and Natural Resources Department.

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Foreword

The World Bank is committed to helping its developing country partners implement their obligations under the Convention on Biological Diversity. This commitment, backed by an action agenda, is described in the 1995 report *Mainstreaming Biodiversity in Development: A World Bank Assistance Strategy for Implementing the Convention on Biological Diversity*. A key element of the action agenda is to help countries design and implement biodiversity-friendly sector policies and programs. The Bank's sector work in agriculture, natural resource management, and rural development must be fully responsive to this need, and its lending protograms crafted to help Governments mainstream biodiversity at the project level.

The Global Overlays Program, launched by the Bank's Environmentally Sustainable Development Vice Presidency (ESD) in partnership with bilateral donors and NGOs, seeks to internalize global externalities into national environmental planning and the Bank's sector work, operations, and dialogue with governments and partners. It is an iterative process, combining conceptual studies, reviews of state-of-the-art techniques for measuring and mitigating global externalities, and testing these concepts and tools through country-level studies as a means of identifying good practices for country planners and Bank task managers. The results will help guide national actions to conserve biodiversity, reduce greenhouse gas emissions, and protect international waters.

This study is a key activity of the Global Overlays Program. It provides the foundation upon which in-depth country studies will build to develop good practices in mainstreaming biodiversity in agricultural development.

Agricultural development is linked in important ways to biodiversity conservation, through impacts on natural habitats and the use of biodiversity in sustainable agriculture. In planning agriculture sector development, Governments need to assess the extent to which policies, institutions, and investment programs have to change to accommodate the objectives of conserving biodiversity, as well as the costs and benefits of such adjustments.

Ismail Serageldin
Vice President
Environmentally Sustainable Development

Acknowledgments

This paper was written by Stefano Pagiola and John Kellenberg, of the World Bank's Global Environment Division (ENVGC), under the guidance of Lars Vidaeus, Chief of the Global Environment Division, and Jitendra Srivastava, Principal Agriculturalist in the Agriculture and Forestry Systems Division (AGRAF).

This paper draws heavily on the existing literature and documentation of lessons learned from Bank and other projects. In addition, a number of special studies were undertaken. These include work commissioned by the Agriculture Department on Biodiversity Management for Agriculture, studies by teams of specialists in the Environmentally Sustainable Development Vice-Presidency (ESD) on special topics, and work by the World Resources Institute (WRI) reviewing the conflicts and complementarities of agricultural development and biodiversity conservation. Background materials were prepared by Sanjiva Cooke, Narpat Jodha, John Kellenberg, William Magrath, Stefano Pagiola, and Ann Thrupp (WRI).

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Executive Summary

Agriculture has played a major role in the decline of biodiversity, as it is the human activity that affects the largest proportion of the earth's surface and is the single biggest user of freshwater worldwide. Its expansion and intensification are considered to be major contributors to loss of habitat and reductions of biodiversity worldwide. Agricultural landscapes, however, can contain considerable biodiversity; indeed, biodiversity often plays a crucial role in agricultural production. As the world's population continues to grow, finding ways to increase agricultural production without destroying the many benefits provided by biodiversity—not least to agriculture itself—will be a major challenge.

Interactions Between Agriculture and Biodiversity

Because production increases require either agricultural expansion or intensified production within existing areas, the two broad areas of concern are the *effects of conversion of natural habitat* to agriculture and the *effects of agricultural intensification.* Habitat conversion is particularly harmful to biodiversity, since it substantially modifies natural areas. Agricultural landscapes also contain biodiversity, however, and intensification of land use can affect this remaining biodiversity. In each case, effects experienced *on-site* must be distinguished from effects experienced *off-site;* agriculture can have effects far beyond the area actually cultivated.

Current patterns of agricultural development are undermining biodiversity and the many valuable services it provides. By destroying or disturbing their habitat, agriculture threatens the survival of many species, some of which are valuable in themselves and some of which are critical to ecosystem functions. Conversion or modification of natural habitats for agricultural use also affects the services provided by ecosystems and their stability and resilience.

Agriculture is highly dependent on ecosystem products and services, including genetic information for development of new crop varieties, crop pollination, soil fertility services provided by microorganisms, and pest control services provided by insects and wildlife. Yet agricultural practices often threaten the ecosystem's ability to continue providing these services, thus jeopardizing the long-term sustainability of agricultural production.

Preventing loss or damage to biodiversity can be an important means to enhance agricultural production and development. For example, ecosystem resilience within agricultural landscapes may be safeguarded by maintaining spatial biodiversity (using relatively large numbers of species, preferably with significant genetic variation within each crop) and temporal biodiversity (frequently changing crops or varieties). Likewise, soil health may be maintained through the use of intercropping, cover crops, and increased use of manure and crop residues.

Understanding the Causes of Conflict

Understanding why the relationship between agriculture and biodiversity has been so marked by conflict requires understanding the incentives driving land-use decisions made by millions of individual farmers.

Any decision to change land use should weigh the benefits obtained from a change against its costs. However, the costs of biodiversity loss often are not borne by those deciding whether or not to conserve it. Many benefits of biodiversity are either externalities or public goods, so individual farmers have little incentive to take them into consideration when making land-use decisions. As a result of the poorly functioning or non-existent markets for many services provided by biodiversity, these services are systematically undervalued by resource managers. This results in socially-excessive rates of biodiversity loss.

The under-valuation of biodiversity's benefits is often exacerbated by the effects of *government policies,* including both agriculture-specific policies and broader economic policies. In many countries, for example, policies have discriminated against agriculture, thus stifling agriculture and discouraging intensification, leaving agricultural expansion as the only means to increase production. Governments have also often subsidized the use of harmful inputs, such as pesticides. In some countries, land settlement programs have led to wide-scale conversion of natural habitats.

Responses to the Problems

Recognizing and diagnosing the causes of biodiversity loss is a prerequisite for appropriate responses. Despite recent efforts, however, most countries have so far made little progress in this regard.

Reforming economy-wide and sectoral policies is an important first step to conserving biodiversity. Moreover, win-win policies often exist, since policy distortions which exacerbate damage to biodiversity also tend to be economically inefficient. A basic principle of biodiversity-friendly policy reforms is to *discourage agricultural extensification* and *encourage agricultural intensification.*

Eliminating the market failures that are the root of the undervaluation of biodiversity is difficult, but the payoff can be substantial. Possible approaches include imposing environmental taxes, revising property rights, developing new income opportunities dependent on biodiversity conservation, and developing mechanisms to compensate local communities for genetic material collected in their areas.

Farmers' choices are limited to what is technically feasible. *Improvements to available technologies* could go a long way towards both reducing conflicts between agriculture and biodiversity and increasing the sustainability of agricultural development. New approaches to agricultural research, which emphasize better management of biological resources, are being tested around the world. Research is increasingly turning to biological assets, including manipulation of genes and predators of insect pests. Improvements to extension are also important to ensure that new techniques, inputs, and information emerge that promote biodiversity-friendly agricultural production reach farmers.

Since the pressures on biodiversity in agriculture are so great, targeted conservation efforts are needed to complement the broader responses and help to minimize damage. Such *complementary measures* might include protection of particularly important parts of areas being converted to agriculture, including nesting sites, riparian areas, and wetlands; preservation of corridors between remaining habitats; *ex situ* conservation of particularly valuable species; and efforts to protect threatened species *in situ.*

Mainstreaming biodiversity in agricultural development means addressing these strategic elements. Factors that constrain or encumber such mainstreaming fall into three main categories:

- *Lack of information* and a generally poor understanding of the nature of effects make problem assessment and identification of appropriate and specific responses difficult.
- The *traditional focus* on sectoral production and employment objectives and institutional barriers to cross-sectoral coordination have effectively prevented inclusion of biodiversity conservation in agricultural development planning.
- *Lack of proven methods* to address biodiversity loss problems. Although a wide range of tools and mechanisms have been proposed, experience with their use remains limited.

The Challenge for the Bank

The Bank's commitment to assisting its developing country partners in mainstreaming biodiversity in agricultural development is essential for several reasons:

- Conservation of biodiversity is linked to sustainable agricultural development.
- The Bank is committed to helping client governments meet their obligations under the Convention on Biological Diversity.
- As an implementing agency for the Global Environment Facility (GEF), the Bank has a direct responsibility to help client governments mainstream biodiversity in development.

To deliver on this commitment, the Bank needs to integrate, where appropriate, biodiversity conservation as an objective into its operations at the levels of country assistance strategy, agricultural sector review and analysis, and project design and implementation.

The *Bank's Country Assistance Strategies* (CASs) have traditionally focused on macroeconomic performance. Although increased emphasis has been given to addressing constraints in key sectors of the economy in recent years, sectoral and environmental issues are generally not fully integrated in the CASs.

While there is no a priori reason for all CASs to address biodiversity conservation, it would be legitimate to do so in cases where

- agriculture is the main engine of growth and the maintenance of a diverse biological base is critical to such growth;
- prudent use and conservation of biodiversity amounts to management of an important part of the national capital stock; and/or
- the country harbors globally significant biodiversity which it is committed to preserve as a Party to the Convention on Biological Diversity.

At the level of *agricultural sector work*, the Bank needs to strengthen its ability to help developing country partners address four main questions:

- What impact do agricultural development activities have on biodiversity, both in the areas actually used for agriculture and outside them?
- How can sustainable uses of biodiversity enhance agricultural development?
- How can economy-wide and agriculture policies and programs be modified to reduce biodiversity losses? What factors constrain policy adjustments and institutional reforms?
- What are the tradeoffs between agricultural development objectives and biodiversity conservation, and how can they be evaluated?

Good practice in addressing these questions is being developed under the Global Overlays Program, initiated by the Bank with donor, NGO, and other partners. The next step envisaged in the program is to support efforts by developing country partners to answer the above or similar questions as part of proposed agricultural planning studies.

Finally, at the project level, the challenge for the Bank is fourfold:

- *Promote identification of synergies* between biodiversity conservation and agricultural development, and build them into project design.

- *Broaden the use of environmental assessments* as a tool to mainstream biodiversity in agriculture. This includes using sectoral and regional environmental assessments to screen both public investment programs and upstream project design options against the objectives of biodiversity conservation.
- *Use agricultural investment and sector adjustment operations as instruments* to support policy reform, institutional capacity, and awareness of mainstreaming biodiversity in agricultural development.
- Deepen the implementation of 'do no harm' strategies in the design of agricultural projects by effective use of environmental assessments, and by systematically applying the Bank's policy on compensatory actions for natural habitats threatened by proposed project activities.

1. Introduction

The past century has seen a strikingly high rate of species loss as a result of human-induced processes of conversion and degradation of natural habitats and the increasing specialization of human-managed habitats. Agriculture has played a major role in the decline of biodiversity, as it is the human activity that affects the largest proportion of the earth's surface and is the single biggest user of freshwater worldwide. Its expansion and intensification are considered to be major contributors to loss of habitat and reductions of biodiversity worldwide. Agricultural landscapes, however, can contain considerable biodiversity; indeed, biodiversity often plays a crucial role in agricultural production. As agricultural production continues to rise to meet the growing demands of the world's population, finding ways to minimize conflicts and enhance the many complementarities between agriculture and biodiversity is critical.

Biological diversity, often shortened to *biodiversity*, encompasses the variability among living organisms from all sources, including terrestrial and aquatic ecosystems and their ecological complexes. This includes diversity within species, among species, and of ecosystems (Box 1). Biodiversity plays a fundamental role in sustainable development, and diverse ecosystems provide many important benefits. They often contain a variety of economically useful products that can be harvested or serve as inputs for production processes. Diverse ecosystems also provide economically valuable services, such as improving water availability for irrigated agriculture, industry, or human consumption; reducing sedimentation in reservoirs, harbors, and irrigation works; minimizing floods, landslides, coastal erosion, and droughts; improving water quality; providing recreational opportunities; filtering excess nutrients; and providing essential habitats for economically important species. They contain genetic material that can help develop useful products such as pharmaceuticals and improved crops. Moreover, many people value ecosystems for aesthetic, moral, or spiritual reasons, even if they do not use them. The specific benefits provided by any given ecosystem vary substantially.

For the purposes of this paper, a broad definition of agriculture as the science or art of cultivating the soil, producing crops, and raising livestock is adopted. A varying but often substantial proportion of the benefits of biodiversity accrue to agriculture itself. Although human management has often greatly modified natural ecosystems, agricultural activities remain dependent on many biological services. The provision of genes for the development of improved varieties and livestock breeds are an important part of these services, but far from the only one. Others include crop pollination, soil fertility services provided by micro-organisms, and pest control services provided by insects and wildlife. The term *agrobiodiversity* has been coined to describe the important subset of biodiversity that contributes to agriculture. Damage to biodiversity often has important implications for agriculture itself, but at the same time there is substantial

Box 1. What is biodiversity?

Biodiversity encompasses all species of plants, animals, and microorganisms, the genetic variability within these species, and the ecosystems and ecological processes that they form and which sustain them. It is more than just the number of species, but also includes variety, representation, and uniqueness. Biodiversity can be measured at three different levels: (a) ecosystem diversity, which describes the variation in the assemblages of species and their habitats across the earth's surface; (b) species diversity, which refers to the variety of different species; and (c) genetic diversity, which refers to genetic variability within a species.

Although biodiversity is often measured simplistically by counting species, the variety of species is also important. Introducing new, exotic species might increase the local species count, but does not increase overall biodiversity. On the contrary, introducing exotics, disturbing a habitat, or invasion by natural weed species may come at the expense of native species that may be rare, threatened or very localized in their distribution (endemic), leading to a net loss in overall biodiversity.

potential to exploit biodiversity to enhance agriculture.

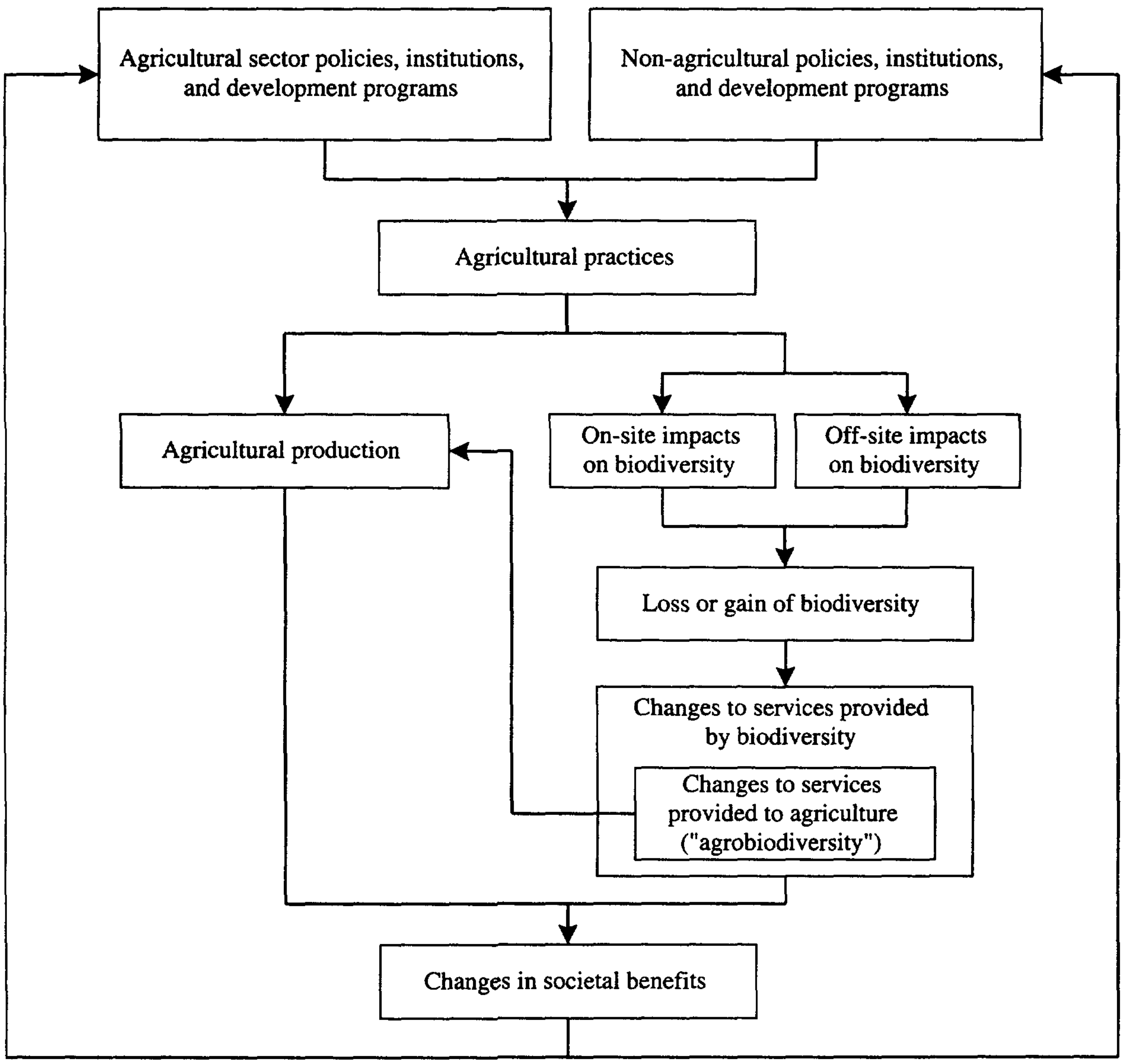
Growing populations and rising incomes are increasing the demand for agricultural products. Meeting this need without destroying the many benefits provided by biodiversity —not least to agriculture itself—will be a major challenge. Part of the solution will be to meet agricultural production needs without converting additional areas of already much-diminished natural habitats. A more intensive, knowledge-based agriculture will be required, and agrobiodiversity is likely to play an important role. Given the very wide area of the earth's surface already used for agricultural production and the inevitability that it will increase, part of the solution must lie in retaining as much biodiversity as possible within agricultural landscapes. Maintaining biodiversity is also likely to prove critical to the sustainability of agricultural production.

Planners face a difficult task in reconciling the imperative of increasing agricultural production without damaging the biodiversity that forms the basis of sustainable agricultural development, as well as numerous other benefits. This paper seeks to aid in this complex task by reviewing current knowledge on the relationship between agriculture and biodiversity; by analyzing the factors that have exacerbated conflict between the two and prevented complementarities from being exploited; and by proposing ways in which conflicts can be reduced and complementarities enhanced. Specifically, the paper addresses four main questions:

- What impact do agricultural development activities have on biodiversity, both in the areas actually used for agriculture and outside them?
- How can sustainable uses of biodiversity enhance agricultural development?
- How can economy-wide and agriculture policies and programs be modified to reduce biodiversity losses? What factors constrain policy adjustments and institutional reforms?
- What are the tradeoffs between agricultural development objectives and biodiversity conservation, and how can they be evaluated?

The conceptual framework used in this study is based on a number of propositions that are embedded in Figure 1. Most decisions affecting the relationship between agriculture and biodiversity are made by individual farmers, not by national planners. The incentive structure under which farmers and other local resource managers make decisions about conversion of natural habitats is influenced by agriculture *and* non-agriculture policies, institutions, and development programs. The resulting agricultural practices will, of course, affect the level of agricultural production, as well as both on-site and off-site biodiversity. Changes in the level of biodiversity translate into losses or gains to society through changes in the level of services provided by biodiversity, including direct uses such as extractable products, valuable ecosystem services, and

Figure 1
Conceptual framework



option or existence values. An important subset of these services is directly beneficial to agriculture—changes in their level will affect agricultural production. Changes in agricultural production and services influenced by biodiversity also lead to changes in societal benefits, but these have been largely ignored. In many cases, resources have not been used optimally, and societal benefits, if they had been measured correctly, would have been even lower than they appear. This paper attempts to show how consideration of biodiversity in planning agricultural development offers different policy prescriptions.

Chapter 2 begins by discussing the nature of conflicts and complementarities between agriculture and biodiversity. Although agriculture has long depended on and benefited from biodiversity, global trends have increased the conflict between the two, with adverse consequences for both. Chapter 3 attempts to analyze the causes of conflict by examining the factors that have driven farmers and other resource managers to actions that degrade biodiversity. These factors include the nature of markets for services provided by biodiversity, which often work poorly or not at all, and the incentives created by government policies. Chapter 4 examines the possible responses to the problem, including changes in economy-wide and sector policies, efforts to reduce market failures, and improvements in research and extension. The problems of valuing benefits and assessing tradeoffs are also discussed. Few of these measures will be easy to implement, and are discussed in the last part of the chapter. Chapter 5 concludes by examining the role of the World Bank and discussing how to mainstream biodiversity in the Bank's work.

This paper should not be interpreted as a good practice handbook on mainstreaming biodiversity in agriculture. Instead, it is a first step in an intellectual journey that will, as indicated by the title, ultimately lead to good practice. Because this topic is so diverse, many generalizations and an abundant use of qualifiers are inevitable.

2. *Conflicts and Complementarities Between Agriculture and Biodiversity*

Biodiversity has enabled farming systems to evolve since agriculture developed some 12,000 years ago. Traditionally, agricultural production systems were based on diverse biological resources within a variety of managed landscapes. A majority of agricultural products consumed today evolved through repeated experimentation, collection of plant and animal species, and breeding programs dating back hundreds—sometimes thousands—of years. In recent years, however, unrestricted expansion into forests and marginal lands, combined with overgrazing, urban and industrial growth, monocropping, and changes in crop rotation patterns and pest management strategies, have contributed to the erosion of biodiversity both within and outside agricultural landscapes. This erosion affects the services biodiversity provides to both agriculture and other sectors.

Global Trends

Population growth. The earth's population was 2 billion in 1927, had doubled by 1974, and reached 5 billion in 1987 (a billion is 1,000 million). Over the next 30 years, the population is projected to grow by two-thirds, from the current 5.5 billion to 8.5 billion, of which about 7 billion will live in developing nations. This growth has substantially increased the demand for food, energy, water, health care, sanitation, and housing, which in turn has induced a serious conversion of natural habitats for a variety of human uses. Demand for agricultural products has also increased as a result of rising incomes, which lead to higher consumption and in a shift in consumption towards foods higher on the food chain. This pressure has often been further aggravated by other factors, such as government policies and inequitable distribution of land and resources. Biodiversity is particularly threatened in countries with higher population growth rates because of more rapid conversion of land to agricultural uses and greater demands for wood for fuel and building materials.

Production trends. At several times in the postwar period there have been concerns about imminent food shortages—in the period immediately following World War II, after the failure of the monsoons in South Asia in the mid-1960s, and in the early 1970s, when production shortfalls in several areas coincided with rapid demand expansion and caused agricultural prices to skyrocket. In general, however, aggregate global production and agricultural yields have increased steadily. Over the past fifty years, gains in agricultural production have come from three sources: area expansion, increased land-use intensity (principally through expanded irrigation), and yield increases (from a combination of improved varieties and improved agronomy and animal husbandry practices).

Extensification. In some parts of the world, expansion of cultivated areas accounts for an important part of the growth in agricultural production—particularly in Africa, where yield increases have lagged far behind those achieved in other regions. From 1700 to 1980, global forests and woodlands declined from an estimated 6.2 billion hectares to 5.1 billion hectares, or nearly 20 percent. Over the same period, cropland increased from approximately 270 million hectares to 1.5 billion hectares, or about 460 percent. A large proportion of global deforestation has been attributed to the expansion of permanent and shifting agriculture. There are limits to the potential for increasing agricultural production through additional extensive growth, and that limit has already been reached in many areas. Although remaining unconverted areas tend to be very marginal for agricultural production, extensification continues to be a threat to natural habitats in many areas.

Intensification. Intensification increases the use of inputs, changes land use, or uses both to increase productivity (output per unit of land). Two broad types of intensification can be distinguished:

- Conventional forms focus on increased use of purchased inputs such as improved seed, agrochemicals, machinery, and external energy and water inputs. The bulk of past and current intensification has taken this form.
- Agroecological forms of intensification blend improved knowledge about agricultural ecosystems, intercropping, use of diverse species, integrated pest management, and efficient use of resources. These approaches represent a small but growing portion of intensification efforts.

Global agricultural production has substantially increased, although not all regions nor all people within any given region have benefited equally. Conventional forecasts for the coming decades, however, indicate that world food production must at least double by 2025 to meet the rising demand for food. There is not only growing concern over the ability of agriculture to meet this demand, but also over the long-term sustainability of growth that has already occurred. Current patterns of agricultural development impose substantial external costs on society at both the national and the global level. With shrinking areas available for agricultural expansion, increasing world food production must come from sustainable intensification.

Interactions Between Agriculture and Biodiversity

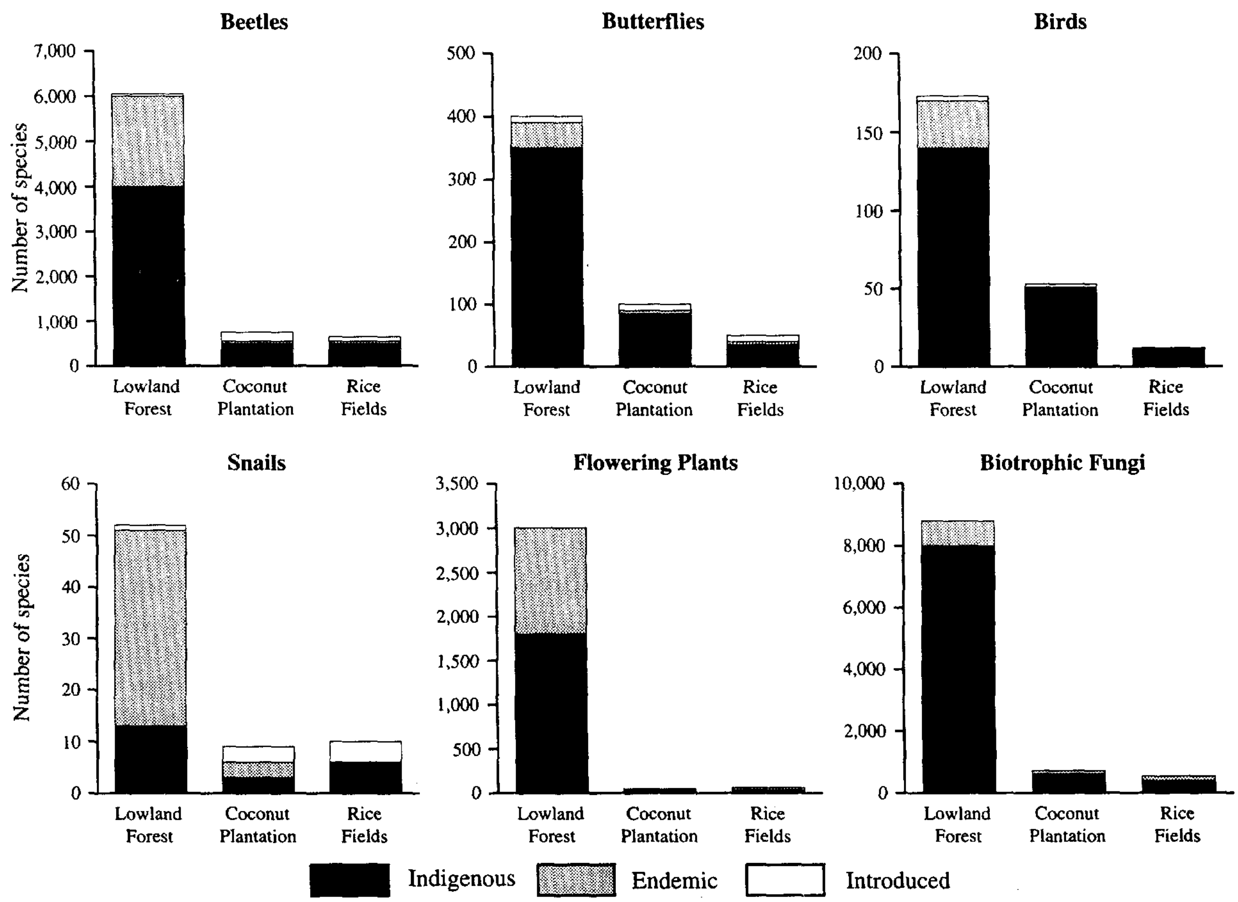
The interactions between agriculture and biodiversity are complex and diverse. Because production increases require either expanded agricultural areas or intensified production within existing areas, the two broad areas of concern are the effects of conversion of natural habitat to agriculture and the effects of intensification. In each case, effects experienced *on-site* (in the areas actually used for agriculture) must be distinguished from effects experienced *off-site* (outside the area of land use change).

Conversion of Natural Habitats

Although many ecosystems have been modified to some extent by human activities, many remain composed largely of native plant and animal species and have not had their primary ecological functions essentially modified by human activities; these we shall refer to as *natural habitats.* Conversion of natural habitats to agricultural use places a heavy toll upon biodiversity. Indeed, agricultural expansion is a major contributor to a continuing loss of natural habitats and biodiversity.

On-site effects. Conversion of natural habitat to agricultural use substantially changes the converted area. Naturally-occurring plant species are replaced by a small number of introduced species (usually non-native and identical to crops produced elsewhere), wildlife are displaced, and insects and microorganisms are decimated by pesticides. There is also a change in functions—especially in energy and nutrient cycling and storage and in water

Figure 2
Comparison of biodiversity in forest and agricultural ecosystems in Borneo



infiltration and storage. Conversion of a given area to agriculture, therefore, modifies and substantially reduces the level of biodiversity on that piece of land. Figure 2 compares the number of species found in forest and agricultural eco-systems in Borneo for a range of organisms. The number of species found in agricultural areas is substantially lower than in forest ecosystems. Moreover, species in agricultural areas include a larger proportion of common species, while species in forest ecosystems tend to have a higher proportion of endemic and indigenous species.

All conversion is not equally harmful. For example, some traditional agroforestry systems in Sumatra contain as much as half the species diversity found in neighboring primary forest —substantially more than other agricultural land-use systems in the area. Conversion of primary forest to this type of agroforestry, while definitely reducing biodiversity, reduces it less than conversion for other uses.

Off-site effects. The nature of off-site effects depends on the use that is made of the converted area. Conversion of natural habitat to agriculture also induces changes in remaining natural areas:

- *Edge effects.* The area at the interface between natural and managed land-use systems is generally modified precisely because it serves as an interface. Common opportunistic species tend to move into these areas, displacing local or endemic plants and animals. The disturbance created by conversion, therefore, reaches far beyond the individual piece of converted land.

- *Fragmentation of remaining habitat.* The level of biodiversity is strongly affected by the size of the remaining habitat and its connectedness. Conversion of habitat frequently results in substantial fragmentation of the remaining habitat, thus modifying the number and types of species it can support.
- *Changing disturbance patterns.* Disturbances such as fires and flooding often play important roles in ecosystems. With the arrival of agriculture, efforts are often made to control these disturbances.
- *Changes in water cycles.* The substantial changes in water infiltration and storage which take place in converted areas often affect hydrological patterns in other areas. This problem is compounded when agricultural use of converted areas involves irrigation, as discussed below.

Cumulative effects. The individual effects of a given conversion might be minor, but they can increase dramatically as they accumulate over time, over space, or both. Except where a critical habitat is affected (for example, a nesting area), conversion of an *individual* hectare of land to agriculture may have little effect on biodiversity. As the area converted to agriculture increases in proportion to that of natural habitat, indigenous species will be outcompeted, a process accelerated by any fragmentation of the remaining habitat. Unfortunately, the thresholds in this process are still very poorly understood.

Changes Within Agricultural Landscapes

Discussion of the effects of agriculture on biodiversity has often focused on conversion of natural habitat, but biodiversity is not limited to just natural habitats. Although the levels of biodiversity in agricultural landscapes are substantially lower than in natural habitats, they are not zero and they still provide many valuable services, many of which contribute directly to agricultural productivity. Concern for biodiversity in an area, therefore, should not cease after it has been converted.

The levels of biodiversity in agricultural landscapes vary, depending on the nature of specific land-uses within them. Changes in land-use can further reduce biodiversity within agricultural landscapes or lead to a relative increase, depending on the nature and context of the changes. By choosing agricultural practices appropriately, loss of biodiversity can be minimized.

On-site effects. Changing production patterns can alter the level of biodiversity on individual agricultural fields. For example, increased use of chemicals, specialized production, and standardized crop varieties all tend to reduce biodiversity. Not all changes are harmful, however. Some agricultural practices, such as integrated pest management or polyculture cropping are more environmentally benign than others, and shifting land use toward them will tend to reduce harmful effects on biodiversity, allowing local species to survive. In some cases, local biodiversity may increase as species that had earlier been lost return to the site. The extent of the impact, good or bad, will obviously depend on the magnitude of the change in use. A large increase in pesticide use, for example, will cause greater problems than a smaller one. Likewise, a substantial reduction in pesticide use will allow a greater recovery of insect populations than a smaller one. The nature of the impact also depends on the point of departure. Displacing rich agroforestry systems by cattle ranching, for example, lowers biodiversity, while rehabilitating degraded pastures may increase local diversity.

Land use mosaic. The overall level of biodiversity in agricultural landscapes does not depend solely on individual land uses; the mix of land uses is also important. Areas dominated by monoculture will tend to have lower biodiversity than areas with a rich mosaic of land uses.

Off-site effects. The impact of agricultural activities upon natural habitats is not confined to areas actually converted to agricultural use. Other areas are also affected, some directly, others in more complex ways:

- *Run-off.* Agricultural run-off (whether waterborne or airborne) carries pesticides, fertilizers, and sediment into adjacent and downstream areas, affecting ecosystems in a variety of ways. The danger posed by dispersion of pesticides into the environment has been well recognized since the publication of Rachel Carson's *Silent Spring*. Other substances also cause problems: fertilizers can be toxic to some organisms while encouraging excessive growth of others, and sediments can increase the turbidity of water and modify water flow by clogging watercourses. Sediment deposition is also a major threat to coral reefs near river outlets. In California, a naturally-occurring soil chemical carried off in solution from irrigated fields proved extremely toxic to birds when it became concentrated in down-stream wetlands.
- *Water use.* Agricultural activities can also affect areas far off-site through use of inputs other than land, especially water. Management of water for agricultural purposes can substantially affect the timing, volume, and velocity of water flow and groundwater recharge, thereby altering natural lake, riverine, estuarine, and marine habitats. Adjacent habitats and their associated flora and fauna can be altered by limited water or saline intrusion as a result of excessive extraction for agriculture. Water use for agriculture can also affect upstream habitats because aquatic systems are often altered far into their watersheds to regulate downstream water delivery. Any pollution exacerbates problems—pollution and high water use are often correlated because high water use increases the likelihood that pesticides and other substances will be carried away.

Cumulative effects. Changes in the use of agricultural landscapes often have important cumulative effects. The pesticide-contaminated runoff from a single field in a given year, for example, may be easily diluted in a watercourse and have only a minor effect. But such runoff from many farmers is likely to be significant, especially in the case of persistent pesticides and those that concentrate in the food chain.

Other Forms of Interaction

Effects of supporting infrastructure. Agriculture is more complex than just fields planted to crops or grazed by livestock. The supporting infrastructure (including roads, irrigation systems, and housing for farm families) can also significantly affect biodiversity:

- Infrastructure developments—especially roads—often encourage opening up new areas to pioneer farmers. This effect has been well documented in Brazil, Belize, Ecuador, and southeast Asia. Roads, therefore, have been a major contributor to loss of biodiversity resulting from conversion of natural areas.
- Whether infrastructure leads or follows agricultural development, it also has its own effects. Roads, for example, convert habitat to a particularly sterile alternative, produce edge effects over large areas, fragment remaining habitats, and subdivide populations. In Bangladesh, construction of roads and embankments in agricultural areas has significantly changed local drainage patterns, which in turn has profoundly modified the habitat for floodplain fish.

Special role of water. Water deserves particular attention because of the special role it plays in the many interactions between agriculture and biodiversity. The agriculture sector is the single biggest and, due to policy distortions and market failures, often the most inefficient user or surface and groundwater worldwide. Water is, of course, vital to practically all life forms, but for many species it forms the very basis of their habitat. Changes in water quality and quantity are likely to significantly affect a large number of ecosystems. Moreover, flowing water can transport effects far from their point of origin, thus activities that affect either the quality or quantity of water can often be felt at great distances. This also complicates detection of problems and formulation of solutions.

Imperfect knowledge. Knowledge of how ecosystems function remains imperfect. Indeed, even estimates of the number of species differ by several orders of magnitude. Among known species, many have not been adequately studied and described. Understanding of the long-term impacts of agricultural activities on biological diversity and ecosystem functioning is extremely poor.

Conversion of natural habitats and changes in agricultural landscapes can result in substantial reductions in biodiversity. The remainder of this chapter reviews the nature of problems that might result from reduced biodiversity.

Agriculture and Biodiversity's Services

Biodiversity generates benefits through the many valuable services it provides. These services are being undermined or lost as a result of current patterns of agricultural development, both as a result of continued expansion of agriculture into natural habitats and as a result of changes in land use practices in existing agricultural areas. The effects of this loss manifest themselves in many ways: within farming systems, undermining production, and in natural habitats, undermining the other services provided by biodiversity. This section discusses the effects of agriculture on the overall benefits of biodiversity, while the following section addresses in more detail the benefits that biodiversity confers on agricultural production.

Loss of Species

Loss of species has emerged as a significant concern. Although data are scarce, the current loss rate is thought to be substantially higher than the background rate of extinction. Species loss is of concern not only because of they are valuable in and of themselves, through their actual and potential uses, but also because of their role in maintaining properly functioning ecosystems that provide valuable services.

- *Value of individual species.* Many species are economically useful—they can be harvested or serve as inputs for production processes. Approximately 80 percent of the developing world's population use plant-based medicine for their primary health needs. Despite progress in synthetic chemistry and biotechnology, plants remain an indispensable source of medicines. Many modern medicines are derived from plants, including steroids from Mexican yams (*Dioscorea composita*) and an anti-hypertensive drug from serpentine wood in India (*Rauvolfia serpentina*). Substances with significant potential uses in medicine have also been isolated from wild animals. Several species also derive value from the hold they have on the popular imagination or from their cultural or religious role.
- *Keystone species.* Some species play a key role in ecosystem functions. There is growing evidence that the complexity and diversity within many ecosystems revolves around a small number of critical processes mediated by critical 'keystone' species (or groups of species). Loss of a keystone species can have a dramatically adverse effect on other species, and can even lead to further extinction. The importance of keystone species frequently hinges on highly specialized relationships between the keystone species and other organisms. For example, mature fig trees are a reliable source of fruit

to primates, birds, and other fruit-eating vertebrates, particularly during dry spells. In this case, fig trees are a keystone species because so many other species depend on them for food during droughts. The health of the figs, in turn, depends upon small, highly specialized fig wasps that pollinate fig flowers. The relationship between the trees and the wasp population, therefore, is important to the entire ecosystem's health.

Agriculture affects the survival of species in several ways. The most obvious is through conversion of habitat, which may lead directly to extinction. Even if species survive the conversion of part of their habitat, their long-term survival prospects might be significantly reduced because the remaining habitat is fragmented and disturbed. As the area of a natural habitat is reduced, the number of species it will support diminishes substantially. The impact of habitat fragmentation is especially severe on specialist species and on species with high area requirements and a low gap-crossing ability. Edge effects further reduce the effectiveness of remaining habitat by promoting conditions that favor generalist species over those with more specialized habitat requirements. Species may also be threatened by the introduction of toxic agrochemicals or by changes in water regimes caused by irrigation.

Loss of Ecosystems

Although the importance of ecosystems has received less recognition than that of individual species, they provide valuable services, not the least of which is habitat for economically important species. In addition, ecosystems improve the availability of water for irrigated agriculture, industry, or human consumption; reduce sedimentation of reservoirs, harbors, and irrigation works; minimize floods, landslides, coastal erosion, and droughts; improve water quality; provide recreational opportunities; and filter excess nutrients.

Agriculture affects the level of services provided by habitats in several ways. The most obvious, and that which has had the greatest effect in terms of area, is through conversion of natural ecosystems to agricultural use. This conversion eliminates many, if not all, of the services provided by a habitat. Effects from agriculture go far beyond the area actually converted: adjacent habitats will also be disturbed because of edge effects and fragmentation, and these modifications can eliminate or reduce services provided by those habitats. Agriculture can also eliminate an ecosystem if a keystone species is lost.

Just as in the case of species, certain ecosystems can also serve as keystones, affecting the functioning of many other ecosystems. Mangrove systems are an example of systems whose disruption can often have significant effects on many others.

Changes in Ecosystem Stability and Resilience

Species and their environments are connected in a complex web. Many ecosystems have mechanisms that allow them to absorb external shocks. Although understanding of ecosystem resilience remains highly imperfect, a consensus is emerging that ecosystem resilience depends on the number of alternative species that can 'take over' particular functions. When ecosystems are diverse, a range of pathways is available for primary production and ecological processes such as water cycling. If one is damaged or destroyed, an alternative pathway may be used and the ecosystem can continue functioning at its normal level. If biological diversity is greatly diminished, however, ecosystem stability an resilience will decline. Consequently, the services and economic benefits provided by the ecosystem will be at risk.

Biodiversity as an Input to Agriculture

Agriculture is a managed ecosystem. Although human management has often modified the natural ecosystem substantially, agricultural activities remain dependent on many ecosystem services. Biodiversity, therefore, is an input to agricultural production, and damage to biodiversity can have important implications for agriculture itself. As discussed below, preventing such loss or damage can become a means to enhance agricultural production and development.

Genetic Diversity for Crops and Livestock

Agricultural production systems must be resilient in order to adjust more readily to changes in the biophysical or socioeconomic environment. Ecosystem resilience within agricultural landscapes can be safeguarded by incorporating indigenous crops, varieties, and production methods, as well as maintaining spatial biodiversity (using relatively large numbers of species, preferably with significant genetic variation within each crop) and temporal biodiversity (frequently changing crops or varieties).

Genetic erosion, particularly the decline and loss of domesticated plant varieties and animal breeds, has important implications for global food security. Specialization within farming systems, homogenization of varieties, and conversion of areas that were home to wild relatives of food crops have led to a decline in genetic diversity. These developments may reduce genetic variation of existing crops, and eliminate near relatives of commercial species (other species in the same genus) and species that may have become the bases for market diversification via new agricultural products. The prevailing models and polices for agricultural research and development, along with market pressures for standardized characteristics, have perpetuated this erosion.

Although thousands of plant species are consumed worldwide, far fewer have entered world commerce, and a mere hundred-odd species account for 90 percent of the supply of food crops by weight, calories, protein, and fat for most of the world's countries. Currently just three crops—rice, wheat, and maize—account for 60 percent of the calories and 56 percent of the protein that people derive from plants. As improved varieties have been adopted, diversity has eroded. Thousands of traditional crop varieties have been eliminated, and many have been subsequently lost. In the Philippines, the introduction of high-yielding varieties (HYVs) of rice are thought to have displaced hundreds of traditional varieties. Homogenization has also been extensive in high-value export crops: for instance, nearly all coffee trees in South America are descended from a single tree from a botanical garden in Holland.

The extent to which introduction of improved varieties erodes traditional varieties is not well understood. Several studies suggest that modern varieties complement rather than replace local varieties, for example, traditional basmati rice varieties continue to be planted alongside HYVs in India and Pakistan. Continued use of traditional varieties, despite their lower yields, might be due to a variety of factors. Consumers may prefer traditional tastes or the choice offered by different varieties within the market. (Taste preferences are not limited to human consumers—Turkish wheat farmers commonly grow age-old landraces to produce inexpensive feed preferred by their cows, goats, and horses.) Risk-averse farmers may prefer to plant different varieties to reduce the risk from unreliable rains and other hazards. Some traditional varieties may be better adapted to various agroecological niches than improved varieties. In Bangladesh, for example, annual flooding limits the area to which shorter-stalked, improved rice varieties can be planted. Empirical research is required to determine the extent to which traditional varieties continue to survive when improved varieties are introduced, and the conditions that favor their survival.

Livestock are also suffering genetic erosion. Modern livestock operations have tended to bottleneck biodiversity as they streamline their activities by concentrating on a few highly productive breeds or strains. The Food and Agriculture Organization (FAO) estimates that at least one breed of traditional livestock is lost each week somewhere in the world as farmers focus on new breeds of cattle, pigs, sheep, and chickens. Sixteen percent of the over 3,800 breeds of cattle, water buffalo, goats, pigs, sheep, horses, and donkeys believed to have existed at the turn of the century have become extinct, and a further 15 percent are threatened. These losses weaken breeding programs that could improve livestock hardiness.

Genetic erosion is troubling because advances in modern plant breeding have been based on a wide range of genetic material provided by close relatives of cultivated species, often referred to as landraces. New varieties frequently reflect crossing commercial plant species with wild relatives, adaptations to changing farming conditions, and responses to the economic and cultural factors that shape farmer priorities. The very success of modern plant breeding, however, now threatens the source of genetic diversity upon which further progress depends. Individual farmers find it less rewarding to maintain the diverse mixture of landraces developed by their ancestors.

Insect and Disease Resistance

One of the main problems associated with homogenization of varieties is increased vulnerability to insect pests and diseases. An insect pest or disease can be devastating if it infests a uniform crop, especially in large plantations. History has shown serious economic losses and suffering from relying on monocultural, uniform varieties. Among the renowned examples are the potato famine of Ireland in the 19th century that caused massive starvation; the mealybug infestation in thirty-four African countries in the 1970s and early 1980s that lowered cassava yields as much as 60 percent; the citrus canker that led to the loss of 12 million orange and grapefruit trees in the Florida in the mid-1980s; and the Black Sigatoka, a fungal plague that damaged expansive banana plantations in Central America and parts of Africa in recent decades. Increased investment in research and development related to major food crop varieties may lessen the impact of such outbreaks—the southern corn leaf blight caused a 15 percent reduction in United States corn yields in 1970, but alternative varieties planted in subsequent years allowed corn yields to rise above pre-1970 levels.

Insects and fungi are commonly seen as enemies of food production, but more recently many species have been recognized as providing valuable services to agroecosystems in addition to pollination. Many insects contribute to biomass as well as nutrient production and cycling, and are natural enemies to insect pests and diseases of crops. However, this diversity has been seriously eroded in modern agricultural systems. The dependence on agrochemicals, and particularly the heavy use and misuse of pesticides, has been largely responsible for this problem, since agrochemicals often kill natural enemies and beneficial insects as well as the target pests. The reliance on monocultures and decline of natural habitat around farms likewise contributes to this serious loss of beneficial insects.

Disruption of agroecosystem balance can lead to resurgence of pests and outbreaks of new pests, as well as provoking resistance to pesticides. Farmers often respond to such outbreaks by increasing pesticide use or changing products. Although this response might be temporarily effective, in the long run it can lead to ineffective pest control as well as ecosystem disruption. By 1980, 260 species of agricultural insect pests had developed insecticide-resistant strains, and by the early 1990s, the ranks of insects resistant to one or more pesticides had swollen to 500 species. This problem, known as the 'pesticide treadmill', has occurred in many circumstances; it is particularly well-known for causing devastating losses in cotton and banana production in Latin America, and rice in southeast Asia.

In contrast, biological agents have proven to be a major component of agroecological forms of intensive agriculture, serving to reduce or eliminate the need for pesticides. Thus far, some 500 insect species have been deployed worldwide to control insect pests, as part of biological control programs, with a further 100 released to check weeds. Recently, parasitic wasps were released in West Africa to control cassava mealybug. In China, researchers found that jumping spiders and wolf spiders are effective at controlling insects, so that chemical insecticides are no longer needed on certain crops. In 1986, Indonesia officially adopted integrated pest management as a national policy, leading to a 70 percent decrease in national pesticide use. During this same period a 10 percent increase in national rice yields was attributed principally to the deployment of insect- and disease-resistant varieties and use of biocontrol agents.

Similarly, breeding commercial species with wild relatives has played a critical role in combating disease and insect pest resistance. For example, on the eve of World War II, the Central American banana industry was rescued from imminent destruction caused by Panama disease by genes from a banana plant collected from a botanical garden in Saigon. A nondescript Mexican maize saved the United States maize crop from southern corn leaf blight in the early 1970s, and a barley plant from Ethiopia provided a gene that protects the $160 million barley crop of California, as well as the Canadian barley crop (all dollar amounts are U.S. dollars).

Agroecosystem Diversity

The losses of germplasm and diverse crops and livestock are related to broader losses in farming systems. Intercropping, polycultures, and agroforestry have been displaced by monocultures. Farmers have been encouraged to adopt standardized breeds and monocultural models, eliminating mixed cropping systems and landraces.

Soil Health

Diverse and abundant soil organisms help maintain soil fertility and productivity. This diversity is fundamental to soil quality—often called 'soil health'. Small organisms, such as insects and other invertebrates, play a vital role in developing and maintaining healthy soils, and help to maintain nutrient cycling, soil structure, moisture balance, and fertility. For example, *mycorrhizae*, which are fungi that live in symbiosis with plant roots, are essential for nutrient and water uptake by plants.

Many soil management practices in conventional agriculture can damage soil health —heavy use of agrochemicals (particularly pesticides), soil fumigants, and chemical fertilizers can destroy or disrupt soil organisms and soil quality. The homogenization of crops and varieties, together with a decline in use of manure, crop residues, intercropping, and cover crops, can reduce soil organisms and deplete the soil of natural nutrients, while intensive tillage practices may disrupt soil structure. In the long term, all these practices undermine soil fertility and reduce productivity.

Summary

Conversion of natural habitats and changes in agricultural landscapes can result in substantial reductions in biodiversity. These changes also bring benefits in the form of increased agricultural production. In some cases, the benefits may exceed the costs of biodiversity loss, making the trade-off a favorable one from a societal perspective. In others, the costs to society resulting from the reduction in biodiversity exceed the benefits obtained from increased production of food and fibre.

The following chapter indicates that there are good reasons to expect that land-use decisions are usually made without sufficient attention to the changes they cause in the level of benefits generated by biodiversity.

3. *Understanding the Causes of Conflict*

Although biodiversity provides a wide range of benefits to agriculture and other sectors, agricultural activities often reduce biodiversity. Agricultural planners need to understand the driving forces behind biodiversity losses in order to address the problem. This chapter analyzes why the relationship between agriculture and biodiversity has been so marked by conflict, and why little progress has been made in exploiting the many potential complementarities between the two. In practice, this means understanding the incentives driving land-use decisions made by millions of individual farmers. Governments, NGOs, and other agents seek to influence these decisions using a variety of tools, but farmers make decisions in light of their own objectives and constraints.

Any decision to change land use should weigh the benefits obtained from a change against its costs (including the loss of both actual and potential benefits). The costs of converting an area of natural habitat, for example, are more than just the cost of clearing the land. There are also foregone benefits from continued use of the land in its present form, including extractive benefits from harvesting various products and non-extractive benefits generated by biodiversity on the site. The loss of these services will be felt both on-site and off-site. In addition, there are often costs imposed on other parties that are not specifically related to reduced biodiversity, such as erosion on cleared areas producing sedimentation downstream. All of these costs must be weighed against the benefits of increased agricultural production on the converted land over a specific time period.

Land-use changes within an agricultural landscape also have costs over and above those of actually implementing the change itself, some of which will be borne by parties other than those making decisions. In principle, if the services provided by biodiversity are valued accurately and completely, and if prices accurately reflect the opportunity costs of all goods and services to society, decisions to change land use would be optimal because expected benefits from the change would exceed expected costs. These conditions are not generally fulfilled, as discussed in this chapter. Many services provided by biodiversity are not valued by those making decisions, leading to excessive reductions. Moreover, policies and other distortions further affect decisions through their effects on price signals received by farmers.

The chapter begins by reviewing the markets for services provided by biodiversity, many of which function poorly or not at all. Numerous other factors that affect decisionmaking are discussed next. In particular, a variety of government policies that have had a substantial impact on patterns of agricultural development and declining biodiversity by modifying prices and other signals received by decisionmakers. The final part of the chapter summarizes the effects of these multiple factors in two stylized settings, extensification and intensification decisions.

Market Failures

Although biodiversity provides many benefits, markets for these benefits often either do not exist at all or function poorly. This is caused by a variety of factors.

- *Externalities.* The benefits of biodiversity often do not accrue to those deciding whether or not to conserve it. Benefits such as water filtration, for example, are enjoyed primarily by water users downstream from a wetland. But farmers do not receive any payments from downstream beneficiaries, so they are not considered during decision-making. In this case, the cost of lost ecosystem services is an externality that farmers have no economic incentive to consider.
- *Public goods problems.* The benefits of services provided by biodiversity often accrue to a group—in many cases to the global community or to very large subsets of it. For example, the genetic information contained in plants is of interest to all potential users of plant-derived pharmaceuticals. Even though farmers often belong to the group of potential beneficiaries, the individual incentive to conserve biodiversity is low. As individuals they would enjoy the full benefits of conversion (increased agricultural income), but only bear part of the consequences of reduced biodiversity benefits (such as reducing the availability of pharmaceuticals). Conversely, farmers often bear a disproportionate share of the cost of conservation (in terms of foregone agricultural income), but only enjoy a fraction of the resulting benefits.
- *Incomplete information.* The specific benefits of biodiversity are often hard to identify, let alone value. Moreover, the effect of any given action (such as conversion of a given hectare of land to agriculture or increased use of pesticides) on the benefits of biodiversity is very difficult to predict. Farmers, therefore, are often unaware of how their actions might affect the services provided by biodiversity.

These distinctions are more than theoretical curiosities—they have important effects on the design of solutions, as will be shown below.

Poorly functioning or non-existent markets for many services provided by biodiversity mean that these services are systematically undervalued by resource managers. Consequently, decisions that reduce biodiversity are common. As they evaluate choices, farmers tend not to include the benefits of conserving biodiversity. They will generally consider on-site, extractive benefits because they benefit directly, but are much less likely to consider the consequences of their actions on other benefits provided by biodiversity.

On-site extractive benefits. Natural habitats often contain a variety of products that can be harvested for consumption or sale, including gums and resin, flowers, fruit, seeds, leaves, fuelwood, game, fish, insects, and mushrooms. Converting an area to agriculture usually eliminates future harvests of most or all of these products. As long as they have a clear title to them, farmers will take this loss into consideration when making conversion decisions. If the extractive benefits are sufficiently high and the returns from agriculture sufficiently low, they may maintain the area in its natural state. But if others have the right or ability to appropriate some of these benefits, the incentives for individual farmers to forego conversion are reduced. Clear tenure rules (including usufruct rights over various categories of benefits) can play an important role in ensuring that on-site extractive benefits are internalized. Even when titles are clear, however, extractive benefits alone may be insufficient to convince farmers to refrain from conversion given the high returns per hectare that are often possible from production of specialized crops.

On-site productivity effects. Potential negative effects from lost biodiversity, such as the build-up of pests and damage to soil microfauna, can affect farmers directly by reducing crop yields or increasing costs. One would expect farmers to consider these consequences in their decisions, but two factors often militate against this. First, on-site productivity effects may be very difficult for farmers to assess, and so may not be adequately considered. Links between ecosystem functioning and agriculture are often extremely complex and may not be detected until substantial, sometimes irreversible, damage has occurred. The effect of pesticides on beneficial insects that prey on insect pests, for example, may only be detected after years of heavy pesticide use. Second, even on-site productivity effects often have a significant public good dimension. Pollinators, for example, are not limited to a single field. Any decline in pollinators is likely to be caused by the actions of many farmers rather than just one.

Off-site effects. Farmers will generally not have any economic incentive to consider off-site effects because these are pure externalities. (Where the off-site effect is on a public good consumed by the farmer community, however, there may be social norms regulating behavior, as discussed below.)

The failure of markets for benefits from biodiversity is also reflected in decisionmaking at higher levels. In principle, government authorities should incorporate their benefits into decisionmaking because many externalities are experienced within their borders. In practice, however, government policies have generally been made with little or no thought to their potential effects on biodiversity. This failure to consider the benefits of biodiversity in policymaking at the national level has two main causes:

- *Incomplete information.* The information available to government authorities has often completely ignored non-market benefits such as those provided by biodiversity, even for effects that are felt primarily within the nation.
- *Global externalities.* Even at the national level, several important benefits of biodiversity remain externalities because they affect the global community. Loss of a wild crop species with valuable genes, for example, affects all growers of that crop worldwide. Just as individual farmers have little incentive to take these effects into consideration, neither do individual governments.

Factors Affecting Farmer Incentives

Given the absence of effective markets for its benefits, biodiversity tends to be systematically undervalued by all decisionmakers. Within this already imperfect setting, however, many other factors also affect decisions—some exacerbate the problem, while others can reduce its effects. This section discusses the most important such factors, particularly the effects of policies. In many countries, patterns of agricultural development and biodiversity loss have been heavily influenced by government policies, including those aimed specifically at the agriculture sector, and broader economic policies. These policies affect decisions through their impact on prices and other signals received by farmers. Merely announcing or even legislating a policy change will not affect behavior unless the change is reflected in signals received by farmers and other resource managers.

Prices

The prices of purchased goods and services play a crucial role in farmers' decisions and will therefore clearly affect biodiversity. The direction of price effects is often hard to predict —high prices of agricultural products can make converting additional land to agriculture more attractive, for example, but the same high prices can also make intensified production on already cultivated land more profitable, reducing pressure on natural habitats. Which of these effects will dominate in any given case is difficult to predict. The problem is further complicated because prices are affected by a variety of factors, including government policies, marketing arrangements, infrastructure, consumer preferences, and variations in weather conditions.

Price effects of policies. Many government policies directly or indirectly affect the prices of agricultural goods and services: fiscal policies affect the prices of goods through taxes and subsidies, tariffs increase the price of imported goods directly, and import quotas increase them indirectly. Exchange rate policies affect the value of all tradable commodities, and government agencies actively buy and sell commodities, often at administratively-determined prices. Although policy effects on incentives to conserve biodiversity can be difficult to predict in general, three broad sets of policies have often been thought to be especially harmful to biodiversity:

- *Policies that stifle agriculture and discourage intensification.* The vast majority of developing countries have until recently had policies that discriminate heavily against agriculture. Resources have been extracted from agriculture in a variety of ways: overvalued exchange rates, protection of competing sectors, price controls, and high direct taxation. A sample of eighteen developing countries found that transfers out of agriculture averaged 46 percent of agricultural GDP during 1960-84. These policies made agriculture less attractive than other sectors of the economy and substantially slowed agricultural growth. Investments in improving productivity have been discouraged, leaving area expansion as the only way to increase agricultural production. Where reduced returns to agriculture have not been matched by increased labor absorption in other sectors (a common occurrence in developing countries), labor was often shed into marginal areas, thereby deepening rural poverty. Poor farmers have been driven to forest frontiers and other marginal lands, increasing pressure on natural environments.
- *Policies that encourage extensification.* In many countries, agricultural policies have explicitly promoted conversion of natural areas to agricultural use with no consideration for the value of biodiversity, often in spite of high costs. Government sponsorship of land settlement is a prime example of a policy that promotes conversion of natural areas, and is an important source of pressure on biodiversity in Brazil, Ecuador, and Indonesia.
- *Underpricing inputs and encouraging overuse.* Many developing country governments have subsidized the use of various inputs, partly to encourage increased agricultural production and partly to support the industries producing those inputs. Pesticide subsidies, for example, have been common. In the mid-1980s, Indonesia was spending about $150 million annually on pesticide subsidies, which led to considerable overuse. Far from increasing production, this overuse may actually have been harmful because targeted insects rapidly developed resistance, and natural controls were reduced. Moreover, high levels of pesticide use also caused substantial downstream pollution and seriously affected the health of farmers using them. In some countries, overuse of pesticides has been further encouraged by making access to credit conditional on their use. The price of irrigation water has also had serious adverse consequences for biodiversity. Throughout the world, irrigation water has typically been priced far below the cost of supplying it, which has inevitably led to overuse. As a result, modified timing and stream flows have degraded conditions for aquatic life, a problem which has been exacerbated by pesticides and fertilizers carried in return flows.

Rules and Regulations

Farmers do not exist in a vacuum, but live and work in a setting where social rules and norms of their communities (whether they be villages, tribes, producer cooperatives, or neighborhood associations) have an important influence on their decisions.

Tenure rights in cultivated areas. Insecure land tenure can affect farmer incentives to conserve biodiversity in several ways:

- Insecure tenure reduces farmer incentives to consider long-term productivity effects on their land, including any long-term effects from damage to biodiversity, and reduces farmer incentives to minimize on-site damage. Improved tenure, however, would not change incentives to protect benefits from biodiversity that accrue off-site. Because many of these benefits are public goods, improving tenure on agricultural land may not significantly affect biodiversity.
- Insecure tenure reduces incentives to intensify agricultural production. Intensification often requires investment in land improvements or equipment that farmers may be unwilling to make if their tenure is insecure. Growth may therefore be extensive rather than intensive, which is much more harmful to biodiversity.
- Some relatively biodiversity-friendly land uses, such as agroforestry, tend to be discouraged by insecure tenure because they require fairly long periods to provide a return on investments.
- In some cases, tenure security can be established or increased by clearing land. This has notably been the case in the Brazilian Amazon, where it has resulted in substantial conversion of natural ecosystems.

Tenure and usufruct rights in communal areas. Communal areas (including community forests, pastures, and wastelands) are generally thought to be open-access resources that anyone can exploit (an image popularized by Hardin's *Tragedy of the Commons*). Because habitats in these areas are often less modified than areas used more intensively for agriculture, they often tend to have higher levels of biodiversity. If resources in communal areas are misused, therefore, damage to biodiversity could be substantial. Evidence is accumulating, however, that use of such areas is often closely regulated by local communities. An extensive literature has developed which demonstrates that local communities can overcome the collective action problems which plague common-property resources and to successfully regulate their use.

Community norms. When the benefits of biodiversity and the costs of failing to conserve it are experienced primarily within communities, those communities have strong incentives to regulate. Local communities have significant advantages for monitoring and enforcing resource-use rules over more distant (and usually less trusted) government organizations. Unfortunately, the authority of local communities has often been undermined—sometimes deliberately—by central governments. Consequently, many common-property resources that were once highly regulated by local communities have degenerated into open-access resources.

Laws. Rules and regulations promulgated by governments can also affect conservation decisions. Brazilian tax and tenure laws that encouraged clearing of the Amazon are the best-known example of laws that had an adverse effect on biodiversity. Even laws intended to protect biodiversity can sometimes have perverse effects. Laws against cutting trees, for example, while intended to protect forests, have often reduced incentives to undertake agroforestry practices. In many cases, rules and regulations often prove unenforceable, but can affect behavior by forcing farmers and others to avoid them (for example, by bribing enforcers to overlook infractions).

Technology

Whatever the incentive structure, farmers' choices are limited by the characteristics of available technologies—emphasizing research on monoculture has limited the available options. Modern crop breeding strategies focus on improving a limited number of characteristics such as grain yield, drought tolerance, pest resistance, or growth rate. Breeders identify elite breeding lines and then incorporate controlling genes in subsequent generations. This strategy has been extremely successful at raising yields, but has also narrowed the range of yield-increasing technologies. Moreover, improved varieties have often been accompanied by prescriptions of heavy, prophylactic pesticide use.

Stylized Examples of How Biodiversity Is Undervalued

The diverse elements of the incentive framework of farmers have complex effects on biodiversity. This section discusses how they interact in two stylized settings: extensification and intensification decisions.

Extensification Decisions

Converting natural habitats to agricultural use probably has the greatest negative effect on biodiversity.

- *Motivation.* Several factors might motivate farmers to consider converting a given piece of land to agricultural use: producing more food to meet the subsistence needs of a growing family; replacing land that is already farmed because its productivity has declined through misuse or overuse; or simply seizing an opportunity to increase income and improve the standard of living. The precise motivation is important: farmers displaced by declining productivity or who need to meet subsistence requirements will likely see tradeoffs between short-term and long-term benefits differently than farmers motivated by opportunities for higher profit.
- *Benefits of not converting natural habitat.* The benefits that farmers expect to personally receive from leaving an area in its natural state will play a significant role in the decision. The magnitude of these benefits depends on what products the area produces and in what quantities; the proportion of these products that the farmers can expect to appropriate for themselves (and hence tenure and usufruct rights and social norms); the cost of collecting these products; and the price for which they could sell them (and hence marketing arrangements and the effects of government policies), or their value for household consumption.
- *Benefits of conversion to agriculture.* On the other side of the ledger, farmers will consider the cost of clearing the land (which might be partially offset if clearing yields salable or usable products such as timber); the value of crop production, which in turn depends on achievable yields, available technology, cost of inputs and outputs, marketing arrangements, and the effects of government policies; and the time available for crop production, which might be limited by declining productivity or insecure tenure.

Biodiversity plays but a minor role in farmer decisions about extensification: through the extractable benefits it might provide, and through the possible long-term effects of damaging it on productivity (an effect which is likely to be very difficult to detect). The benefits of all other services provided by biodiversity do not enter into the equation. The many other factors that affect this decision at different times illustrate the complexity of the problem and the difficulty in making reliable predictions about the effect of any specific factor. Price changes could either encourage or discourage conversion, depending on the products affected and the magnitude of the change.

Intensification Decisions

Intensification decisions can take a variety of forms. Some decisions to intensify imply a substantial change in land use practices. Replacing traditional crop varieties with high-yielding Green Revolution varieties and their associated package of purchased inputs is one example of such a major change. Another example is the introduction of irrigation, which enables cultivation of very different crops and extends the cultivation period into the dry season. In other cases, intensification occurs as the cumulative effect of many decisions, such as choice of crop and variety, use of retained or purchased seed, and choice of inputs and quantities. The range of choices makes it even more difficult to generalize about intensification than extensification. Moreover, the consequences of intensification on biodiversity also depend significantly on the nature of the change and its context.

- *Benefits of intensification.* As in the case of conversion, the benefits that farmers expect to personally receive from changes in land use play a critical role. In most cases, farmers face a wide range of possible intensification options. The relative attractiveness of each option compared to other options and current land use depends on technical characteristics and prices of inputs and outputs. In turn, prices depend on marketing arrangements and the effects of government policies. That agricultural intensification has often resulted in damage to biodiversity is due partly to the nature of the improved techniques available to farmers and partly to the common practice of under-pricing certain inputs, such as pesticides and water use, whose misuse is especially likely to damage biodiversity. The case of intensification in Bangladesh (Box 2) illustrates how differences in input and output prices can affect the level of pesticide use in intensive agriculture, an aspect of intensification that is often of considerable concern.
- *Costs of intensification.* The key cost for farmers to consider is that of adopting a new practice, whether it is an investment or acquiring different inputs. Even when damage to biodiversity affects a farmer's own long-term productive potential, such as damage to pollinators or other beneficial insects, these costs are unlikely to be considered because they are difficult to identify.

Box 2. Intensification and pesticide use in Bangladesh

Agriculture in Bangladesh has intensified in recent decades. High-yielding varieties have been widely adopted, expanded irrigation allows double- or triple-cropping where only one crop was previously grown, and use of purchased inputs has grown rapidly. Concern is mounting over possible environmental problems from intensification, including damage to floodplain aquatic ecosystems.

As in other Green Revolution countries, pesticide use was an integral part of the high-yield variety technology package, and use was further encouraged by subsidies. Pesticide use grew rapidly in the early 1970s. However, after fiscal problems led to subsidies being halved in 1973-74, and removed entirely in 1978, use fell dramatically. Although total pesticide use has since recovered and now exceeds the levels of the early 1970s, per hectare use remains low by regional standards and only 10-20 percent of the area planted to HYV rice is treated. Farmers consider pesticides expensive and use them in a purely reactive way: pesticides are applied only when pest infestations are detected. Groundwater tests during 1994-95 in areas with high risk of pesticide contamination found traces in only 13 percent of samples, and most were longer-lived organo-chlorines used in the past rather than the moderately persistent and less toxic organo-phosphates in current use.

Price effects are further illustrated by the different pattern of pesticide use on vegetables, where output prices are often high. While farmers spray rice—if at all—only two or three times a season, it is common to spray vegetables several times a week. A survey of eggplant producers in one area showed a range of 17 to 150 applications per crop cycle. Although farmers consider pesticides expensive, they believe high levels of use on vegetables are justified by the high returns.

These examples illustrate the interactions among the different factors that affect farmer incentives. Despite adopting a technological package that specifically called for relatively high pesticide use, farmers substantially cut back their use once subsidies were removed. On the other hand, when high returns from vegetable production were perceived to depend on heavy use of pesticides, farmers had no compunction about using them. In neither case did the possibility of damage to the surrounding ecosystems—especially to the floodplain fisheries that supply much of the protein to the local poor—enter into the farmer decisions.

Once again, it is clear that loss of biodiversity plays but a minor role in farmer intensification decisions. The possible long-term effects of damage to biodiversity and agricultural productivity are usually not fully considered because these two potential entry points for evaluation are difficult to identify. Training in integrated pest management (IPM), however, helps farmers recognize when damage to biodiversity is likely to harm their productivity (Box 9 below). Even if on-site productivity benefits were fully considered, biodiversity would still be undervalued because productivity is only a small portion of the benefits. As in the case of extensification, many other factors impinge on intensification decisions, often exacerbating problems by making use of damaging inputs and activities seem more profitable.

4. Responses to the Problems

As discussed in the previous chapter, two sets of conditions contribute to reduced biodiversity: non-existent or poorly functioning markets for its many benefits (causing it to be undervalued in land-use decisions), and a number of exacerbating factors that are frequently driven by inappropriate government policies. Because these problems have multiple, synergistic causes, finding solutions is far from easy. This chapter discusses the range of possible responses to biodiversity loss which agricultural planners might consider.

Recognizing and Diagnosing Threats to Biodiversity

Recognizing and diagnosing threats to biodiversity is an indispensable first step. National Environmental Action Plans (NEAPs) and Biodiversity Strategies and Action Plans (BSAPs) were reviewed to gauge the degree to which developing countries have identified threats to biodiversity and diagnosed its causes.

National Environmental Action Plans. NEAPs are intended to provide a framework to integrate environmental considerations into country economic and social development efforts. NEAPs describe environmental problems in a country, identify their principal causes (including policy forces behind environmental degradation), and formulate policies and concrete actions to address these problems. The process through which NEAPs are formulated is demand-driven, action-oriented, and based upon local participation, however. Despite their mandate to address environmental problems, NEAPs have not been particularly effective in addressing issues related to biodiversity conservation.

Of the forty-six NEAPs reviewed for this study, only twenty-seven mention biodiversity loss as a major environmental problem. Of these twenty-seven, the majority present little more than a brief description of the pressures that threaten biodiversity. Four NEAPs (China, Madagascar, Mauritius, and Sri Lanka) offer a slightly more advanced analysis of biodiversity problems, discussing factors such as market failures, macroeconomic distortions, and property rights issues. Although these documents begin the process of mainstreaming the environment into national development, they often do not address biodiversity conservation explicitly. Only six NEAPs (Dominican Republic, Ethiopia, Kenya, Malawi, Pakistan, and Uganda) offer a high level of analysis, including (a) identification and examination of government sector policies, their shortcomings, and impact upon biodiversity; (b) promotion of specific policies to generate long-term environmental benefits and trigger necessary structural changes, including secure land tenure, land rehabilitation, and provision of biodiversity-friendly extension services and credits for activities; and (c) promotion of sustainable agricultural practices, including intensification to reduce demographic pressure on ecologically fragile lands.

National Biodiversity Strategies and Action Plans. BSAPs are key vehicles to implement the Convention on Biological Diversity (CBD). The process of preparing strategies and action plans helps countries define priorities for domestic actions and international cooperation, as well as to strengthen institutional capacities and address the full array of convention mandates. BSAPs include (a) a national strategy that analyzes the data in the country study, identifies potential goals and objectives, and examines gaps between current reality and the aspirations espoused in the objectives; and (b) an action plan that spells out steps needed to implement the national strategy and addresses practical questions about institutional responsibilities, time frames, and necessary resources. At present, BSAPs are less numerous than NEAPs. Of the nine that were reviewed, four simply mention pressure factors threatening biodiversity. Only two address biodiversity conservation with the same level of rigor as the six high-quality NEAPs.

Although NEAPs and BSAPs represent an important step forward in environmental management, they have yet to make a significant impact on development planning, either at the macroeconomic or sectoral policy level, or as a contribution to reorienting public expenditures. In order to strengthen national strategies, rigorous analysis of environmental impacts and their economic consequences—for instance, using benefit-cost analysis where possible, and cost-effectiveness analysis when benefit estimates are not available—must be incorporated. Market-based policy instruments should be promoted as least-cost solutions to selected environmental problems. Such instruments frequently allow for win-win solutions—policies implemented for reasons of economic efficiency often lead to improved environmental quality.

Identifying priority problems must include transparent selection criteria, especially related to economic productivity, ecological functions, and ecosystem integrity. Finally, environmental strategies should be based on consultations with those who are responsible for environmental problems, those who are adversely affected, those who control the policy instruments for solving problems, and those who have the relevant data and technical expertise.

Even when the will and resources to examine biodiversity problems are available, efforts have often been stymied by a lack of information and by the difficulty of using available information—often collected for very different purposes—to analyze problems. To address these constraints, efforts have been made to develop tools and methodologies for rapid assessment of biodiversity problems (Box 3).

Addressing Policy Distortions

Given the many failures that characterize markets for the benefits of biodiversity, removing policy distortions alone cannot create perfect efficiency. Reforms to economy-wide and sectoral policies are nonetheless important for several reasons. First, many distortions exacerbate conflicts between agriculture and biodiversity, and removing them would partially ease the conflicts. Second, policy reform—despite its difficulties—is generally simpler to implement than improving markets for biodiversity's services. Third, there is substantial potential for win-win solutions because policy distortions that exacerbate damage to biodiversity are often also economically inefficient.

The fundamental arithmetic of agricultural production is that total production equals mean yield times area cultivated. Increasing demand for agricultural products, therefore, can only be met by increasing yields or expanding the area under cultivation. Because habitat conversion tends to be much more damaging to biodiversity than land-use changes in agricultural landscapes, encouraging intensification could significantly contribute to the preservation of biodiversity by slowing encroachment into natural areas. A basic principle of biodiversity-friendly policy reforms is to discourage extensification and encourage intensification. The latter can take a number of forms, some of which can be quite harmful to biodiversity, and

Box 3. Rapid assessment of biodiversity

Many regions have scarcely been touched by scientific exploration. The threat posed by large-scale changes in land use worldwide makes it imperative that methodologies be developed to rapidly assess biodiversity in a given area, so that conservation priorities can be developed.

Recently, the Bank developed guidelines for the rapid assessment of biodiversity priorities (RAP or BioRap). Based on methods being adopted for use in developing countries by a consortium of Australian scientists, the World Bank, and the GEF, these guidelines incorporate current ecological theory and best scientific practices in light of three realities. First, there is a limit to the amount of land and water that will be managed primarily for biodiversity protection; second, creating complete inventories of all species and genotypes is not an achievable goal in the near future; and third, land and coastal use will continue to change as people use biological resources to meet their needs. In light of these realities, the guidelines suggest that:

- RAP methods have to be explicit, cost-efficient, and flexible and must attempt to deal with the problem of inadequate knowledge. The guidelines enable users to make an explicit statement of different areas' relative contribution to overall biodiversity protection. Initiatives can then be taken to protect areas that make a significant contribution.
- Competing land uses pose severe constraints on biodiversity protection, and RAP must have maximum flexibility in locating priority areas to facilitate negotiation while ensuring protection of unique areas.
- RAP data bases must be derived from raw data with a consistent level of detail across regions, because identifying priority areas requires making comparisons across regions. The guidelines include methods for designing efficient biological surveys and are accompanied by software tools for collating information from field surveys and museum collections, Geographic Information System (GIS) mapping tools for identifying areas of conservation importance, and a handbook for their application.

in many cases undermine their own long-term sustainability. There is considerable scope for attempts to channel intensification toward more sustainable forms.

Discouraging extensification. Government policies have often exacerbated pressures for extensification by providing direct or indirect subsidies to convert natural habitats. These policies may lead to growth of marginally profitable cultivation or livestock production in formerly natural habitats. Such growth has often proven unsustainable, even over relatively short periods. Moreover, the costs of these policies have often been substantial. There are often win-win options, therefore, that both reduce fiscal drain and alleviate pressure on biological resources. There already has been substantial progress; for example, Brazil has curtailed or scaled back most of the policies that encouraged clearing of the Amazon (Box 4).

Encouraging intensification. Intensification has often been discouraged by policies that discriminate heavily against the agriculture sector. It is by now well documented that these policies have slowed both agricultural and economic growth substantially. Policy reforms that remove impediments to intensification can help increase agricultural production and also ease pressure on remaining habitats. In fact, many developing countries have already made great strides toward liberalizing their economies and removing the worst of the distortions that once afflicted the agriculture sector. At a minimum, policies that discourage intensification should be reformed, but the additional step of actively encouraging intensification is more problematic. The problem may not arise, however—removing constraints may result in intensification occurring spontaneously.

Avoiding the pitfalls. It is important to ensure that intensive agricultural systems are is sustainable. Although intensification is likely to reduce pressure on natural habitats, it may further reduce biodiversity at that location. On-site biodiversity can be reduced because of increased specialization and reliance on a few improved cultivars, while off-site damage can increase through higher use of chemical fertilizers and pesticides. Care must be taken to avoid intensification policies that are likely to damage biodiversity (for example, subsidizing pesticides and fertilizers and underpricing irrigation water). Here too, there is potential for win-win policies because practices that are particularly likely to damage biodiversity, such as pesticide use, have often been artificially encouraged by government policies. The example of Bangladesh in Box 2 above illustrates the degree to which simply removing distortions can avoid some of the worst forms of intensification. Regulatory reform can often help avoid the pitfalls of intensification. Some developing countries still allow use of highly-toxic, persistent pesticides, while in others these are banned but the ban is not enforced.

Although the basic outlines of biodiversity-friendly macroeconomic and agricultural policies are clear, the details are often difficult to work out. Only a limited amount of detailed analytical work is available that has directly traced the impact of overall agricultural policies on biodiversity. Moreover, it is often difficult to predict the consequences of specific policy measures, and each situation needs to be examined individually. This problem will become increasingly important as liberalization progresses and the most obvious sources of inefficiencies (such as pesticide subsidies) are removed. Once these easy gains have been made, further gains will become more difficult to achieve. More detailed analytical work on the impact of specific policy changes on agricultural activities and biodiversity will be needed, as well as close monitoring of the effects of any actions.

Box 4. Policy responses to deforestation in the Amazon

In the past, general tax policies, land allocation rules, and operation of the credit system in Brazil all contributed to accelerating deforestation of the Amazon rain forest—the largest repository of biodiversity in the world. Numerous provisions of the tax laws encouraged conversion of forests into agriculture or pasture, an effect reinforced by the availability of subsidized credit. Rules for allocation of federal land specifically encouraged deforestation because the security of claims was determined by land clearing.

Partly as a result of such policies, the population of Brazil's Amazonian states doubled to about 9 million people between 1970 and 1990. About 100,000 square kilometers of native forest were converted to pasture, and additional areas were converted to crop production. (The actual extent of deforestation is the subject of some dispute due to different definitions, data sources, measurement techniques, and assumed baseline conditions.)

In recent years, policy and institutional changes have enhanced environmental protection, including (a) making fiscal incentives for investing in the Amazon region subject to environmental conditions; (b) abandoning or scaling back road building and colonization projects; (c) mandating environmental impact studies for all public works and private investments; (d) curtailing agricultural tax exemptions; and (e) reducing or eliminating price and credit subsidies for farming and ranching.

These positive policy developments reflect a realization that the short-term benefits of past policies were outweighed by long-term costs. They also require that implementation be supported by adequate resources. An increasingly vocal population in the Amazon region, however, seeks modern infrastructure for an improved standard of living, and the federal government faces the difficult task of balancing those concerns with the broader agenda of environmental conservation.

Reducing Market Failures

Those who make decisions that affect biodiversity (primarily farmers) receive few of the benefits of conservation but bear most of the costs. Improved markets for the services provided by biodiversity would internalize their benefits in farmer management decisions, thus shrinking the divergence between privately-optimal and socially-optimal behavior. Considerable efforts have been made in recent years to find mechanisms that will provide farmers with greater benefits from biodiversity. These include efforts to revise property rights and develop new income opportunities dependent on biodiversity conservation (for example, ecotourism), and mechanisms to return royalties from genetic material collected in an area to local communities. Understanding the structure of incentives is vital to the success of these schemes.

Environmental taxes. Given the potential for inputs such as pesticides to cause external damage, there is ample justification to go beyond avoiding subsidies and actively tax such inputs. Such environmental (green) taxes substitute for the missing markets for the damages and lead farmers to internalize these costs in their decisionmaking. While environmental taxes have received considerable theoretical attention, practical experience remains scarce. Establishing the proper level for such taxes will be difficult. Because the damage caused by pesticides varies substantially from place to place (application upstream from a natural habitat, for example, is likely to cause more damage than application downstream), the appropriate level of the tax would also vary. Implementing such a variable tax would clearly be impractical, thus much work remains to be done in this field.

Secure property or usufruct rights. In principle, assigning property rights to biodiversity or its services would ensure that they are used appropriately. Owners would demand compensation from beneficiaries and protect their property from damage. Enforcing such rights is impractical, however, because most of the services provided by biodiversity are public goods. A more realistic alternative is to ensure that property or usufruct rights on biologically diverse sites are secure, which would often substantially change the way these sites are exploited. To the extent that biodiversity provides extractive benefits or on-site productivity benefits, secure rights to these benefits will make conservation more attractive and may tilt the balance toward conservation. Property rights to individual pieces of land, however, are not a panacea for biodiversity conservation because they do not increase incentives to avoid externalities. In cases where insecure tenure prevents investments in intensification, increasing tenure security could reduce damage to biodiversity by reducing pressures to convert additional natural habitats to agricultural production.

Regulation by local communities. Local communities can be effective resource managers if they have the ability to enforce rules and the incentive to do so. In cases where an important part of the costs of not conserving biodiversity are borne by local communities, giving them authority to regulate the use of habitats in their areas can significantly improve conservation. Community involvement in forestry management in Nepal, for example, appears to have substantially improved the conditions of forested areas. Such authority, however, will not increase incentives to avoid externalities that are not experienced at the local level.

Decentralization. The potential role for communities in safeguarding biodiversity at the local level is becoming more important as many countries decentralize authority and responsibility to lower levels of government. Decentralization can offer a more fine-tuned approach to environmental and natural resource management problems, assuming appropriate investments in the institutional capacity of lower levels of government. Local governments, thanks to their proximity to environmental and natural resource problems, are probably better placed to design a least-cost way to achieve a given reduction in damage, monitor compliance with regulations and conditions attached to subsidies, and adjust policies in light of experience. Local governments, however, will only consider externalities that are felt primarily within their jurisdiction.

Since the impact of damage to biodiversity is unlikely to respect administrative boundaries, local governments will often have less incentive to address externalities than higher-level governments. Thus, while decentralization might increase the chances that spatially-limited externalities will be addressed appropriately, it may decrease the chances that externalities with broader consequences will be dealt with appropriately. Transfers from the central government would be needed to motivate local governments to address externality problems that reach beyond their boundaries. Careful design of incentives and conditions attached to such grants would be needed because the local government would become the central government's agent in implementing policies designed to reduce externalities.

Alternative benefit capture mechanisms. Several different mechanisms have been proposed in an effort to encourage farmers and local communities to conserve biodiversity:

- *Intellectual property rights.* The genetic information embodied in plant and animal species has hitherto been gathered by researchers without compensating local populations. As a result, local populations have had no incentive to conserve these potentially valuable resources. To remedy this problem, there have been efforts to devise mechanisms through which local populations might be compensated for genetic information collected in their areas, either with up-front payments or royalties from sales of products developed from that information (Box 5).
- *Ecotourism.* Ecotourism has often been proposed as a way to generate income from natural habitats without damaging them, but the promise has thus far outstripped reality. Managing tourism in ways that do not degrade natural habitats is far from easy. Possible detrimental effects from ecotourism include environmental stress due to overcrowding, changes in behavior of wildlife, erosion of trails and beaches, over-development of local infrastructure, and increased noise, litter, or resource extraction. Ensuring that the benefits of ecotourism are received by local communities so that the desired incentive effect will be realized is also proving difficult. Moreover, benefits may be offset in the eyes of local communities by the intrusion of tourists, greater income inequality within and between communities, increased pollution, and rising local prices.
- *Subsidies.* Because the benefits of biodiversity are often public goods, there is a logical case for subsidies to those who bear the costs of providing them. Conservation trust funds are one mechanism through which the global community may com-

Box 5. Compensating farmers for intellectual property rights to biological information

Areas with high levels of biodiversity are likely to contain biological information valuable for the development of products such as pharmaceuticals and improved crops. Historically, the biological samples used to search for useful products have generally been extracted without compensation. The rosy periwinkle, from which drugs for childhood lymphocytic leukemia were developed, is an often cited as an example of biochemical discoveries that have failed to benefit source countries (in this case, Madagascar). There have been recent efforts to develop mechanisms to compensate source countries and local populations. These mechanisms provide one avenue for local populations to benefit from biodiversity, thus increasing their incentives to conserve it.

The agreement signed between pharmaceutical company Merck & Company and the Costa Rican National Biodiversity Institute (INBio) in 1991 is often cited as a model for such schemes. Under the agreement, INBio supplied Merck with samples from plants, insects, and microorganisms collected in Costa Rica's protected forests, which Merck has the right to use in the creation of new pharmaceutical products. Merck paid INBio $1 million for the rights to analyze and use these samples, as well as $180,000 in equipment for chemical extraction, and training in species identification and collection to Costa Rican scientists and field collectors. If the search yields commercially viable products, Merck will pay INBio royalties on sales. Ten percent of the initial $1 million fee and 50 percent of any royalty were to be invested in biodiversity conservation through Costa Rica's Ministry of Natural Resources.

Despite widespread positive reaction to the agreement, it has had few followers to date. Whether these mechanisms provide sufficient incentive to local people to conserve potentially valuable biodiversity remains to be demonstrated. The incentives may not be important enough to make a difference in practice. Even where the benefits are potentially significant, implementation details are likely to play an important role. For example, the Merck-INBio agreement did not provide any explicit compensation to local populations, only indirect compensation through investments by the Ministry of Natural Resources and INBio.

Box 6. Trust funds: compensating local communities for biodiversity conservation

Conservation trust funds are an innovative mechanism through which the global community may compensate local communities for protection of critical biological diversity. They have the potential to provide long-term, sustained financing to meet the recurring costs of operating and maintaining protected areas, and to ensure sustainable use of natural resources through community support. Examples of conservation trust funds include:

Uganda's Mgahinga and Bwindi Impenetrable Forest Conservation Trust was established in 1994 to protect two of the most biologically diverse forests in East Africa. These two areas have suffered significant ecological losses from timber harvesting and agricultural encroachment. The Trust finances park management, research, and community-based development programs that are compatible with conservation. Specific benefits from the Trust include (a) lowered probability of drastic reductions or loss of endemic, rare, or endangered species; (b) continued provision of environmental services; (c) long-term economic gains for local communities by ensuring that forest resources are used in a sustainable manner; and (d) economic gains through development of compatible and complementary economic enterprises, such as gorilla watching.

Bhutan's Trust Fund for Environmental Conservation was created to help conserve the nations forests and preserve rich biological diversity that has come under pressure from population growth and economic development. The Trust is financing a national system of protected areas and the development of institutional capacity and human resources to manage the system. It is overseen by a board of directors that includes members of the Royal Government of Bhutan, UNDP, and international NGOs.

It is too early to determine whether trust funds will play a significant role in promoting the conservation and sustainable use of biological diversity. There are, however, promising signs: policy reforms when the Trust was established included legislation aimed at protecting natural habitats, and there have been successes in sensitizing local communities to the need for conservation efforts.

pensate local communities for the protection of critical biodiversity (Box 6).This solution encounters all the usual problems with subsidies, including difficulties in setting appropriate levels and ensuring compliance, the danger of creating perverse incentives, and high transaction costs.

All these mechanisms have a role to play. Their applicability and ease of implementation will clearly vary substantially from case to case.

Given the nature of biodiversity, it will likely prove impossible to create functioning markets for all its benefits, but in many cases it will not be necessary to achieve complete markets. Any change that increases the benefits farmers receive from biodiversity will reduce biodiversity losses. It will not always be necessary for farmers to appropriate all or even most of the benefits provided by biodiversity—all that is necessary is for the benefits they receive to offset the benefits of actions that damage it. Efforts to create markets or market substitutes for at least some of the benefits of biodiversity are likely to have an important effect on the overall conservation of biodiversity, especially if negative policy effects have been alleviated through reforms.

Improving Research and Extension

Even if markets work and incentives are not distorted by government interventions, farmer choices are limited by the technologies available to them. Some technologies already exist which could—often at little or no cost to farmers—help conserve and enhance biodiversity in agricultural landscapes (Box 7). Incorporating them in land-use planning and extension programs would mark an important step forward. In many cases, however, research is needed on improved technologies that reduce conflicts and enhance complementarities between agriculture and biodiversity. Such technologies are also likely to substantially improve the sustainability of agricultural development.

New approaches to research. New approaches to agricultural research are being tested around the world. Many of these approaches emphasize better exploitation and management of biological resources than has prevailed in the past. Instead of reliance on an arsenal of potent chemicals to improve soil fertility and thwart the attacks of insects and disease-causing organisms, agricultural research is increasingly turning to biological assets, including manipulation of genes and predators of insect pests. When crops and livestock are bred so that they can thrive under the incessant onslaught of challenges to productivity, agricultural production systems become more resilient.

Improved inputs. The threat posed by agricultural inputs has been lowered. Newer pesticides, for example, are generally much less persistent, have a narrower spectrum, tend to have lower concentrations of active ingredients, and are often less toxic. The use of biopesticides and granular insecticides has also been increasing. Granular formulations are less likely to contaminate water than foliar insecticides, and thus are less likely to cause damage far from their area of application. Many newer insecticides also pose lower health risks to farm workers and their families. Despite these positive trends, many problems persist. Older, more toxic, and more persistent pesticides are still widely used in many developing countries. Improved registration procedures designed to ensure pesticide safety have at times perversely slowed adoption of less damaging newer pesticides; meanwhile, already-certified pesticides, which tend to be more damaging, continue to be used.

Fertilizer use has also improved. Recommended application rates were once based on average conditions, but excess nutrients would often contaminate ground and surface water. In recent years, fertilizer recommendations have increasingly been based on more site-specific conditions. In some countries, including Kenya and Indonesia, soil testing programs for individual farms determine fertilizer requirements. Despite these improvements, there is still considerable scope to develop inputs that are less environmentally damaging and increase the use of less-damaging inputs through appropriate extension strategies.

Box 7. How can agriculture promote biodiversity conservation?

Agriculture practices and management systems can often make important contributions to biodiversity conservation. Some examples of methods that maintain biodiversity within the context of agriculture activities include:

Measures to avoid the unnecessary threats to biodiversity:

- Using Integrated Pest Management (IPM; see Box 9) to protect wildlife and natural enemies of crop pests from unnecessary damage.
- Using more diversified practices such as polyculture, crop rotations, understorey agriculture, or agroforestry whenever possible.
- Conserving riparian forests and ecosystems, and other biodiversity corridors.

Measures to manage landscape structure and functioning:

- Retaining uncultivated strips within holdings as habitat for weedy relatives of crop plants—especially in areas known to be centers of origin or diversity for crop plants.
- Maintaining disturbance patterns whenever and wherever possible. Fire and floods, for example, can play an important role in biodiversity conservation.
- Planning the arrangement of crop plots. Patches, corridors, and barriers can be located and oriented to minimize species loss and promote dispersion of certain species or, on the contrary, to act as natural barriers to avoid the dispersion of harmful populations.

Measures to conserve the genetic pool:

- Supporting traditional agriculture systems, especially those employing polyculture methods and/or agroforestry patterns.
- Using native woody species when establishing windbreaks or woodlots.

Need for a new agricultural research and development model. Although incorporating natural resource management and on-farm trials in research has progressed at international, regional, and national agricultural research centers, much more needs to be done. A new research paradigm that systematically incorporates agrobiodiversity is already evolving in different parts of the world. In contrast to the old research model that emphasized maximizing output and tended to be commodity-focused, the new vision for agricultural research adopts a more holistic approach.

It is more sensitive to environmental concerns while still addressing the need to boost yields and incomes (Box 8). Integrated Pest Management (IPM) is one of the most successful examples of how biodiversity can contribute to agriculture (Box 9).

Farmers will not adopt new, less harmful technologies if returns are not at least as high as those of current practices. Just as research that emphasized increased yield without regard to cost was often spurned by farmers, research that addresses environmental problems but does not offer either higher output or lower costs is also unlikely to be widely adopted. The attraction of IPM for farmers, for example, does not lie in its benefits to biodiversity, but rather in its lower costs and higher yields.

As new techniques, inputs, and information emerge that promote biodiversity-friendly agricultural production, it is important that this information reach farmers. Training extension workers to effectively promote adoption of these technologies by farmers is essential, and it may also be necessary to involve alternative extension channels such as non-governmental organizations (NGOs) or private sector distributors.

Complementary Conservation Measures

In many countries, the pressure to expand agriculture is so great, at least in the short term, that adopting an appropriate policy framework and addressing market failures might only succeed in slowing the rate of expansion. Complementary conservation measures are necessary to ensure that such expansion causes the least possible damage.

Protecting and enhancing critical habitats. Although some degree of overall agricultural expansion might be unavoidable, the extent of damage to biodiversity can be contained by protecting key areas within the growing agricultural landscape. Within any region, certain areas tend to play a particularly important role in the ecosystem. Nesting sites, migration stop-off points, riparian areas, and wetlands, for example, are all especially important for ecosystem functions. Converting them to agri-

Box 8. Elements of a new agricultural research and development model

Participatory approach. On-farm research should not be limited to demonstrations on farmer fields. It should include experimental work that involves farmers and other stakeholders in design of models from the inception of the study. Farmers should be actively involved in selecting desirable plants for their growing conditions.

Use of indigenous knowledge. Patterns of natural resource use by indigenous people can provide important information for more appropriate agricultural research and development efforts.

Greater attention to lesser-known crops and animals. Many traditional varieties and breeds are particularly well-suited to difficult environments but have been neglected by research. They should be included in a broadened research effort. Relatively minor investments in some neglected crops and livestock breeds could generate significant returns.

Research on new crops and livestock. Scope exists for new crops and livestock to fill specialty market and environmental niches.

Greater sensitivity to the value of a mosaic of land uses. Even land uses that are desirable from a biodiversity viewpoint can be promoted too far. Biodiversity in managed landscapes is often best served by promoting a mixture of land uses that provides varied habitats for plants and wildlife.

More diverse habitats within land use systems. Diverse habitats on the landscape create more niches for plants and wildlife, some of which control insect pests. More diverse habitats, including managed ones, also promote more efficient use of nutrients and create microclimates that can help buffer crops from inclement weather.

Greater reliance on recycling of organic matter. Crop rotations, incorporating livestock or green manure, and no-till or minimum-till farming help sustain diverse soil microorganisms important in nutrient recycling.

Determine the critical number of breeds for conservation purposes. DNA analysis of genetic variation can be used to accentuate the genetic spacing between breeds, and to identify those breeds that are significantly different or unique from others.

Research on genetic components of adaptation in livestock. A better understanding of traits such as tick resistance and use of body stores would aid breeding efforts and likely underscore the importance of safeguarding so-called minor breeds.

Box 9. Integrated Pest Management: biodiversity and ecological knowledge at work

Integrated pest management (IPM) techniques seek to exploit ecological knowledge to control insects. Rather than attacking insects with insecticides, IPM techniques attempt to manipulate the crop environment by taking advantage of its biodiversity to reduce the chances of damage. The actual techniques vary depending on the crop and the ecosystem, but they typically include use of insect-resistant varieties, changes to planting times and other operations to exploit insect life cycle, encouragement (or introduction) of natural enemies (biocontrol agents), and mixed cropping. Pesticide use, if any, is limited to reacting to particularly high levels of infestation, rather than prophylactic applications. Where possible, use of biopesticides is encouraged. With such techniques, many countries have achieved substantial reductions in pesticide use without adverse effects on yields; indeed, yields have often increased.

Indonesia adopted IPM as a national policy in 1986 following recognition that pesticide use was threatening rice production. In addition to adopting IPM, Indonesia banned fifty-seven broad-spectrum insecticides and phased out subsidies on pesticides. The IPM program includes field classes on ecology, crop husbandry, physiology, insect feeding habits, and population dynamics. As a result of these efforts, pesticide use had fallen 70 percent nationally within 5 years, while rice yields increased 10 percent. Higher yields and lower production costs have increased farmer profits.

culture can be particularly damaging, so direct intervention may be warranted. Targeted actions can also be undertaken to improve biodiversity within an agricultural landscape, for example corridors can be preserved between remaining habitats to facilitate the movement of species, remnants of natural habitats can be protected and expanded, and nearby natural habitats can be buffered by limiting land use in adjacent areas to uses such as forestry or agroforestry that minimize edge effects and enhance the retention of ecological functionality.

Although the integration of habitat strategies can serve multiple goals, they often involve land-use tradeoffs. Planting a buffer strip or integrating a habitat strip takes up space that could be used for growing crops. Restricting land use in some areas may prevent farmers from making the most profitable use of that land. In these situations, varying benefits and costs need to be weighed and compared with available public and private resources. If most of the benefits are external, farmers are unlikely to adopt them unless they receive some form of compensation.

Restoring biodiversity. In degraded and unproductive agricultural areas, vegetation can be restored either deliberately by replanting native flora or passively by allowing the area to reseed itself. Recent research has shown that planting trees on degraded sites can significantly increase the otherwise slow rate of natural forest succession by ameliorating unfavorable soil and understory conditions and attracting seed-dispersing wildlife. Large areas suffering from alkalinity and salinity have been reclaimed as productive agricultural lands through the use of regenerative agricultural practices. Selection among these options depends on the nature of degradation, conservation goals, and available resources. These strategies often can achieve multiple functions —helping conservation by alleviating pressure on critical habitat areas and stabilizing the agricultural landscape. The regrowth process is usually quite slow, and experience with such strategies is relatively limited, but successful implementation has been demonstrated in various areas (such as in orchard systems in California), and has been practiced traditionally as well. To the extent that these activities are undertaken in degraded areas, their opportunity cost is often low.

Ex situ conservation. Saving seeds and other plant material away from their original sites is *ex situ* conservation. This genetic material is stored in genebanks under controlled conditions, and is available for breeding. Although this system has been very successful since it was pioneered by the Russian botanist N.

Box 10. Global plan of action for conservation and sustainable use of plant genetic resources

Plant genetic resources for food and agriculture provide the biological basis for world food security. The conservation and sustainable utilization of these resources is key to improving agricultural productivity and sustainability, thereby contributing to national development, food security, and poverty alleviation. Properly managed, plant genetic resources need never be depleted, for there is no inherent incompatibility between conservation and utilization. However, these resources are seriously threatened. The chief contemporary cause of the loss of plant genetic resources has been the spread of modern, commercial agriculture. The largely unintended consequence of the introduction of new varieties of crops has been the replacement—and loss—of traditional, highly variable farmer varieties. The lack of capacity to conserve and optimally utilize these resources undermines the quest for food security and sustainable development.

Responding to this crisis, the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture, adopted by representatives of 150 countries in Leipzig, Germany in June 1996, provides the impetus and framework for putting conservation and utilization activities on a solid foundation. The Global Plan of Action, addressing priority actions at the local, national, regional and international level, deals with (1) *in situ* conservation and development; (2) *ex situ* conservation; (3) utilization of plant genetic resources; and (4) capacity building for conservation and sustainable utilization. Assessments, intermediate and long-term objectives, strategic approaches to implement priorities, human and institutional capabilities, and research priorities are identified in each of the four main section.

Vavilov in the early twentieth century, it is not without problems. Maintaining genebanks is expensive, especially in developing countries, and use of the material is limited by the degree to which its properties have been catalogued. In several cases, valuable germplasm collections have been lost because of neglect, insufficient or inadequate storage facilities, funding limitations, and wars. Often, stored material may not be viable. In recent years, issues of access to germplasm have become increasingly contentious. While this approach may preserve individual species, it does nothing to safeguard other valuable aspects of biodiversity such as ecosystem services, and halts further evolution of the conserved species. Nonetheless, for species threatened by the imminent destruction of their habitat, *ex situ* conservation might be the only viable alternative.

In situ conservation. While measures to improve the usefulness of *ex situ* collections of plant and animal genetic resources are warranted, considerable attention is now focused on *in situ* conservation of plant and animal genetic resources. In contrast to *ex situ* conservation, *in situ* conservation preserves not just individual species but also the process by which they evolve through crossing with wild and weedy relatives. Major conceptual and practical obstacles remain to the implementation of effective *in situ* conservation programs.

Valuing Benefits and Assessing Tradeoffs

When market failures are reduced, the need for valuation of the benefits of biodiversity by government agencies will diminish because the incentives for farmers and other resource managers to consider the benefits in their own decisions will improve. In combination with reforms to reduce the extent of policy-induced distortions, the divergence between privately-optimal and socially-optimal resource use will be smaller. Nonetheless, it will often be necessary to attempt to evaluate the benefits of biodiversity, because protecting them might in some instances conflict with other objectives. Likewise, activities to restore biodiversity benefits require cost-benefit analysis.

Valuing the benefits of biodiversity remains intrinsically difficult. Many ecological relationships are uncertain, and it is difficult to assign value to goods and services because many do not enter markets. Nonetheless techniques exist to estimate the value of at least some of the benefits generated by biodiversity and the effects of agricultural activities upon them. When damage to biodiversity reduces agricultural productivity, the change in output also reduces benefits. When other services are affected, replacement costs can often be used; for example, the cost of treating water to replace the water filtration service provided by wetlands can be used as a measure of its benefit.

Where there are threats of serious or irreversible damage, the lack of full scientific certainty should not be used as a reason to postpone cost-effective measures designed to prevent environmental degradation.

Implementation Problems

Mainstreaming biodiversity in agriculture will create a series of possible responses to the problems to be solved, and each response is likely to confront important implementation problems. First, the institutional capacity to implement responses is often limited. Second, many of the responses are likely to have distributional consequences that could trigger either opposition or have undesirable equity implications. This section discusses these problems.

Institutional Problems

Improved government policies that affect biodiversity will require more and better information to be provided to policymakers. Currently, the bulk of information available to policymakers completely ignores non-market benefits such as those provided by biodiversity. First, information is required on the extent and nature of damage to biodiversity and the consequences of this damage; however, monitoring the state of biodiversity and the pressure on it is often limited. In addition, there is almost no monitoring in agricultural landscapes, and what little monitoring exists is generally limited to natural habitats. Monitoring is also often insufficiently detailed to allow identification of specific problems in particular areas.

Second, prioritization will also require a damage assessment and an estimation of the likely returns to interventions so that scarce resources can be used optimally. The state of the art in this field remains poor, but lack of information should not lead to paralysis. In many instances, sufficient information is available to both justify intervention and indicate the nature of the required response. It is important that the effects of any intervention be closely monitored to ensure their success and guard against unintended side effects, and to build up the data base so that future interventions can be better designed.

Although biodiversity provides clear benefits to agriculture, these benefits are only beginning to be recognized. In many cases, biodiversity is still perceived as the preservation of butterflies and panda bears and dismissed as a rich-country extravagance. Although this attitude is slowly changing as evidence mounts of the importance of biodiversity to agricultural development, significant educational work remains. Improved information will provide sectoral planners with concrete evidence of the relationship between agriculture and biodiversity in their own countries. The educational effort should not be limited to agriculture sector planners, because many of problems originate in non-agriculture sector policies (Chapter 3). In many developing countries, coordination between different ministries remains difficult.

Agriculture sector planners are likely to face resistance from planners in other sectors to reforms needed to improve the relationship between agriculture and biodiversity. Similarly, agriculture sector planners are also likely to have few incentives to implement measures that help conserve non-agriculture-related services provided by biodiversity if doing so threatens to reduce the performance of their sector. In Kenya, for example, it is difficult to reconcile increasing water use in agriculture with the needs of wildlife, even though wildlife clearly benefit the nation through tourism. Where conserving biodiversity encounters tradeoffs with agriculture-specific objectives, a strong voice is needed to press the cause of conservation, along with a higher authority to adjudicate disputes. Even then the global dimensions of the problem will not be given adequate consideration unless they are brought to the table by external agents such as the Global Environment Facility (GEF). Some NGOs have also played an important role by arranging debt for nature swaps.

Tensions may arise between governments as social planners and governments as economic agents. As social planners, governments might realize that conserving biodiversity is necessary for sustainable development and improving incentives to local farmers is important for this objective. But as economic agents they often attempt to appropriate revenue from ecotourism or bioprospecting for their own uses rather than allowing it to flow to local communities.

Distributional Issues

Closer attention to biodiversity in agriculture is likely to increase societal benefits at both the national and global levels through increased and more sustainable agricultural production, and preservation of the many other valuable services that biodiversity provides. The distribution of these benefits is likely to be uneven, however; there may well be individuals or groups that stand to lose even as society as a whole benefits.

Ensuring that participants obtain positive benefits is likely to prove vital to successful implementation of any response, particularly in an agricultural context, because adoption is ultimately in the hands of individual farmers. Groups that stand to lose, however, may go beyond non-cooperation and actively oppose necessary reforms. Both farmers and pesticide industry workers, for example, are likely to oppose lifting pesticide subsidies even though removing them is clearly a win-win policy from a societal perspective. Opposition to reform of pesticide regulation and subsidization policies by industrial groups in India has meant that many toxic, persistent pesticides continue to be produced and used in that country.

Distributional consequences may also matter even if the affected groups are unable to oppose reform. Some might be poor, for example, and there will be equity concerns over implementing policies that affect them adversely even if the net societal gains are positive. If possible, policies should be designed to minimize such effects, but to the extent that this is not possible, compensation schemes might be necessary.

5. *The Challenge for the World Bank*

As the world's population continues to grow, agricultural production must meet the rising demand for food. Current patterns diminish the biodiversity that provides many valuable services to agriculture and other sectors, and undermine long-term sustainability of agricultural production. The conversion of natural habitats to agricultural use is of particular concern because it substantially reduces biodiversity. Intensification can generally be beneficial if it reduces pressures to expand cultivated areas, but it can also be harmful. Meeting the imperative of increasing agricultural production in a sustainable way while conserving and prudently using biodiversity is a major challenge.

This chapter summarizes the strategic responses to this challenge and the constraints that mitigate against such responses as they have been outlined in the previous chapters. The Bank's role in helping its developing country partners to remove such constraints and effectively mainstream biodiversity in agricultural development is examined—first, in the context of the Bank's country assistance strategies; second, in relation to agriculture sector work; and finally, exploring implications for the agricultural lending program.

Mainstreaming at the Country Level

The preceding chapter outlined a framework to embrace biodiversity conservation as agricultural development policies and programs are formulated. This framework includes five strategic elements to reduce conflicts and build on the complementarities between agriculture and biodiversity. The relevance and importance of each element, summarized below, will vary from country to country, and strategies and actions to implement them must be designed in the context of country and local conditions.

- First, conflicts and complementarities between biodiversity conservation and agriculture need to be recognized and diagnosed. To ensure that this happens, biodiversity considerations must be included on the economic development agenda by (a) improving the effectiveness of national strategic planning frameworks, including National Environmental Action Plans (NEAPs) and Biodiversity Strategy and Action Plans (BSAPs); (b) heightening awareness at technical and political levels of the conflicts, complementarities, and trade-offs between biodiversity conservation and agricultural development; and (c) broadening agriculture sector planning objectives and processes to embrace biodiversity conservation.
- Second, policy distortions that exacerbate pressure on biodiversity must be addressed through macroeconomic and sectoral policy reforms that benefit biodiversity while improving economic efficiency (win-win policies). Also, cross-sectoral policies such as those regulating land use should be consistent with biodiversity conservation objectives.
- Third, the effects of extensive market failures must be reduced to the extent possible. The broad instruments available include (a) using green taxes; (b) enhancing security of

property or usufruct rights; (c) empowering local communities to manage natural resources, including biodiversity; and (d) finding effective means to return the benefits of biodiversity to local communities.

- Fourth, research and extension must be re-oriented to provide more and better technical options to farmers who use biodiversity as an input to enhance agricultural productivity on a sustainable basis.
- Finally, recognizing that the previous four elements may still leave critical aspects of biodiversity vulnerable to the actions of humans, targeted interventions for conservation will be required to protect critical natural habitats—either in the agricultural landscape or through *ex situ* means.

Mainstreaming biodiversity in agricultural development means addressing these five strategic elements. The preceding chapters have identified a number of factors that tend to encumber such mainstreaming and prevent or restrain biodiversity-friendly policy reforms, institutional adjustments, or other interventions designed to conserve biodiversity in the agricultural landscape. These factors fall into three broad categories:

- *Lack of information.* A weak information base and a generally poor understanding of the nature of effects make problem assessment and identification of appropriate and specific responses difficult. These deficiencies prevent awareness of conflicts between agricultural development and biodiversity conservation. This lack of awareness undermines the sense of urgency for high-level policy decisions to support biodiversity conservation.
- *Tradition.* The traditional focus on sectoral production and employment objectives and institutional barriers to cross-sectoral coordination have effectively prevented inclusion of biodiversity conservation in agricultural development planning. Lack of technical understanding on the part of agricultural planners about how agriculture depends on biodiversity and the relative isolation that characterizes sectoral and environmental planning in many countries are contributing factors.
- *Few proven methods.* Implementation of policies is impeded by the lack of proven modalities and instruments to address biodiversity loss problems. Although a wide range of tools and mechanisms have been proposed, experience with their use remains limited.

The Role of the Bank

Bank support to its developing country partners for mainstreaming biodiversity in agricultural development is essential for several reasons. First, conservation of biodiversity is linked to sustainable agricultural development, and for many developing countries agricultural production is the main engine of economic growth. Second, the Bank is committed to helping client governments meet their obligations under the Convention for Biological Diversity (CBD). These obligations call for conservation and sustainable use of biodiversity to be integrated into the plans, programs, and policies for sectors such as agriculture, fisheries, and forestry, and for cross-sectoral planning. Finally, as an implementing agency for the Global Environment Facility (GEF), the interim financing mechanism for the CBD, the Bank has a direct responsibility to help client governments mainstream biodiversity in development.

The Bank's commitment to its developing country partners in this effort was spelled out in the 1995 report *Mainstreaming Biodiversity in Development: A World Bank Assistance Strategy for Implementing the Convention on Biological Diversity.* The agenda for action was broadly defined to (a) help 'green' country assistance strategies, (b) help countries design biodiversity-friendly sector policies and programs,

(c) facilitate cross-sectoral planning for biodiversity conservation, (d) ensure that Bank policies and practices help countries mainstream biodiversity, and (e) foster and expand strategic partnerships in support of biodiversity conservation. The first two of these tasks are directly relevant to mainstreaming biodiversity conservation in agricultural development. They are elaborated below.

Biodiversity Conservation and Country Assistance Strategies

The Bank's Country Assistance Strategies (CASs) have traditionally focused on macroeconomic performance, including the questions of external debt management and domestic resource mobilization. More recently, addressing constraints to development of key sectors of the economy has assumed greater importance. Notwithstanding these developments, sectoral issues generally remain less than fully integrated into the diagnosis or the proposed solutions presented in the CASs.

An increasing emphasis on environmentally sustainable development and environmental and natural resources management is underpinning Bank assistance. While the purpose of and audience for a CAS does not allow extensive treatment of biodiversity conservation issues, it is important that they are given due attention when closely linked to the overall goals of development assistance delivery. In recent CASs for Mexico, Brazil, and Nepal, for example, biodiversity conservation as part of a broader set of environmental management priorities has been integrated into the analysis of development constraints and the formulation of the Bank's assistance strategy (Box 11).

Most of the Bank's client governments are parties to the Convention on Biological Diversity, and the Bank, together with other donor agencies and partners, has an obligation to help these governments meet their obligations under the Convention. The Bank has a special obligation because it is one of three

Box 11. Greening Country Assistance Strategies: toward good practice

Mexico. Loss of globally significant biodiversity, ecosystem destruction, soil erosion, and aquifer depletion threaten Mexico's development. The Government's strategy to address these problems encompasses two mutually reinforcing sets of initiatives: a multisectoral approach in subregions with high-priority environmental problems, and a national approach in specific sectors. The 1994 CAS supports this strategy through analytical work, institutional development, and lending operations. Strengthening environmental institutions and extending on-going initiatives to state and municipal agencies are part of the strategy. Specific sector efforts include promoting sustainable use of forests and other natural resources and harnessing private sector initiatives through incentives for environmental protection. Public participation in creating and enforcing environmental policy is supported, as well as a NEAP.

Brazil. The 1995 CAS aims to strengthen federal and state environmental protection agencies; help the federal government reduce its involvement and redefine its role in agriculture through projects that decentralize extension services to the municipal level; collaborate with farmer associations on effective on-farm and microbasin activities; and support management of competing water uses through water markets, small-scale irrigation, and environmentally-sound water use practices. Specific reforms proposed in the CAS include (a) reducing tax rates for native forests relative to rates for agricultural land; (b) establishing separate rules and regulations for native and plantation forests; (c) devolving most implementation and enforcement of environmental protection to the states; (d) providing incentives to collect environmental user fees; and (e) improving identification and demarcation indigenous reserves, and strengthening protection of these reserves to reduce encroachment and illegal exploitation.

Nepal. The 1996 CAS notes that economic and social development requires efficient and sustainable management of Nepal's biological and natural resources, particularly agriculture and forestry. In response to Nepalese Government priorities, the Bank will help design and maintain an environmental policy framework, with accompanying sectoral work to include water and land resource management strategies. The CAS details a lending program to promote sustainable watershed protection, forest management, and soil conservation, with biodiversity management as an explicit component. Lending operations will not only address biodiversity conservation in protected areas, but also mainstream biodiversity management in agriculture and forestry sector work.

Box 12. The Global Environment Facility

The Global Environment Facility (GEF) provides funding to achieve agreed global environmental benefits. Biodiversity conservation is one of the GEF's four 'focal areas.' The GEF's objectives in this area include biodiversity conservation, sustainable use of its components, and the fair and equitable sharing of the benefits of genetic resources. GEF-financed biodiversity activities are guided by several strategic considerations, including:

- integration of conservation and sustainable use of biodiversity within national and regional sustainable development plans and policies;
- protection and sustainable management of ecosystems through targeted and cost-effective interventions;
- integration of efforts to achieve global benefits in the area of land degradation, primarily desertification and deforestation; and
- development of a project portfolio that encompasses representative ecosystems of global biodiversity significance.

Enabling activities in biodiversity are a basic building block of GEF assistance to countries, preparing the foundation and implementation of effective responses required to achieve objectives of the CBD. These activities assist recipient countries to develop national strategies, plans, or programs referred to in Article 6 of the CBD, and to identify components of biodiversity together with processes and activities likely to have significant adverse impacts on conservation and sustainable use of biodiversity, pursuant to Article 7 of the CBD. Countries thus enabled have the ability to formulate and direct sectoral and economy-wide programs to address global environmental problems through a cost-effective approach within the context of national sustainable development efforts.

implementing agencies for the Global Environment Facility (Box 12). The CAS process and document are the logical context for determining the Bank's role in providing such assistance.

The Bank's current operational policy establishes that, where appropriate, global environment issues and the role of the GEF should be addressed in the CAS (BP 2.11). Global environment issues such as conservation of biodiversity, however, have important links to generation of domestic benefits (extractive and non-extractive) and resource management. On such grounds alone, as well as the commitment under the CBD, biodiversity conservation would in many cases warrant explicit consideration and attention in Bank assistance strategies:

- Prudent use and conservation of biodiversity in cases such as the Galapagos Islands in Ecuador or the savannahs of Kenya and Tanzania amount to management of an important part of the national capital stock. The Bank's strategy for helping countries design and implement plans for rational use and conservation of such assets should form an essential part of the CAS. This means supporting policy reforms and priority investments that help to conserve biodiversity, including measures to minimize threats to these assets from agricultural development.
- The challenge of biodiversity conservation demands attention in CASs for countries in which maintenance of a diverse biological base is critical for sustainable agricultural growth. This is particularly relevant for the drought-affected countries of sub-Saharan and Sahelian Africa, where diversified plant genetic resources and farming systems form part of a strategy aimed at reducing risks for farmers, and for the countries in the Indo-Gangetic basin, where a narrow base of biodiversity is constraining sustainable growth in rice and wheat production systems.

Two conditions must be satisfied for CASs to appropriately address biodiversity conservation:

- The Bank's economic and sector work needs to be strengthened to address, where appropriate, biodiversity conservation as an explicit development objective. Such work is underway as collaborative exercises involving client government institutions and other partners in the delivery of development assistance. To address this need, the

Bank's ESD Vice Presidency has launched the Global Overlays Program (Box 13).

- There must be a strong commitment and deliberate process to integrate into the CASs strategic recommendations that emerge from relevant sectoral and cross-sectoral studies and assessments, whether prepared by the Bank, country institutions or jointly. This includes agriculture sector reviews, natural resource management studies, country environmental strategy papers, as well as documents emerging from the country's own strategic planning in relevant areas (including agriculture development plans, national environmental action plans, biodiversity strategies, and action plans).

Biodiversity Conservation and Agriculture Sector Work

As part of the Bank's traditional sector work, agriculture sector reviews (ASRs) have concentrated on policy reform and sector investment priorities designed to increase agricultural production, secure rural employment, promote food security, and reduce poverty. The Bank's agriculture sector work has recently changed. First, what used to be Bank-prepared sector reports based on the work of visiting Bank missions are now sector assess-ments and planning studies undertaken in collaboration with government institutions and other local partners. Second, the traditional all-encompassing sector-wide review is gradually being replaced by more narrowly focused studies and analyses, addressing subsectors or issues of special relevance to country planning or decisionmaking for agricultural develop-ment. In this process, natural resource mana-gement studies (including food production, land use and tenure, forestry development, rural employment, or rural infrastructure) have become increasingly common.

Current practices. Coverage of biodiversity issues within the Bank's agriculture sector work varies significantly. A 1995 review conducted

Box 13. The Global Overlays Program

Background. A 'global overlay' adds a new dimension to traditional sector economic planning by analyzing environmental impacts and opportunities to internalize global externalities. From a sectoral perspective it poses the question: How and at what cost would policies, institutions, and investment priorities change if global environmental objectives were added to conventional sectoral objectives?

Objectives and key features. The Global Overlays Program, launched by the Bank in partnership with bilateral donors and NGOs, seeks to internalize global externalities into national environmental planning and the Bank's sector work, operations, and dialogue with governments and partners. It is an iterative process, combining conceptual studies, reviews of state-of-the-art techniques for measuring and mitigating global externalities, and testing these concepts and tools through country-level studies as a means of identifying good practices for country planners and Bank task managers. The results will help guide national actions to reduce greenhouse gas (GHG) emissions, conserve biodiversity, and protect international waters.

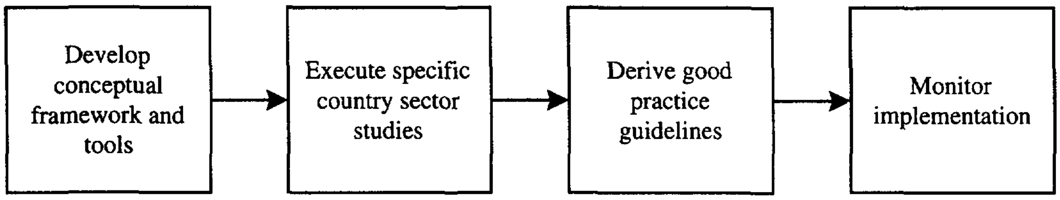
Implementation status. Accomplishments by mid-1996 include Good Practice Guidelines for GHG Overlays and a GHG Assessment Handbook. In addition, two GHG overlays have been completed, for Argentina and Mexico, and planning for a number of biodiversity and agricultural sector overlays is underway. The Bank is seeking partnerships with bilateral donor organizations, GEF, NGOs, and foundations to support the program.

The proposed activities of the Global Overlays Program for fiscal 1997-99 include:

- *Analytical base.* The Bank will improve its understanding of the technical, economic, and social relationships among relevant sector activities and global environment effects and examine how these are affected by policies, especially in biodiversity conservation and international waters protection.
- *Sector studies.* About twenty global overlay applications in climate change mitigation, biodiversity conservation, and international waters protection will be undertaken, involving the energy, transport, agriculture, and forestry sectors
- *Good practice guidelines.* Guidelines for global overlays in climate change, biodiversity conservation, and international waters protection will be prepared, building on monitoring of the above activities.

The above activities will be planned and implemented with the help of a Global Overlay Advisory Group, which includes representatives from NGOs, the scientific community, bilateral donor agencies, and developing-country governments.

Figure 3
Key steps in mainstreaming biodiversity in World Bank sector work



by the Bank's Agriculture and Natural Resources Department found that biodiversity was addressed within the context of agricultural development in only seven of twenty-four ASRs undertaken between 1987 and 1995.

Several of these studies attempted to examine the relationship of agricultural development to biodiversity conservation, and some demonstrated good practices. The Ecuador *Agricultural Sector Review 1993* focused on enabling factors leading to biodiversity loss such as distortionary macroeconomic policies, cross-sectoral mispricing, and insecure land tenure. The review recommends removing energy subsidies (which produced a distortion favoring frontier expansion), strengthening property rights in forested areas, and imposing land taxes on agricultural lands to promote agricultural intensification. While the ASR for Brazil did not address biodiversity, this topic is covered in another report, *The Management of Agriculture, Rural Development, and Natural Resources 1994*. This study recognizes the abundance of biodiversity and diverse ecosystems in Brazil, and addresses policy measures aimed at conserving biodiversity (such as reducing subsidized credits to the livestock sector and liberalizing trade in agricultural products, thereby increasing the profitability of farming in existing agricultural areas relative to frontier areas). It also makes specific recommendations about land allocation and titling, management of protected areas, and taxation of land in native forests and cleared areas.

As a contrast, ASRs from several biodiversity-rich nations, including Madagascar (*Agricultural Strategy Note 1994*), Ethiopia (*Agriculture: A Strategy for Growth: Agriculture Sector Review 1987*) and Papua New Guinea (*Revitalizing Agriculture: Issues and Options 1992*) make little effort to analyze obvious conflicts between agriculture and biodiversity. These studies also do not address the importance of biodiversity within the agricultural production systems of these countries.

Integrating biodiversity issues in agriculture sector work. The Bank needs to strengthen its agriculture sector work to effectively help developing country partners mainstream biodiversity conservation in planning for this sector. In a local context, Bank staff interacting with country sector planners need to be able to address four questions that this paper has attempted to answer from a general perspective:

- How do agricultural development activities in the sector or subsector affect biodiversity?
- How can the sustainable use of biodiversity enhance agricultural development?
- How can government policies and programs be adjusted to reduce biodiversity loss?
- What are the costs of such adjustments? And how can tradeoffs be evaluated?

The development of good practices begins with forming a suitable conceptual framework to help analyze the relationship between agricultural development (including policies, programs, and practices) and biodiversity conservation (Figure 3). It also depends on the availability of analytical tools and methods to measure effects of biodiversity losses or gains. Most important, country-sector studies will help test the conceptual framework, refine analytical tools and methods, and prepare a set of good practice guidelines to incorporate biodiversity conservation objectives into agriculture sector work and operations.

These tasks form part of ESD's broader initiative to promote mainstreaming global environment objectives in Bank operations. This initiative, which is coordinated under the Global Overlay Program involves ESD departments working with the Bank's regional departments (Box 13). To help conserve biodiversity, the Global Overlay Program envisions the following three activities over the next three years:

- First, based upon relevant studies and country experience, propose an analytical framework to examine effects of sector activities and policies on biodiversity. Initial work will focus on agricultural development (the present study) and extend to forestry management and land degradation control.
- Second, building upon ongoing or recent sector reviews, evaluate up to eight global overlay applications (such as country studies) involving agriculture and forestry sectors in collaboration with developing country governments and institutions. ENV/AGR, together with regional Sector Operations Divisions, are currently discussing suitable countries in which overlays may begin during early fiscal 1997. The country studies would initially focus on the complementarity between sector development and global environment objectives (the 'no regrets' options). They would identify opportunities to capture additional global environment benefits through markets for such benefits (limited as such markets may be), or international resource transfers (through institutions such as GEF). They should provide policy prescriptions, sector investment priorities from global environment standpoint, and identification of associated incremental costs.
- Third, using the results of the previous two activities, prepare good practice guidelines for global overlays for use by country planners, sector practitioners, and Bank staff.

Overcoming institutional constraints to mainstreaming at the country level. The integration of biodiversity conservation objectives into sectoral planning at the country level faces significant institutional constraints. Agriculture sector planners and technical staff are typically not accustomed to working with their counterparts in environmental ministries and vice versa. Senior officials in ministries of agriculture tend to view environmental considerations and conservation priorities as standing in the way of urgent crop and livestock production programs. Their colleagues in charge of environmental management are often perceived as overly conservationist, and in many cases are isolated from the sectoral development agenda. That most NEAPs have been prepared with little input and ownership from sectoral ministries may explain their ineffectiveness in bringing about the changes necessary change to achieve environmentally sustainable development.

The Bank, working with its partners in development, must be prepared to help its client governments lower or overcome the barriers to integrating the agendas for sectoral development and environmental management, including biodiversity conservation. The Bank can help in these ways:

- First, helping to prepare environmental and biodiversity conservation strategies or action plans should secure the active participation of sectoral interests. A centrally-placed coordination mechanism that has governmental support from the highest level should be included.
- Second, by supporting these strategic national frameworks covering biodiversity conservation, the Bank should emphasize the importance of (a) assigning respon-

sibilities to individual sectors of the economy to adopt and implement policies and programs that address identified priorities for biodiversity conservation; (b) identifying win-win policy reforms; and (c) establishing a system to monitor the execution of such responsibilities by sectoral ministries or agencies.

- Third, Bank support for country planning studies designed to integrate biodiversity conservation into agriculture sector planning should emphasize cross-sectoral and broad-based participation, embracing not only government agencies, but also the local NGO and scientific communities. Support should be designed to foster capacity building rather than producing a study report. International NGOs working with local NGOs may be positioned to facilitate such a process.

Biodiversity and the Lending Portfolio

The first generation of biodiversity projects in the Bank's portfolio, dating back to the 1970s, helped Government institutions establish and manage national parks and protected areas. At the time, management meant protecting biodiversity by keeping all other activities out and relying on penalties (enforcement) as the incentive. Bank support for these purposes came either in the form of free-standing projects or as components of forestry or other relevant operations. A recent example of this type of project is Madagascar's *Forest Management Project 1988.*

It soon became clear that this approach was unsustainable from most perspectives. As a result, a second generation of biodiversity projects recognized the need to involve local communities in management and sharing benefits. These projects recognized that the sustainability of any regime to protect biodiversity in national parks depends largely on how effectively it reduces the pressure generated by the production and consumption needs of communities neighboring the protected areas. Examples of projects that reflect this approach include Uganda's *Bwindi Impenetrable National Park and Mgahinga Gorilla National Park Conservation Project 1995* and India's *West Bengal Forestry Project 1992.*

A third generation of projects now needs to effectively promote biodiversity outside traditional protected areas. The development of such projects should follow naturally by successfully mainstreaming biodiversity conservation at the sectoral level, and should manifest itself in two main ways—agricultural lending operations should include biodiversity conservation among project objectives, and the design of agricultural projects should reflect the use of environmental assessment (EA) to select the most cost-effective means of supporting biodiversity.

Biodiversity conservation in agricultural lending. A review of the recent agriculture and related natural resource management portfolio carried out by the Bank's Agriculture and Natural Resources Department concluded that while only a limited number of projects explicitly address biodiversity conservation, the proportion of biodiversity-friendly agricultural projects is increasing.

Of 402 agricultural projects (IBRD loans or IDA credits) approved between 1988 and 1995, 10 percent recognized biodiversity as an explicit objective with activities that typically supported strengthening existing protected area management and national strategic planning for biodiversity conservation. While such activities are important, they often have few direct functional links to agricultural development activities of the project. In such cases, the agricultural project serves more as a convenient vehicle to support biodiversity management activities than as a means to integrate biodiversity conservation in agricultural development.

There are important exceptions, however, including agricultural projects that have been designed explicitly to promote biodiversity conservation, either through activities that otherwise would not have been undertaken, or projects that have exploited important synergies between biodiversity conservation and agricultural development. The experience of Bank projects promoting agricultural development in North Sulawesi in Indonesia and in the Mahaweli Ganga Basin in Sri Lanka are successful attempts to capture such synergies (Box 14). While these projects date back more than ten years, they contain important lessons.

It is important to note that the approach of these projects is distinctly different from that of agricultural projects which, consistent with Bank operational policy, establish new protected areas to compensate for natural habitats or wildlands that would be lost or threatened as part of the project's proposed activities.

For the overwhelming majority (320) of the agricultural projects approved during 1988-95, biodiversity conservation did not figure as an objective. Many of these have potentially harmful effects on biodiversity by promoting pesticide use, encouraging monoculture crops, and constructing irrigation canals through nature reserves. The share of such projects in the agricultural portfolio is, however, declining —in the 1988 portfolio one out of every three was judged (by the recent Bank review) to have potentially harmful effects on biodiversity, but this ratio dropped to one out of fifteen for projects approved in 1995.

An increasing number of agriculture sector projects have direct or indirect positive effects on biodiversity through agroforestry, integrated pest management, natural resources management, crop rotation, and genetic resources preservation. Examples of such projects include Burundi's *Muyinga Agriculture Project 1988*, which includes soil conservation efforts such as the creation of protection forests, on-farm erosion control, and agroforestry; Algeria's *Agriculture Research and Extension Project 1990*, which promotes contour plowing, bench terracing, and reducing erosive mechanization; and Indonesia's *Integrated Pest Management Project 1993*, which strengthens and expands the use of IPM through farmer education, field investigation, links with research and extension systems, and strengthening the regulatory framework for pesticides.

Within the group of projects that indirectly benefits biodiversity conservation are those that increase productivity either through restoration

Box 14. Capturing the convergence between conservation and agricultural interests

Indonesia: Fifteenth Irrigation Project (1980). In North Sulawesi, agricultural expansion threatened forests surrounding the Toraut River, an area of globally significant biodiversity. A convergence of conservation and agricultural interests led to the establishment of the 300,000-hectare Dumoga-Bone National Park as part of a $54 million irrigation scheme to promote agricultural development, especially irrigated rice, in the Dumoga valley. The project secured protection of the forested catchment watersheds, ensuring low sedimentation loads in the Toraut River and extending the life of newly-constructed irrigation canals. As a result annual rice production was expected to increase by 46,000 tons, while creation of the national park served to safeguard many plants and animals endemic to Sulawesi.

Sri Lanka: Fourth Mahaweli Ganga Development Project (1984). The Mahaweli river basin is biologically rich, with over ninety endemic plants and animals and important populations of large mammals. Agricultural expansion threatened natural habitats in the area, displacing and crowding wildlife onto smaller, fragmented land parcels. The project met the dual purposes of harnessing Sri Lanka's largest river for irrigation purposes while establishing new protected areas with forest reserves and jungle corridors to safeguard migration routes for wildlife. In addition buffer zones were created with land-use restrictions to reduce conflicts between wildlife and local communities. This system of integrated land use and conservation areas provides important benefits to local communities, including flood control, reduced downstream sedimentation, bank stabilization, reduced human and wildlife conflicts, less wildlife damage to crops, conservation of fisheries, conservation of genetic resources and medicinal plants, local employment opportunities, and opportunities for research and education.

processes or successful intensification, and thereby reduce the pressures on adjacent biodiversity-rich lands or natural habitats. A good example is India's *Uttar Pradesh Sodic Lands Reclamation Project 1993*. This project includes investments in land reclamation (such as improved drainage networks) while promoting soil management practices (including reduced tillage systems, increased use of natural fertilizers, and retention of organic matter), and diversifying cropping systems (incorporating food crops, salt-tolerant fruit trees, and high-value aromatic plants) to further arrest expansion of sodic lands.

Biodiversity-friendly agricultural projects are the result of more systematic and effective use of environmental assessments and an increased awareness of unsustainable forms of agricultural production. Good practice examples of environmental assessments of agricultural projects include Brazil's *Agricultural Credit Project 1988*, which recognizes the divergence between private and social benefits of services provided by biodiversity; Bolivia's *Agro-Export Development Program 1992*, which addresses safeguards needed to prevent private enterprises from adversely affecting the environment; Uruguay's *Irrigation Development and Natural Resource Management Project 1994*, which identifies relevant environmental issues related to irrigation projects such as soil degradation, water contamination, and related effects on biodiversity; and Sudan's *Rahad Irrigation Project 1973*, where early intervention to integrate environmental concerns led to altering the design and routing of an irrigation canal to avoid important wildlife migration routes.

An Agenda for the Future

The challenges for the Bank in mainstreaming biodiversity at the project level are fourfold:

- Deepen the implementation of 'do no harm' strategies in the design of agricultural projects by effective use of environmental assessments, and by systematically applying the Bank's policy on compensatory actions for natural habitats threatened by proposed project activities.
- Promote identification of synergies between biodiversity conservation and agricultural development, and build them into project design.
- Broaden the use of environmental assessments as a tool to mainstream biodiversity in agriculture. This includes using sectoral and regional environmental assessments to screen both public investment programs and upstream project design options against the objectives of biodiversity conservation.
- Use agricultural investment and sector adjustment operations appropriately as instruments to support policy reform, institutional capacity, and awareness of mainstreaming biodiversity in agricultural development.

Glossary

Agrobiodiversity - Plant and animal genetic resources, soil organisms, insects, and other flora and fauna in agroecosystems, as well as elements of natural habitats that pertain to agricultural production.

Agroecosystem - An ecosystem managed for agricultural use.

Biodiversity - Short for *biological diversity*; it encompasses the variability among living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Ecosystem - The organisms living in a particular part of the environment and the physical part of the environment that impinges on them.

Endemic - Species or race native to a particular region and found only there.

***Ex situ* conservation** - Conservation of plant genetic material in genebanks under controlled conditions, away from the site at which it normally grows.

Extensification - Increasing agricultural production by expanding the area under cultivation.

Habitat - An environment of a particular kind.

***In situ* conservation** - Genetic resource maintenance in the field.

Intensification - Increasing the use of inputs and/or changing land use so as to increase productivity (output per unit of land).

Keystone species - A species that affects the survival and abundance of many other species in an ecosystem.

Landraces - Geographically or ecologically distinctive populations of plants and animals which are conspicuously diverse in their genetic composition.

Natural habitat - Land and water areas where (i) the ecosystems' biological communities are formed largely by native plants and animal species, and (ii) human activity has not essentially modified the area's primary ecological functions.

Off-site effects - Effects of a land use change that are felt outside the area on which the land use change is carried out.

On-site effects - Effects of a land use change that are felt within the specific area on which the land use change is carried out.

Bibliographic review

This section provides suggestions for additional readings on the topics discussed in this paper. It is not intended as a complete bibliography of the topic, but to point readers to important work in the areas covered. Many of these sources themselves include pointers to other materials. The sources are presented in the same general order as the material in the paper itself.

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1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.
Telephone: (202) 477-1234
Facsimile: (202) 477-6391
Telex: MCI 64145 WORLDBANK
MCI 248423 WORLDBANK
Cable Address: INTBAFRAD
WASHINGTONDC
World Wide Web:
http://www.worldbank.org/
E-mail: books@worldbank.org

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