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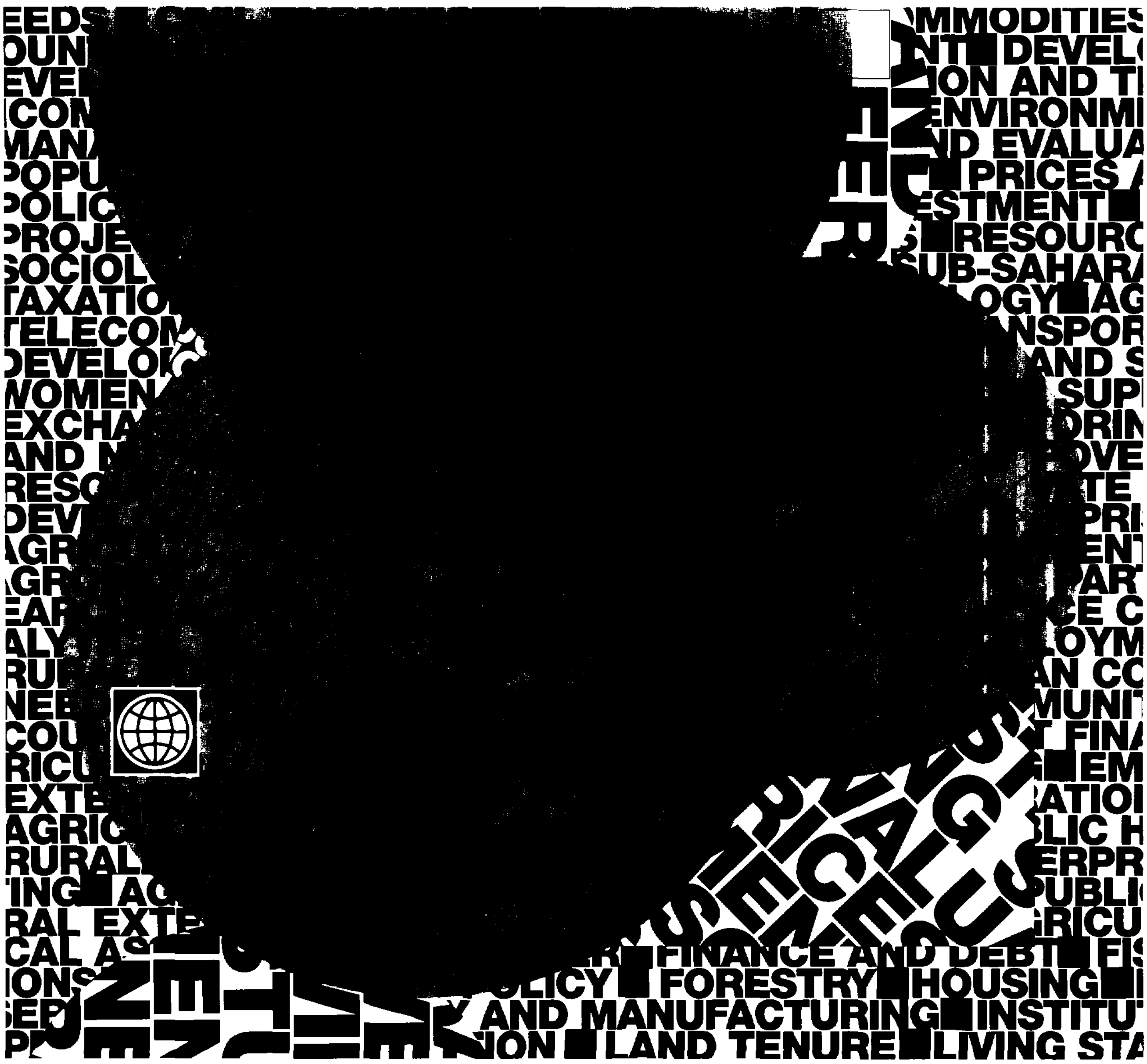
Biodiversity and Agriculture

Implications for Conservation and Development

Jitendra Srivastava, Nigel J. H. Smith, and Douglas Forno



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FOREWORD

This short concept paper explores in a preliminary fashion some of the linkages between biodiversity and agriculture. The main conclusion is that biodiversity conservation and agricultural development are co-dependent. Biodiversity is an essential resource to improve agriculture, and little biodiversity will ultimately survive unless the peoples' needs for agricultural products are met. If agriculture is not intensified on areas already in production, then many of the remaining wildlife habitats will be destroyed as people attempt to eke out a living by cutting down forests, draining wetlands, and plowing savannas that have hitherto served as havens for wildlife.

The human population will continue to grow for the next several decades, and most of this growth will occur where most of the biodiversity is concentrated in the tropics and subtropics. As income levels rise in many regions, demand for food and other products from agricultural landscapes is sure to increase. Furthermore, as grain prices on world markets rises, developing countries will look for ways to boost domestic food production. This paper is a step toward identifying some of the policies and practices that deserve attention in attempts to better harness biodiversity for improving rural well-being.

Alexander F. McCalla
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ABSTRACT

For too long the agricultural and environmental communities have been at odds with each other over biodiversity when in fact they share many concerns. Agriculture is often cast as a homogenization agent on the landscape, obliterating much of the biodiversity to make room for crops and livestock. Some agricultural practices also trigger downstream impacts on biodiversity, such as water pollution with agrochemicals. While it is true that agriculture has caused harm to the environment, agriculture is the key to saving biodiversity and farming and livestock practices can be honed to minimize environmental damage.

Agriculture and biodiversity are inter-linked. Without biodiversity, agriculture cannot progress. Biodiversity in both wild and managed habitats is a vital resource for crop and livestock improvement. And without improved agriculture, most of the remaining habitats for wildlife will be destroyed to make room for farms, plantations, and ranches. Biodiversity is thus much more than the preservation of habitats for unique and interesting plants and animals. People in rural, and even urban, areas are intimately involved in using biodiversity to supply their needs. Most of the earth's surface has been transformed by human activities and how biological resources are treated in cultural landscapes will largely determine how much biodiversity survives in the next century. Both indigenous knowledge and scientific research are needed to meet the challenge of intensifying agriculture in an environment-friendly manner and understanding how the landscape mosaic of cultural habitats could contribute to conservation of biodiversity.

EXECUTIVE SUMMARY

The conservation and sound management of biodiversity are essential for improving agriculture and a host of other economic activities. However, the linkages between biodiversity and agriculture are poorly understood, to the detriment of efforts to better conserve and utilize biodiversity. To many, biodiversity is synonymous with saving butterflies or setting aside reserves for endangered mammals. But biodiversity entails much more than setting aside parks and reserves; it also encompasses the use of biological resources for economic growth through agricultural development. In the Bank's policy dialogue with member countries and in its lending programs, little attention has been paid to agrobiodiversity concerns, and even less to the interplay between agriculture and biodiversity conservation.

Our definition of biodiversity includes all living things and has three dimensions: genetic variation within species, species diversity, and habitat management and preservation. This paper seeks to identify the critical issues surrounding agricultural development and biodiversity. Biodiversity needs to be better conserved and managed in both natural and human-modified habitats. Accordingly, the interactions between biodiversity and farmers in a diverse array of production systems, ranging from intensive cropping with annuals to agroforestry and plantations, warrant scrutiny. The land use framework serves as a template for an overlay of various policy questions arising from agricultural practices in each farming system.

Sustainable agricultural development is essential for the well-being of humankind, but it must be reconciled with the need to conserve biodiversity. Intensification of agricultural operations and forest extraction that focus on short-term economic gain often trigger their own set of environmental problems, including the accelerated loss of biodiversity. A holistic approach to biodiversity conservation and use, covering both wild and domesticated plants and animals is needed. While it is recognized that protected areas are crucial for conservation, their sustainability will depend on what happens in managed habitats. This paper seeks to identify the critical issues surrounding agricultural development and biodiversity such as: 1) what are the fundamental relationships between the use of agricultural resources and loss of biodiversity, both on and off farm? 2) how do agricultural policies and development programs, including technology choices, impact biodiversity both on and off farm? 3) how could such policies and practices be modified to harmonize biodiversity conservation with agricultural development? and 4) what are the constraints (technical, institutional, financial, social and botanical) that inhibit such modifications? The paper does not offer answers to these issues. However, it proposes in-depth reviews and in-country studies for a better understanding of the questions raised above. This better understanding will help in the development of a strategy paper for a more rational use of biodiversity in agriculture and ways to mitigate the impacts of agricultural development on biodiversity.

Although economic development poses many divergent pressures on the conservation and management of biodiversity, particularly in agricultural areas, all of us are stakeholders in the safeguarding and better utilization of the world's biological riches. The challenge is to develop the incentives and instruments to encourage broad-based participation to achieve the goal of harmonizing agricultural development and biodiversity conservation.

Agriculture's Vital Role in Biodiversity Conservation and Management

Agriculture is often seen as the villain with respect to biodiversity, because it dramatically transforms ecosystems, and in some cases destroys biodiversity. Farms encroach on wilderness, thereby depriving habitat for some wild animals and plants. Containing the spread of agriculture is thus of major concern to conservationists. But three aspects of the interface between agriculture and biodiversity are often overlooked. First, changes in the mixture of land use patterns in an area can also have a major impact on biodiversity, such as the displacement of rich agroforestry systems or forest extraction by cattle ranching. Second, intensification of agriculture is essential if remaining protected areas are to be saved. Third, agricultural intensification can only be accomplished successfully by blending traditional knowledge with scientific research and tapping a greater array of biological resources.

The relevance of biodiversity to agriculture is often overlooked because biodiversity concerns typically focus on attempts to save endangered species, or to protect particular habitats, such as wet lands, coral reefs or mangroves. As laudable as such efforts are, they often eclipse another important dimension to biodiversity: the connection between raising the productivity of crops and livestock and safeguarding biological riches of the environment.

Most of the developing nations are striving to enhance the productivity, profitability and stability of their major farming systems without depleting their natural resource base. Biodiversity is an essential resource for agriculture along many fronts, from incorporating traits for resistance to diseases and pests, to improved nutritional qualities, more effective soil nutrient uptake, and more environmentally-friendly methods to control pests[1]. Agriculture can mitigate damage to the environment by providing viable livelihoods to rural communities, but if improperly conducted, can accelerate the loss of biodiversity.

Trade-offs are inevitably involved between biodiversity and any economic development of an area. Our intent is not to promote greater biodiversity at all costs, particularly a decline in crop yields. Rather, our goal is to identify ways in which agricultural development impacts biodiversity, and approaches that mitigate damage to biodiversity as a result of agricultural interventions in the landscape. Judicious deployment of biodiversity can enhance yields. Conservation of

[1] Srivastava, J. P. and M. Subramaniam. 1994. Biodiversity, sustainable development, and challenges for the 21st century. Paper presented at an international conference on *Global Genetic Resources—Heritage of Mankind*, Vavilov Institute of Plant Industry, St. Petersburg, Russia, 7-13 August.

biodiversity is considered essential for several reasons, particularly creating opportunities to tap a greater array of biological resources for agricultural development. Other issues touched on here, but requiring a fuller analysis, are how agricultural sector policies and programs impact biodiversity, and what factors constrain institutional reform. Our overview thus touches on some of the critical linkages between agriculture and biodiversity that are not widely appreciated and underscores the dynamic nature of the relationship between agriculture and biodiversity as new technologies emerge, conservation strategies shift, and new trade agreements and conventions on biodiversity surface.

A conceptual framework that analyzes the interface between biodiversity and agriculture will sensitize policymakers to the relevance of biodiversity for agricultural improvement. This conceptual framework should also help countries that have signed the Convention on Biodiversity to develop strategies and programs at the national level to promote biodiversity conservation and utilization for agricultural development.

Definition of Biodiversity

Before exploring some of the ramifications of biodiversity for agriculture, a definition of biodiversity is needed. Biodiversity encompasses all living things and has three main dimensions: the genetic variation within species and populations, the number of species, and habitat preservation.

Agricultural biodiversity, or agrobiodiversity as it is sometimes called, also potentially includes all living things, but is restricted to plants, animals and microorganisms used in commerce or having potential for such use. This paper focuses primarily on plants but recognizes the importance and linkage of agriculture with overall biodiversity. Genetic resources of plants include current and obsolete varieties, primitive landraces developed by indigenous people, related wild and weedy species of crops, and special stocks maintained by breeders. Animal genetic resources, ranges from modern and traditional breeds, to wild and feral populations of livestock, to related species.

The significance of variation within a species is less widely appreciated but is critical, particularly for agriculture. The continued productivity of existing crops and livestock hinges in large part on harnessing the genetic variation found within each species.

The second dimension of biodiversity is fairly straightforward: it is an index of species richness, or the numbers of distinct plants and animals in a given environment. Thus tropical rainforests are rich in species of current and potential value[2], whereas colder or semi-arid regions generally have far fewer plants and animals because of the harsh living conditions. The concentration of biodiversity in the tropics has major policy implications: it is especially critical to conserve and manage biodiversity in the humid tropics.

In order to protect species and genetically-distinct populations of each species, it is necessary to safeguard their environments. Wild species in protected or managed habitats are important for agriculture because they are a source for new economic plants and animals, and because advances in biotechnology are making it increasingly possible to exchange genes between completely unrelated organisms[3]. In order to conserve and better utilize biodiversity, a diverse array of habitats must be managed carefully or protected. A species cannot thrive if its environment is destroyed or seriously impaired. Agricultural scientists, including breeders, ecologists, farmers, and ultimately consumers thus share a common concern for the conservation of natural areas and a better understanding of how such ecosystems function[4].

The issue of habitat conservation has two parts: safeguarding *natural habitats* for wild species and populations; and managing *cultural habitats*, or environments that have been modified for human use, such as farmland. The second item is less well understood among the general public and many policymakers. Economic growth and poverty alleviation hinge in large measure on managing wisely biodiversity in habitats transformed by humans, such as farmland, rangeland, and forests exploited for lumber and non-timber forest products.

Human culture is thus woven into the broader biodiversity fabric. Traditional knowledge systems are critical to understanding how biodiversity can be better used and protected[5]. Local peoples have co-evolved with their environments and have acquired considerable knowledge about the locations and appropriate strategies for harvesting and managing their resources. Indigenous cropping patterns often help suppress weeds and insect pests, and some aspects of folk

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[2] For a discussion of the extraordinary biodiversity of the tropics, particularly in rainforests, and their relevance for agriculture see: Jablonski, D. 1993. The tropics as a source of evolutionary novelty through geological time. *Nature* 364:142-144.; Myers, N. 1988. Threatened biotas: 'hotspots' in tropical forests. *The Environmentalist* 8:1-20; Smith, N.J.H., J. T. Williams, D. L. Plucknett, and J. P. Talbot. 1992. *Tropical Forests and Their Crops*. Princeton University Press, Princeton; Whitmore, T. C. 1985. *Tropical Rain Forests of the Far East*. Oxford: Clarendon Press. Wilson, E. O. 1988. The current state of biological diversity. In: Wilson, E. O. and F. M. Peter (Editors), *Biodiversity*, pp. 3-18. Washington, D.C.: National Academy Press.

[3] I.K. Vasil. 1994. Molecular improvement of cereals. *Plant Molecular Biology* 25:925-937.

[4] K.H. Redford and S.E. Sanderson. 1992. The brief, barren marriage of biodiversity and sustainability? *Bulletin of the Ecological Society of America* 73(1):35-39.

[5] N. S. Jodha and T. Partap. 1993. Folk agronomy in the Himalayas: implications for agricultural research and extension. *IIED Research Series* 1(3):15-37; Juma, C. 1989. *Biological Diversity and Innovation*. Nairobi: African Center for Technology Studies; Oldfield, M. L. and J. B. Alcorn (Editors). 1991. *Biodiversity: Culture, Conservation, and Ecodevelopment*. Boulder: Westview Press; Pichón, F. J. and J. E. Uquillas (1995). Sustainable natural resource management and poverty alleviation in Latin America's risk-prone areas: the role of farmer participation in agricultural research and technology development. Draft paper, LATEN, World Bank, Washington, D.C.

knowledge, honed over millennia of working with nature rather than against it, could be incorporated in current agricultural research and development projects.

Agriculture is ultimately linked to biodiversity in its widest sense because it is highly dynamic, and the boundaries between domesticated plants and animals and wild species are constantly shifting. Today's lesser-known crop, confined to one region, can become tomorrow's major breadwinner in many countries: witness the spectacular spread of the kiwi fruit that is native to southern China and is now grown on a large scale in many temperate areas, such as New Zealand and California. Rubber was hardly used in its native environment in Amazonia, but became a major plantation crop in Southeast Asia soon after it was introduced there in the late 19th century.

Similarly, a wild plant or animal of little or no current market value could eventually provide significant employment and income in the future. Little is known, for example, about many medicinal plants used by local peoples. One-quarter of the prescription drugs sold worldwide are plant-based and not all pharmaceutically-active compounds can be synthesized in the laboratory[6]. Medicinal plants thus represent a largely untapped potential for agricultural diversification. And many microorganisms provide important services to farmers, through reduced fertilizer costs and pest control. Soil microfauna and microflora are critical in nutrient cycling, and may be destroyed or enhanced by agricultural practices.

Biodiversity's Links to Agriculture

Biodiversity is a fountain of riches to improve agriculture. One way that conserving biodiversity can lead to higher yields and incomes for the rural poor is the domestication of new plants adapted to harsh conditions. Most of our important crops were brought into cultivation long before the advent of modern, scientific agriculture. A new wave of plant domestication is on the horizon which will help meet the challenge of boosting agricultural production in marginal areas, as well as satisfy consumers' demands for novelty in their diets. Ethnobotanical prospecting for intriguing new fruits, nuts, cosmetics, and medicinal plants is emerging as a growth area in science and industry[7].

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[6] Plotkin, M. J. 1993. *Tales of a Shaman's Apprentice: An Ethnobotanist Searches for New Medicines in the Amazon Rain Forest.* New York: Viking.

[7] Arora, R. K. and E. R. Nayar. 1984. *Wild Relatives of Crop Plants in India.* New Delhi: National Bureau of Plant Genetic Resources; Blum, E. 1993. Making biodiversity conservation profitable. *Environment* 35(4):16-20, 37-45; Myers, N. 1984. *The Primary Source: Tropical Forests and Our Future.* New York: W.W. Norton; NRC. 1989. *Lost Crops of the Incas: Little Known Plants of the Andes with Promise for Worldwide Cultivation.* Washington, D.C.: National Research Council, National Academy Press; Schultes, R. E. 1980. The Amazonia as a source of new economic plants. *Economic Botany* 33(3):259-266; Schultes, R. E. and R. F. Raffauf.1990. *The Healing Forest: Medicinal and Toxic Plants of the Northwest Amazonia.* Portland, Oregon: Dioscorides Press; Vietmeyer, N. D. 1986. Lesser-known plants of potential use in agriculture. *Science* 232:1379-1384; Wilkes, H. G. 1984. Germplasm

The exchange of existing crops can also enrich the biodiversity of managed landscapes and produce higher incomes for rural producers and urban folk who process and market agricultural goods. The diversification of farming systems increases the options of farmers and reduces risk[8]. Most farms in the tropics contain both indigenous and exotic crops, and the relative mix changes over time in response to shifts in environmental and market conditions. In temperate areas, most of the crops are often introduced. The maintenance of agrobiodiversity in one area can thus produce payoffs for another region. Several cultivars of mango that arose in Florida are now grown on a commercial scale in several Latin American countries, such as in Mexico, Guatemala, and Peru, even though mango was domesticated in tropical Asia.

Existing crops need to be constantly upgraded to combat emerging pests and disease problems, and to adapt to shifting market conditions. About half the yield increase of major crops in this century is attributed to genetic improvements; the remaining increase is due to agronomic practices, such as irrigation and fertilization. One of the most important ways that farmers attempt to stay ahead of challenges to productivity is to deploy new varieties of their current crops. Breeders, in turn, are continuously scouring "genepools" for desirable genetic traits to make crops more inherently productive, thereby reducing dependence on purchased agrochemicals[9]. The selective manipulation of genes from within the species pool represents the most common way biodiversity is used for crop improvement. Occasionally, however, breeders cannot find what they need in the domesticated genepool and they must turn to wild populations or even near relatives of crops for desirable traits: the net is then dipped into the wider genepool.

Certain microorganisms— part of the broader biodiversity picture—are also vital for the long-term productivity of agriculture[10]. These organisms perform functions which prime fuel the metabolism of soils, plants and animals. The development of sustainable agricultural productivity will depend increasingly on the maintenance of biodiversity among invertebrates and microorganisms. Spurred by the contamination of water supplies with nutrients from fertilizer applications, and the need to reduce the cost of fertilizers to farmers, scientists are working with a number of organisms to rationalize fertilizer and pesticide use. New strains of

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conservation toward the year 2000: potential for new crops and enhancement of present crops. In: Yeatman, C. W., D. Kafton, and G. Wilkes (Editors), *Plant Genetic Resources: A Conservation Imperative*, pp. 131-164. Washington, D.C.: American Association for the Advancement of Science.

[8] Guillet, D. 1983. Toward a cultural ecology of mountains: the central Andes and the Himalayas compared. *Current Anthropology* 24(5):561-574.

[9] Chang, T. T. 1984. Conservation of rice genetic resources: luxury or necessity? *Science* 224:251-256; Plucknett, D. L., N.J.H. Smith, J. T. Williams, and N. M. Anishetty .1987. *Genebanks and the World's Food.* Princeton: Princeton University Press.

[10] Hawksworth, D. L. (Editor). 1991. *The Biodiversity of Microorganisms and Invertebrates: Its Role in Sustainable Agriculture.* Wallingford: C.A.B. International.

bacteria help fix nitrogen, while certain fungi can assist plants in nutrient uptake. More efficient strains of beneficial root fungi promise to reduce the amount of fertilizer needed to achieve higher yields, thereby mitigating water pollution. One species of bacterium is used commercially to control caterpillar pests of certain leafy crops. Scientists have hardly scratched the surface in the use of invertebrates and microorganisms to safely check agricultural pests and promote soil fertility.

Insects, normally thought of as pests, can also be a farmer's friend. Integrated pest management (IPM) can reduce dependence on insecticides since it involves a mix of agronomic practices, such as the release or protection of biocontrol agents, to check pests. IPM is not new; various predators and parasites combined with crop rotation and mixed cropping has historically helped reduce insect pest problems in farmer's fields. But with the advent of DDT during the Second World War, the onslaught of chemical pesticides began. Today, enormous sums are spent worldwide to combat insect pests in farmer's fields, often at great environmental cost. By 1980, 260 species of agricultural 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[11]. In spite of the relentless application of pesticides in many parts of the world, the proportion of crops lost to pests in the field and in storage is about the same as in the last century: between a quarter and one-third. Although insecticides are likely to remain a significant part of the arsenal of many modern farms for the near future, interest is growing in the payoffs and potential of IPM strategies (Box 1)[12].

[11] Altieri, M. A. 1992. Sustainable agricultural development in Latin America: exploring the possibilities. *Agriculture, Ecosystems and Environment* 39: 1-21; Brattsten, L. B., C. W. Holyoke, Jr., J. R. Leeper, and K. F. Raffa .1986. Insecticide resistance: challenge to pest management and basic research. *Science* 231:1255-1260; May, R. M. 1993. Resisting resistance. *Nature* 361:593-594.
[12] Barfield, C. S. and M. E. Swisher. 1994. Integrated pest management: ready for export? Historical context and internationalization of IPM. *Food Reviews International* 10(2):215-267.

Box 1: Integrated Pest Management (IPM) and Biodiversity

Biocontrol agents are a major component of integrated pest management strategies and can reduce or eliminate the need for pesticides. Frequently, the use of pesticides destroys natural biocontrol agents, and puts farmers on the path of purchasing ever more expensive chemical control measures. Biocontrol agents range from insect predators to parasites, and have historically been a natural part of agriculture until relatively recently. Within the last few decades, biocontrol agents have been systematically released to control some agricultural pests, mainly on a few tree crops and on small islands. More recently, however, a range of biocontrol agents has been released on a national or regional scale, such as parasitic wasps to control cassava mealybug in West Africa. In 1986, Indonesia officially adopted IPM as a national policy, aimed particularly at rice production. By 1991, pesticide use had dropped nationally by 70 percent, and in some locations by 90 percent, yet national rice yields increased by 10 percent during the 1986-1991 period. The increased productivity of rice is attributed mainly to the deployment of pest and disease resistant varieties and the encouragement of biocontrol agents. Profits achieved by rice farmers in Indonesia increased even more and doomsday predictions that a rapid weaning from heavy dependence on commercial insecticides would lead to a collapse of rice production never came to pass. The significance of IPM to biodiversity is clear: we need to safeguard habitats as reservoirs of biocontrol agents for future deployment

Thus far, some 500 insect species have been deployed worldwide to control crop pests, with a further 100 insects released to check weeds. The success rate of such efforts has ranged from 30 to 40 percent[13]. While not matching the dramatic impact of potent insecticides, biocontrol agents typically produce more longer-lasting results with no collateral damage to the environment. IPM incorporates biodiversity, and can trim operating costs.

Astounding advances in biotechnology research sometimes lead to the impression that we can do away with biodiversity. A leading business magazine recently published an article arguing that biodiversity is now essentially superfluous[14]. According to that perspective, we do not need to waste time trying to save tropical rainforests now that creative scientists can synthesize genes in laboratories.

Genes are being altered in "test tubes", and in a sense such feats create some biodiversity. For several decades now, plants have been coaxed into producing mutants by bombarding them with radiation, chemicals, or growing them in tissue culture form. Some of the genetic mutations have been of interest to breeders, but

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[13] Waage, J. K. 1991. Biodiversity as a resource for biological control. In: *The Biodiversity of Microorganisms and Invertebrates: Its Role in Sustainable Agriculture*, D. L. Hawksworth (Editor), pp. 149-163. Wallingford: C.A.B. International.

[14] Huber, P. 1992. Biodiversity vs. bioengineering? *Forbes* 150(10):266.

there is much trial and error. The concoction of genes and mutants in the laboratory are useful tools, but scientists need blueprints for cloned DNA and DNA base sequences. The blueprints come from nature. Moreover, aseptic laboratories cannot replicate the myriad evolutionary trajectories underway in nature. The accomplishments of biotechnologists, as impressive as they are, cannot recreate biodiversity lost through human interventions in ecosystems; they can only add modestly to the great variation that is already out there. If policymakers become bedazzled by breakthroughs in genetic engineering, they might overlook the need to conserve biodiversity in natural and modified environments. Advances in biodiversity may actually reduce biodiversity: for example by reducing species biodiversity. The long term implications of biotechnology for both *in-situ* and *ex-situ* conservation are not yet clear.

Each of the millions of species of plants and animals on earth is on an evolutionary saga. Populations of each species are often following separate tacks during which they change subtly with each generation. We have hardly tapped this bountiful offering of variation, yet we are losing much of it in a spasm of human-induced extinction. Much of the world's heritage of biodiversity might be lost before it is even described, let alone its value ascertained. Estimates of the number of animal and plant species on earth range from 1.4- 80 million, but only about 15 percent have been studied in any detail[15]. The "natural" laboratories of evolution need to be safeguarded so that we have the tools to face challenges to agriculture and health in the future.

The impacts of agriculture on biodiversity, and the significance of wild and human-modified habitats to farming and livestock raising, have global repercussions. The conservation of biodiversity in one region often has considerable external benefits for people living in other regions. Thus, water buffalo owners in Southeast Asia and Latin America may benefit in the future from traits found in the few remaining wild herds of water buffalo in South Asia. Coffee growers in Colombia and Java may benefit from disease resistance genes found in wild coffee of southern Ethiopia. Biodiversity conservation is thus a transnational concern and raises issues such as compensation to people living in centers of biodiversity.

[15] Basset, Y. 1992. Host specificity of arboreal and free-living insect herbivores in rain forests. *Biological Journal of the Linnean Society* 47:115-133; Myers, N. 1993. Questions of mass extinction. *Biodiversity and Conservation* 2:2-17; Raven, P. H. and E. O. Wilson. 1992. A fifty-year plan for biodiversity surveys. *Science* 258:1099-1100; Wilson, E. O. 1992. *The Diversity of Life*. New York: W. W. Norton.

Biodiversity and Agriculture: On a Collision Course?

Modern agriculture often homogenizes landscapes. By relying on fewer crops, and only a handful of varieties for each crop, modern farms do not come close to matching the higher levels of species diversity and genetic variation within species found among many traditional agricultural systems[16]. Modern livestock operations also tend to bottleneck biodiversity as they streamline their activities by concentrating on a few highly-productive breeds or strains. In contrast, highly-localized breeds are typically found in more traditional farming and pastoral areas. Genetic erosion is thus underway among both crops and livestock[17].

Agriculture is following a trend in that more productive systems tend to have fewer species[18]. It is the degree of genetic simplification and species elimination that is at issue here. When farmers adopt hybrids and other modern technologies, much indigenous agrobiodiversity is typically lost. Moncultures replace an intricate quilt of traditional varieties and patches of mixed crops. This bulldozer effect is particularly acute when these farming techniques penetrate centers of crop diversity.

Although traditional farming systems in centers of diversity of plants and animals have historically maintained high levels of species diversity, as well as a rich assortment of crop varieties, few would argue that rural peoples should be locked in to their agricultural practices. All agricultural systems evolve, including traditional ones. The issue is how can agricultural systems be intensified without drastic loss of biodiversity and other damage to the environment. Here the news is not all bad: in some regions, commercial farmers grow both modern and traditional varieties. In some cases, only the area devoted to older varieties is reduced, whereas in other instances, both the area and some of the diversity of traditional varieties diminish as farmers switch to modern varieties. What prompts some farmers to retain a basket of traditional varieties warrants further investigation because it has implications for *in situ* conservation efforts.

Modern farmers must be increasingly agile managers because the higher the productivity of their operations, the greater their dependence on a supply of new crop varieties and livestock breeds or strains. Continued investment in agricultural R&D is thus needed to prevent backsliding by ensuring a continued stream of improved varieties and populations[19]. Genetic erosion of both domesticated and

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[16] Chang, T. T. 1994. The biodiversity crisis in Asian crop production and remedial measures. In: Peng, C. and C. H. Chou (Editors), *Biodiversity and Terrestrial Ecosystems*, pp. 25-41. Taipei: Institute of Botany, Academia Sinica, Monograph Series No. 14.
[17] Hall, S.J.G. and J. Ruane. 1993. Livestock breeds and their conservation: a global overview. *Conservation Biology* 7(4):815-825.
[18] Pimm, S. L. and J. L. Gittleman. 1992. Biological diversity: where is it? *Science* 255:940.
[19] Chang, T. T. 1993. Sustaining and expanding the `green revolution' in rice. In: H. Brookfield and Y. Byron, *South-East Asia's Environmental Future: The Search for Sustainability*, pp. 201-210. Tokyo: United Nations University Press/Oxford University Press;

wild plants and animals threatens to disrupt this flow of improved varieties and breeds. Biodiversity is literally a lifeline for modern agriculture.

The unrestricted expansion of agriculture into forests and marginal lands, combined with overgrazing, urban and industrial growth, the spread of monocropping, and changes in crop rotation patterns and pest management strategies contribute to erosion of biodiversity. There are compelling reasons on economic and biological grounds to arrest or mitigate such impacts that are occurring in many parts of the world. But to devise appropriate policies, it will be necessary to understand more fully the linkages between various production systems and biodiversity.

Developing countries embrace the richest reservoirs of biodiversity, and agriculture is still the principal livelihood in many of them. In many of these countries, the expansion and indiscriminate modernization of agriculture have seriously threatened the biodiversity of natural ecosystems and managed landscapes. To promote sustainable agriculture in these centers of biodiversity it will be necessary to promote conservation and the utilization of a much wider range of food and cash crops, as well as livestock. Ironically, at the same time that interest in harnessing new crop plants and domestic animals grows, we are witnessing one of the greatest assaults on biodiversity due to radical habitat transformation.

The hemorrhaging of biodiversity has not yet been picked up by market signals. Indeed, in many areas of rapid biodiversity decline, income levels may actually be rising, such as in many parts of Southeast Asia. Market failure in this regard is due to a host of factors, ranging from property rights issues to policy distortions[20]. Waiting for markets to finally reflect a drastic loss of biodiversity is a risky proposition. Many of the changes in human-environment interactions are non-linear. Problems may emerge in several places suddenly, rather than in a predictable manner[21]. Change is often dramatic, rather than gradual. Human responses that rely on waiting for a signal to change and then adapt to the new circumstances will not always work. Human societies must ensure that they are resilient to accommodate the unexpected and biodiversity provides a critical buffer against such shocks.

Plucknett, D. L. and N.J.H. Smith. 1986. Sustaining agricultural yields: as productivity rises, maintenance research is needed to uphold the gains. *Bioscience* 36:40-45; Ruttan, V. W. 1982. *Agricultural Research Policy*. Minneapolis: University of Minnesota Press.

[20] Flint, M. 1991. *Biological Diversity and Developing Countries, Issues and Options: A Synthesis Paper*. London: Overseas Development Administration.

[21] Holling, C.S. 1994. An ecologist view of the Malthusian conflict. In: *Population, Economic Development, and the Environment*, K. Lindahl-Kiessing and H. Landberg (Editors), pp. 79-103. New York: Oxford University Press.

Rationale for the World Bank's Involvement in Biodiversity Management

Through its policy advice, developmental aid, and lending portfolios, the World Bank can play a major role in assisting national governments to develop policies and practices that capture the benefits of managing biodiversity for rural development. One way to accomplish this is to underscore the importance of biodiversity for agriculture.

Agricultural systems must respond to the need to raise productivity and increase their resiliency, especially in areas with increasing population and limited arable land. This imperative will require the adoption of improved technologies and the better harnessing of local and global biodiversity. Biodiversity management strategies for areas should therefore be compatible with the ever-increasing need to raise and sustain productivity. The issue of biodiversity thus cross-cuts with various sectors and themes of concern to the World Bank, including the environment, agriculture, industry, health, and poverty alleviation.

International biodiversity agreements have evolved in piecemeal fashion and in some cases have been forged too late to have much impact. Often, they are confined to the issues of endangered species and protected areas with little detail on their implementation. Agriculture should feature prominently in future conventions, and policies and strategies for overall biodiversity conservation and use should be demanded. The World Bank can play an important role through policy dialogue with numerous countries that contain centers of biodiversity to promote the wiser use of this important resource. Among the other players with whom the World Bank can play a catalytic role in promoting the conservation and management of biodiversity, are other development agencies, non-government agencies, farmers' organization, and indigenous groups.

Biodiversity in the Bank's Agricultural and Environmental Portfolios

The World Bank's environmental lending has increased considerably since the early 1980s. Not surprisingly, biodiversity is often singled out as one of the areas of concern in such projects. But this preoccupation with biodiversity has mostly translated into a concern for setting aside parks, creating buffer zones around such reserves, and for promoting the management of tropical forests for "sustainable" timber production. Little attention has been given to agricultural considerations in projects supporting biodiversity, and conversely, little attention has been given to biodiversity in the Bank's agricultural development projects.

A preliminary scanning of agricultural projects since 1988 indicates that out of a total agriculture sector portfolio of 377 projects, only 19 contained biodiversity components, and 10 of these were in the forestry sub-sector. Of the remainder, 7 are agriculture sector loans, while fisheries, irrigation, and drainage account for 1 loan each. Thus less than two percent of the agriculture projects since 1988 deal explicitly with biodiversity issues.

A closer look at the 19 projects with biodiversity components, reveals that 14 involve protected areas, 3 are concerned with marine biological diversity, while one project supports research on biodiversity research, and another entails biodiversity conservation through land management. Four projects address policy issues; 6 involve management plans, often associated with forested areas; 8 projects emphasize farmer participation and/or natural resource management by local communities; 6 address rural development issues. Only 8 projects embrace agricultural aspects. Regionally, six projects are located in South Asia, while 5 each are located in Latin America and the Caribbean and East Asia and the Pacific. Sub-Saharan Africa, and Europe and Central Asia, account for 4 and 2 projects, respectively.

A wider-ranging look at biodiversity projects in other sectors of the Bank confirms a relative lack of attention to agricultural dimensions of the issue. Preliminary results of a review of the World Bank's and GEF's portfolio related to biodiversity identified 79 projects between 1988 and 1995, with a total expenditure of $1.25 billion. Few of these projects address agrobiodiversity issues directly: most deal with establishing or strengthening management of protected areas

Towards a Strategy for Biodiversity Conservation in Harmony with Agricultural Development

Some ground has been broken on clarifying issues that bridge biodiversity and agriculture, but much more work needs to be done to develop sound policy recommendations. To develop a conceptual framework for improving the dialogue between all stakeholders in biodiversity, it will be necessary to investigate in more detail certain linkages between biodiversity and agriculture. Four items, in particular, warrant closer scrutiny:

1) *The impact of agricultural production systems on the conservation and use of biodiversity*
2) *Approaches to the conservation and management of biodiversity and constraints to the use of sound policies and practices.*
3) *Policies, regulatory mechanisms, and implications of agricultural development on biodiversity management.*
4) *The World Bank's agriculture and biodiversity related portfolio, sector work and assistance strategies for their implications for agrobiodiversity conservation and management.*

Analysis of the above items should be framed by a consideration of technical, economic, social, and policy dimensions to agriculture and biodiversity. Crosscutting aspects that need to be addressed include:

- Policies, incentives, regulatory measures, institutional development, and practices to promote the conservation and utilization of biodiversity
- Indicators of performance in mitigating damage to biodiversity and the incorporation of greater biodiversity in agricultural production systems
- Traditional knowledge, community and farmer participation in the use and conservation of biodiversity

The issue of performance indicators is particularly germane to decision-makers[22]. Considerable thought needs to be given as to how the impacts of various agricultural production systems and practices on biodiversity can be measured realistically, and the extent to which biodiversity is being utilized by agriculture. Eventually, an internationally agreed framework or matrix is needed with a set of indicators that are robust, discriminating, easily understood, and linkable to various policy levers. Much work remains to be done before such an internationally-acceptable framework can be achieved, and this paper is only a step in that direction.

[22] The importance and difficulties of establishing performance indicators in the environmental and sustainable development areas are highlighted in: World Bank. 1995. *Monitoring Environmental Progress: A Report on Work in Progress.* Environment Department, World Bank, Washington, D.C.

The impact of agricultural production systems on the conservation and use of biodiversity

An undergirding theme here is the resiliency of agricultural production systems—their capacity to respond to changes in the biophysical or socioeconomic environment. Sustainable agricultural systems tend to reduce pressure on surrounding habitats. The resiliency of an agricultural production system rests to a large degree on the availability and deployment of plant and animal resources in order to meet challenges to productivity. Another transcending theme is the need to intensify agricultural production; how this is playing out in various land management systems need a to be analyzed with respect to its impact on, and utilization of, biodiversity. Agricultural intensification in annual cropping systems, for example, can exacerbate environmental problems, such as increased sedimentation in rivers and reservoirs to contamination of water supplies with pesticides and herbicides and thereby adversely affect biodiversity.

Any discussion of the impact of farming on the environment, and more specifically biodiversity, needs to be guided by a categorization of land use systems. Intensity of human interventions in landscapes ranges along a spectrum from little if any human use, such as in wilderness areas, to highly managed environments, such as paddy rice farms. A number of different agricultural production systems have been proposed, each the product of varying interests, regional experiences, and expertise of their authors[23]. The land use classification adopted here is drawn from several sources and is tailored more to tropical and subtropical regions, where most of the world's biodiversity is found. The classification employed here provides a starting point for analyzing specific policy issues: is not intended to establish hard and fast categories, since production systems often overlap. Furthermore, many variations and subsystems are found within each category. It will help in developing a better understanding of the fundamental relationships between the use of agricultural resources in major farming systems and loss of biodiversity both on and off farm. The broad categories to be considered include:

- *Intensive Cropping Systems*
- *Rainfed Cropping Systems without Fallow Regeneration*
- *Shifting Agriculture*
- *Agropastoral Systems*
- *Agroforestry*
- *Plantation Systems*

[23] Norman, M.J.T. 1979. *Annual Cropping Systems in the Tropics: An Introduction.* Gainesville: University Presses of Florida; NRC. 1993. *Sustainable Agriculture and the Environment in the Humid Tropics.* Washington, D.C.: National Research Council, National Academy of Sciences; Ruthenberg, H. 1980. *Farming Systems in the Tropics.* Oxford: Clarendon Press.

• *Forest extraction*

A matrix of biodiversity performance indicators needs to be applied to each of the main agricultural production and forest extraction systems. Although the set of indicators in Box 2 are still at an early stage, it is designed to provide an analytical tool to guide thinking on how to assess whether certain agricultural and forest extraction practices are more or less likely to impair biodiversity.

Box 2: Some preliminary performance indicators on biodiversity conservation and management in various agricultural production and forest extraction systems

Indicator	Cause(s)	Proposed mitigating action(s)
Natural habitat loss	Encroachment by agricultural production systems	Intensify systems to increase productivity and income-generating options
Habitat fragmentation	Encroachment of agriculture in uncoordinated manner	Minimize fragmentation (and interruption of gene flow, and loss of certain species because remnant patches are too small to support them) by providing wildlife corridors along "bridges" of natural habitat
Species loss even when natural habitat still intact	Air and/or water pollution; excessive sedimentation of water courses; excessive hunting, fishing, collecting, or logging	Decrease dependence on agrochemicals by shifting to IPM; incorporate crop rotation and/or more perennials; promote "organically-grown" or other "green" labels for environmentally-friendly production systems; devise management plans for harvesting wild plant and animals resources
Decline of biodiversity of crop species on farm	Adoption of new farming practices, such as monocropping with a cereal crop, possibly propelled by fiscal incentives	Eliminate fiscal and/or regulatory measures that are promoting homogeneity; explore aspects of traditional, polycultural systems that can be rehabilitated while still raising yields and income
Decline in biodiversity within species	Release of modern varieties and application of agrochemicals to protect them, possibly propelled by fiscal incentives; adoption of intellectual property rights	Support research on traditional varieties that can achieve high yield; support research on modern varieties that may be replaced frequently (biodiversity over time) but are less dependent on agrochemicals to achieve high yields; promote heterogeneous crop varieties rather then genetically pure varieties; provide incentives for both modern and traditional varieties; eco-labelling of products certifying that they come from traditional varieties

Intensive Cropping Systems

Intensive cropping systems include some traditional farming operations, such as paddy rice and raised bed agriculture, that rely on manual labor and mulching, and modern systems that depend heavily on mechanization and purchased inputs. Intensive agriculture is essential to further raise food production and relieve pressure on other habitats, but it can lead to resource degradation. The world's population is expected to double before it stabilizes sometime in the middle of the twenty-first century, and much of the increased food production will have to come from areas that have already been brought into cultivation, otherwise a great deal of the remaining biodiversity heritage of the world will be irretrievably lost.

Modern plant breeding, biotechnology, and the related issue of intellectual property rights all have the potential to adversely affect the conservation and rational use of biodiversity. High-input, modern farming with its reliance on monoculture, mechanization, and deployment of an arsenal of agrochemicals diminishes biodiversity and destroys many florae and fauna including beneficial insects and microorganisms, and diminishes biodiversity.

It is therefore necessary to examine new models for high productivity agriculture, models that retain the benefits of increased productivity and the potential to raise incomes, while being more environmentally-friendly. One policy recommendation emanating from this tidal shift in the way we look at agriculture is the need to promote research on genetically-diverse populations of crops and animals on and agricultural diversification on managed landscapes. Hybrids and HYVs may have a comparative advantage under favorable conditions where irrigation, fertile soils, and generous socioeconomic infrastructures are in place, but they may have a limited role in more marginal and high-risk environments where population growth is often especially rapid. As the twentieth century draws to a close, we are on the threshold of new types of intensive agricultural production systems in which the management levels ratchet up and the need to harmonize biodiversity with sustainable agricultural development more wisely is ever more urgent.

Rainfed Cropping Systems

Such systems are often characteristic of the semi-arid regions of the tropics. In the humid tropics they are replaced by slash-and-burn systems whereby farmers take advantage of plant nutrients stored in primary forests and second growth that are released upon burning. The semi-arid rainfed cropping systems are usually based on annuals, are strongly integrated with livestock production, and often employ crop rotation to help combat soil exhaustion. These are more fragile systems, and a diversified agriculture is critical for sustainable management of natural resources including biodiversity.

Shifting Agriculture

Shifting agriculture, whereby farmers clear a patch of forest or bush, burn the debris, and cultivate the resulting plot for a few years before abandoning it, is often indicted as one of the principal causes of deforestation and biodiversity loss. It is not uncommon to see policy recommendations that call for arresting or stamping out shifting agriculture in order to preserve the environment and sequester carbon.

But shifting agriculture systems are highly variable and can be environmentally sound. Furthermore, some shifting agriculture plots eventually evolve into intricate agroforestry systems. Shifting agriculture should therefore be analyzed from a balanced perspective, highlighting those practices and policies that trigger excessive loss of biodiversity, but also pointing out environmentally-sound aspects of this widespread farming system. In many areas of Latin America, for example, insecure land tenure is a major reason why people clear forest and plant some crops. Slash-and-burn agriculture in such cases is practiced more to claim property, rather than to produce food.

Agropastoral Systems

A wide variety of systems are found here, especially in Africa and tropical Asia. Such systems are often particularly appropriate for resource poor areas. Agricultural development policies sometimes promote overgrazing and the loss of biodiversity because the complex cultural and ecological dimensions to pastoral activities are poorly understood. In Latin America, the expansion of cattle raising continues to be a major cause of tropical deforestation. Initially driven by fiscal incentives, market forces are now promoting the spread of cattle ranching in many parts of the region.

The news on the cattle front is not all gloomy for biodiversity. Cattle are increasingly incorporated on small farms, many of which are developing diverse agroforestry systems. Cattle contribute to the sustainability of small farms by providing emergency cash, diverse income sources, transportation for agricultural products, and manure for some crops. Furthermore, small, medium, and large cattle operators are recuperating degraded pastures, rather than clearing more forest[24]. One way that farmers and ranchers are upgrading pastures is by sowing more productive and disease-resistant grasses, all of African origin. Cattle operations, as in the case of crop cultivation, thus hinge on a continued flow of new plant materials to remain productive.

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[24] Smith, N.J.H., E.A.S. Serrão, P. Alvim, and I. C. Falesi. 1995. *Amazonia: Resiliency and Dynamism of the Land and its People.* Tokyo: United Nations University Press.

The animal side of agropastoral systems also has implications for biodiversity. Little attention has been paid to the fate of "traditional" breeds of livestock as farmers focus on highly-productive cattle, pigs, sheep, and chickens. In many cases, traditional breeds are hardier than larger, "super" breeds, and are better adapted to difficult environments. The use of traditional breeds, such as heat-tolerant Bali cattle may make more sense than promoting other tropical breeds, such as the zebu. In some cases, research should be supported on the domestication of wild animals for the production of meat and other goods; such efforts are already underway with crocodiles in New Guinea, iguanas in Central America, and ostriches in the U.S.A.

Agroforestry

Agroforestry, which involves the cultivation of one or more perennial plants along with annual crops , is often promoted as one of the more sustainable land use systems for the tropics, especially in degraded areas. Agroforestry brings numerous environmental benefits, ranging from better protection of the soil and more efficient utilization of water and soil nutrients. The greater floristic diversity of agroforestry systems opens up more niches for wildlife, particularly birds[25].

Although agroforestry is more environmentally-friendly than most annual cropping systems, market forces constrain both the number of species deployed and the extent of mixed cropping systems in comparison to cereal farming and livestock ranching. In many tropical forest areas, agroforestry is still confined mostly to home gardens. In the Brazilian Amazon, for example, most agroforestry systems in fields contain from two to four species. Whereas some farms contain agroforestry plots with dozens of intercropped annuals and perennials, excessive diversity of crops can actually be counter-productive. In the tropics at least, average annual productivity in ecosystems becomes saturated in the range of 10 to 40 species[26]. Economically-viable crop combinations that contain between two and ten species would thus be a high priority for agricultural research and development in the tropics.

The further development of agroforestry hinges on biodiversity of forest environments and the incorporation of local people in the design of new agroforestry configurations. Farmers throughout the tropics are domesticating a wide range of plants in their home gardens, some of which are later adopted for field agriculture. Local knowledge is critical in identifying which plants are useful in surrounding forest, and needs and constraints of communities. Successful

[25] Holloway, J. 1991. Biodiversity and tropical agriculture: a biogeographic view. *Outlook on Agriculture* 20(1):9-13.
[26] Baskin, Y. 1994. Ecologists dare to ask: how much does diversity matter? *Science* 264:202-203.

agroforestry development will thus depend on conserving and better managing forests and tapping local knowledge as well as scientific research.

Plantation Systems

In some cases, the promotion of commercial plantations, such as tea, coffee, oil palm and rubber, has accelerated tropical deforestation and loss of biodiversity. In Malaysia, for example, only a small number of forest-dwelling animal species survives in tree crop plantations. No monocultural system has been shown to support a breeding population of forest-dwelling birds. Only a few birds adapted to disturbed sites can make a home in monocrop tree plantations.

But many perennial tree crops are suitable for rehabilitating degraded areas. And the tree crop plantations have differential impacts on biodiversity, depending on the crop involved. Rubber plantations appear to have greater value as wildlife habitat than oil plantations, in part because they contain pockets of original habitat that is too wet to support rubber trees. Also, rubber trees sport crowns that are more propitious for nest-building by birds than the arching fronds of oil palm.

Plantation forestry is geared mainly to timber and pulp production, and to a lesser extent fuelwood. In the case of fuelwood production, most planting efforts have been in semi-arid regions where the need for cooking fuel is most acute. All told, plantation forestry systems cover some 11 million hectares and are expanding. Plantation forestry impinges on a similar range of biodiversity issues as perennial tree crop plantations. Such plantations are typically based on single species and are thus especially vulnerable to disease and pest pressure. The diversification of such systems should help reduce dependence on chemical control of pests, and help make them more resilient. The difficulty is finding appropriate mixes of perennials that can make a profit for their growers.

Forest Extraction

Pressures on forest lands are increasing as farmers encroach on their margins and timber exploitation increases. In temperate lands, the forest area has increased in this century, mainly with planted species, but in the tropics they are still shrinking. How such forests are used and managed therefore has major implications for biodiversity.

Farmers frequently still extract various animal and plant products, such as fuelwood and game, from surrounding forests even though most of their income is derived from crop and/or livestock production. Livestock, especially goats, are frequently let loose in transitional forests of the drier tropics. In some areas, extractive reserves have been set up that are supposed to provide a viable income without the need to cut down trees. Community-based management is increasingly touted as the way to go in development, particularly for non-timber forest products.

The setting up of extractive reserves or forest reserves for "sustainable" timber production is the easy part. Actually making them work is another matter. Communities may be overzealous in extracting forest products if the market is strong, thereby depleting natural resources and biodiversity. Tropical forests are highly heterogeneous, so one model for sustainable timber cutting in one area may not apply to another. The role of traditional knowledge, the minimal critical size for ecosystem functions, and whether rotations between cutting or harvesting are sufficiently long for environmental recuperation, are among the issues that warrant attention.

Approaches to the conservation and management of biodiversity and constraints to the use of sound policies and practices.

A balanced approach to conservation of biodiversity for agricultural development should include both *in situ* and *ex situ* strategies. The appropriate mix of *ex situ* and *in situ* strategies will depend on the crop and region in question.

Ex situ conservation entails saving seeds or other plant material and animals away from places that it usually grows, such as in a genebank or field genebank in the case of root crops or trees that do not produce seed that can be dried and frozen without killing the embryo. *Ex situ* conservation represents the conventional approach to safeguarding threatened or obsolete plant material, and has served agriculture well. But it has certain drawbacks, such as the high cost of maintaining cold storage facilities, particularly in developing areas with high heat and humidity, the loss of viability of material due to inadequate care, and the onerous task of regenerating materials collected from a diverse array of environments. Furthermore, genebanks contain only a portion of the genepools of crops and are biased in favor of major cereal and legume crops.

In situ conservation involves a range of strategies, from parks and reserves to maintaining "heirloom" varieties on-farm (Box 3). The cultural and ecological principles that have successfully maintained high diversity in traditional agroecosystems need to be considered in order to develop conservation policies for dynamic *in situ* conservation, rather than rely solely on genebanks. While seed and field genebanks play an important role in crop improvement because materials are readily available for use by breeders, more attention is warranted on ways to help maintain biodiversity in its natural setting[27]. Genetic erosion is occurring not only in nature, but also in national and international germplasm collections that were established to conserve genetic resources. Losses in nature, as in the forests of the humid tropics, for example, stem from conversion of land to other uses and a subsequent loss of biodiversity. In gene banks, losses result from lack of data on accessions and inadequate management of necessary activities such as regimentation of collection samples and storage[28].

Box 3: **Conservation units for *in situ* conservation of genetic resources for crops and livestock improvement**		
Conservation Unit	**Wild populations or near relatives**	**Landraces or traditional breeds**
Nature reserves	+	
Indigenous reserves	+	+
Extractive reserves	+	
Managed forests for timber	+	
Religious sanctuaries and shrines	+	+
Range land used by pastoralists	+	+
Ranches		+
Farms		+
Home gardens		+

In the case of wild plants, *in situ* conservation primarily entails establishing parks and reserves. For the most part, parks and reserves have been created for purposes other than conserving the genepools of crop plants. National parks, nature preserves, and reserves set aside for indigenous peoples, and extraction of forest products sometimes fortuitously contain wild populations of such important crops as rubber, avocado, and mango. But few reserves have been set aside to promote the cause of agrobiodiversity. Much work remains to be done in establishing high priority crops for such efforts. *In situ* conservation has its own set of problems: some parks and reserves are not large enough to maintain their full complement of species, such as predators at the top of the food pyramid, and many protected areas are penetrated by loggers, miners, hunters, and gatherers of plant products.

[27] Altieri, M. A. and L. C. Merrick. 1987. In situ conservation of crop genetic resources through maintenance of traditional farming systems. *Economic Botany* 41:86-96; Altieri, M. A. and L. C. Merrick. 1988. Agroecology and in situ conservation of native crop diversity in the Third World. In: Wilson, E. O. and F. M. Peter (Editors), *Biodiversity*, pp. 361-369. Washington, D.C.: National Academy Press; Vaughan, D. A. and T. T. Chang. 1992. In situ conservation of rice genetic resources. *Economic Botany* 46:368-383; Wilkes, G. H. 1991. In situ conservation of agricultural systems. In: Oldfield, M. L. and J. B. Alcorn (Editors), *Biodiversity: Culture, Conservation, and Ecodevelopment*. Boulder: Westview Press.

[28] Day, Peter R. 1994. Managing Global Genetic Resources: Agricultural crop issues and policies. Opening statement on public briefing to discuss the committee's report. Washington, D.C..

In situ conservation of traditional varieties raises a number of important issues. How can agrobiodiversity be preserved on the farm if owners wish to adopt modern, high-yielding varieties (HYVs)? Do HYVs always wipe out traditional varieties? Some studies have shown that commercial farmers sometimes maintain a mix of traditional and modern varieties; only the area devoted to older "heirloom" varieties diminishes to make space for income-generating modern cultivars[29]. If erosion of traditional varieties is marked in a given area, what incentives and strategies can be promoted to arrest or slow this trend? What are the strengths and limitation of community-based in situ conservation strategies?

In some cases, agricultural policies may be driving the adoption of modern varieties, rather than market forces. The availability of credit only for planting high-yielding varieties may discourage the retention of varieties that have been passed down over the generations. In some cases, traditional farms are as productive, or even more so, than systems that rely on a few, modern varieties that depend on purchased inputs to achieve high yields. A greater appreciation of ways that natural resources are managed in traditional systems can provide insights on ways to promote *in situ* conservation without stifling economic growth.

The role of traditional varieties of both major and minor crops in supporting local communities and alleviating poverty is not well understood, nor is the changing role of women with respect to the management of agrobiodiversity as production systems are transformed by modern practices. Ways in which the involvement of local farmers and indigenous groups can be strengthened in the conservation and more rational use of biodiversity warrant particular attention. Little thought has been given to ways that traditional breeds can be maintained on the land, rather than as frozen sperm or embryos. In Britain, the Rare Breeds Survival Trust (RBST) has made impressive strides in reversing the loss of traditional breeds of livestock, and could serve as a model for other regions[30].

It is worth underscoring an important principle: conservation of plant and animal genetic resources will ultimately fail if it is not used. Biodiversity use can even be considered a third strategy for conservation, in addition to *in situ* and *ex situ* strategies. Whenever a plant or animal becomes a "hot" item in the marketplace, farmers and livestock herders scramble for material to incorporate into their operations. It is thus not surprising that wheat, rice, and maize dominate collections in seed genebanks. Only when significant demand exists for a plant or animal, will people pay attention to patterns of genetic variation and the need to

[29] Brush, S. B. 1986. Genetic diversity and conservation in traditional farming systems. *Journal ofEthnobiology* 151-167. Brush, S. B., M. Belton, and E. Schmidt. (1988). Agricultural development and maize diversity in Mexico. *Human Ecology* 16:95-106.
[30] Hall, S.J.G. 1989. Breed structures of rare pigs: implications for conservation of the Berkshire, Tamworth, Middle White, Large Black, Gloucester Old Spot, British Saddleback, and British Lop. *Conservation Biology* 3(1):30-38.

conserve the new-found resource. Biodiversity use can thus stimulate conservation efforts.

Finally, a number of constraints --such as technical, financial, institutional, social and political-- may inhibit the use of sound policies and practices in biodiversity management. These will be considered in detail in a follow-up review.

Policies, regulatory mechanisms, and implications of agricultural development on biodiversity management.

Ultimately, improvement in biodiversity management can come about only through policy considerations by national governments and international agencies. It is crucial to explore the effects of local, national, and international policies and practices that affect biodiversity conservation and utilization. This would include such issues as land tenure, input subsidies, pricing policies, resettlement and migration, equitable sharing of benefits and natural resource management.

The complex issue of intellectual property rights (IPR) also has profound policy implications for the conservation, management, and exchange of biodiversity[31]. The very sustainability of agricultural systems across the globe hinges on the continued exchange of crop plants, varieties, and materials for testing. Exotic crops often provide a parachute for farmers faced with declining yields or diminish market value for their existing crops. IPR has the potential to hinder or accelerate this process, depending on the outcome of a series of debates and discussions now underway at various levels in numerous countries.

The question of how IPR is or will impact on biodiversity is still far from settled. Superimposed on technical issues are the numerous trade agreements, such as WTO (World Trade Organization) and regional trade arrangements, such as NAFTA (North American Free Trade Agreement) and the European Community, that are likely to impinge on the conservation and harnessing of genetic resources. The application of IPR, plant variety protection (PVP), plant breeders' rights (PBR), and Farmers' rights (FR) are part of the discussions of such trade agreements. As of February 1995, 114 countries have signed the Convention on Biodiversity, yet how this convention will impact the use and safeguarding of biodiversity is still unclear. And some non-signatories to this Convention are major players in the international movement of plant and animal materials. A

[31] Lesser, W. 1994. Institutional mechanisms supporting trade in genetic materials: issues under the biodiversity convention and GATT/TRIPs. In: *Environment and Trade No. 4*, pp. 1-72, United Nations Environment Programme (UNEP), Geneva.

careful review and analysis of the impacts of such international agreements on biodiversity and agriculture is thus warranted.

The placing of value on genetic resources, pharmaceutically useful compounds, and new plant and animal species for agriculture is a two-edge sword: on the one hand, establishing economic value for biodiversity will create incentives for conservation. On the other hand, intellectual property rights raise a series of issues related to compensation and the exchange of plant and animal materials. Historically, genetic materials of most crops, and especially those involved in food production, have moved freely among nations. This open-exchange policy has contributed enormously to the spectacular gains in yields for all of the major food crops and some industrial crops in this century.

Concern about ownership of parental lines for hybrid production, compliance with patents on seeds or grafted material, and the profits generated by seed sales based on germplasm from many nations have all contributed to a climate of uncertainty about ways to proceed. Much debate is now underway about farmers' rights with regard to the exchange of plant and animal materials. In the 1970s, the issue of plant breeders' rights, a form of IPR, turned mostly on a perceived North-South tug of war over genes. Increasingly, IPR is also a South-South issue, particularly in regard to tropical tree crops and timber species. Countries that do not recognize IPR may be excluded, or experience delays, in obtaining protected varieties of crop plants. The limited available evidence suggests that IPR promotes seed trade when plant breeder's rights are respected

IPR and biodiversity are tightly intertwined in complex ways. A more in-depth analysis of the economic, social, institutional, and environmental ramifications of intellectual property rights and its impact on agriculture and biodiversity thus need to be explored to strengthen policy formulation. By clarifying the issues involved, it should be possible to identify priorities and establish and action plan.

Specific issues that need to be explored include:

- The impact of various international trade agreements on biodiversity both on and off farm
- The impact of various forms of IPR (patents, plant breeders' rights, trade secrets, trademarks) on biodiversity.
- The seed trade and biodiversity
- International Conservation and Management
- The interplay of the Convention on Biodiversity, IPR legislation, and trade agreements on biodiversity, particularly from the agricultural perspective

Review of the World Bank's agriculture and biodiversity related portfolio and the contributions of other major organizations, for their implications for agrobiodiversity conservation and utilization.

A review of the current status of how biodiversity is treated in the Bank, particularly from an agricultural perspective, would provide a useful feedback for priority setting in the future. A biodiversity "sieve" needs to be applied to the Bank's agriculture projects, including the GEF, and the Bank's agricultural sector work and country assistance strategies. The review would include an analysis of several innovative integrated conservation and development projects recently launched or in the planning stage.

A Call for Change

Some of the major issues related to biodiversity and agriculture have been explored briefly. Although much more work on these issues is warranted, some preliminary conclusions and recommendations can be offered.

We need a new paradigm for agricultural research, one that incorporated the experience and aspirations of indigenous knowledge. In spite of the fact that some agricultural research systems at the international, regional, and national levels have made some tentative steps at adopting programs that emphasize natural resource management and on-farm trials, results appear to be spotty at best. Agricultural research is still largely a top-down, research station enterprise, in many cases. Mechanisms are needed that pool resources to encourage collaboration between agricultural research institutions, NGOs (especially growers' associations), individual farmers, communities, and private companies.

In order to avoid the widespread adoption of genetically-uniform HYVs and "super" breeds, national agricultural programs need to be strengthened so that they can better evaluate and incorporate plant and animal genetic resources into their work to meet local needs. Such genetic resources would include collections in *ex situ* gene banks as well as *in situ* reserves and farmers' fields. The impressive yield gains achieved by the "green revolution" should not lull policymakers into assuming that more of the same is in order. A new generation of HYVs is needed with a much more diverse genetic heritage better adapted to local and regional conditions[32]. Ranches and livestock operations in the next century will contain a different mix of breeds and strains than they do today; how sustainable they are

[32] Jain, H. K. 1993. Plant genetic resources and policy implications for a changing agriculture. *Indian Journal of Genetics* 53(3):223-237.

will depend on how good a job society does in conserving the biodiversity of wild and domesticated animals.

Rapid rural appraisals that focus on agrobiodiversity are warranted as part of the environmental assessment procedures for loans provided by development banks. They should assess (a) the current extent and richness of agriculturally-related biodiversity (e.g. traditional varieties, landraces in use; check for wild or weedy populations and near relatives), (b) explore the impacts of proposed development project on existing biodiversity, both agricultural and "wild", and (c) examine whether proposed agricultural development activities have paid sufficient attention to local needs, natural resource management strategies, and ways to preserve biodiversity within proposed agricultural systems.

Greater support is needed to document species and understand their systematic relationships. Policymakers often envisage systematic specialists as throwbacks to bygone eras when people just collected specimens for museums. But systematics today is highly dynamic, uses computers to help sort out relationships between species, and increasingly takes into account ecological information. Scientists working in herbaria and zoological museums, as well as field biologists, are critical for the conservation and management of biodiversity.

In conclusion, it is emphasized that our global genetic resources are not static. They constitute a living, changing, diverse system that can best benefit humankind when thoughtfully managed. Plant, animal and microorganism, germplasm are and agricultural endowment that offers the dividends of better varieties and breeds of food crops and animals, and resources for sustainable economic and environmentally friendly development. Sound management practices can ensure that the "capital" derived from this endowment will not be squandered[33].

This brief overview has laid out some of the issues that entwine biodiversity and agriculture. More work is clearly required before sound policy recommendations can be made. Given the rapid pace of ecological, cultural, and socioeconomic changes underway in virtually all of the world's major habitats, it is hoped that the required in-depth analyses can be conducted in a timely manner.

[33] Day, Peter R. 1994. Managing Global Genetic Resources: Agricultural crop issues and policies. Opening statement on public briefing to discuss the committee's report. Washington, D.C..

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