# agroBIODIVERSITY
## A new science agenda for biodiversity in support of sustainable agroecosystems

agroBIODIVERSITY
Science Plan and Implementation Strategy

DIVERSITAS
an international programme of biodiversity science

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# DIVERSITAS

Report N°4, **agroBIODIVERSITY Science Plan and Implementation Strategy**


– ISSN: 1813-7105- ISBN: 2-9522982-2-X
Suggested citation: Jackson, L., Bawa, K., Pascual, U., and Perrings, C. (2005). agroBIODIVERSITY: A new science agenda for biodiversity in support of sustainable agroecosystems. DIVERSITAS Report N°4. 40 pp.

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**www.diversitas-international.org/cross_agriculture.html**

# agroBIODIVERSITY

## A NEW SCIENCE AGENDA FOR BIODIVERSITY IN SUPPORT OF SUSTAINABLE AGROECOSYSTEMS

agroBIODIVERSITY is a Cross-Cutting Network of DIVERSITAS

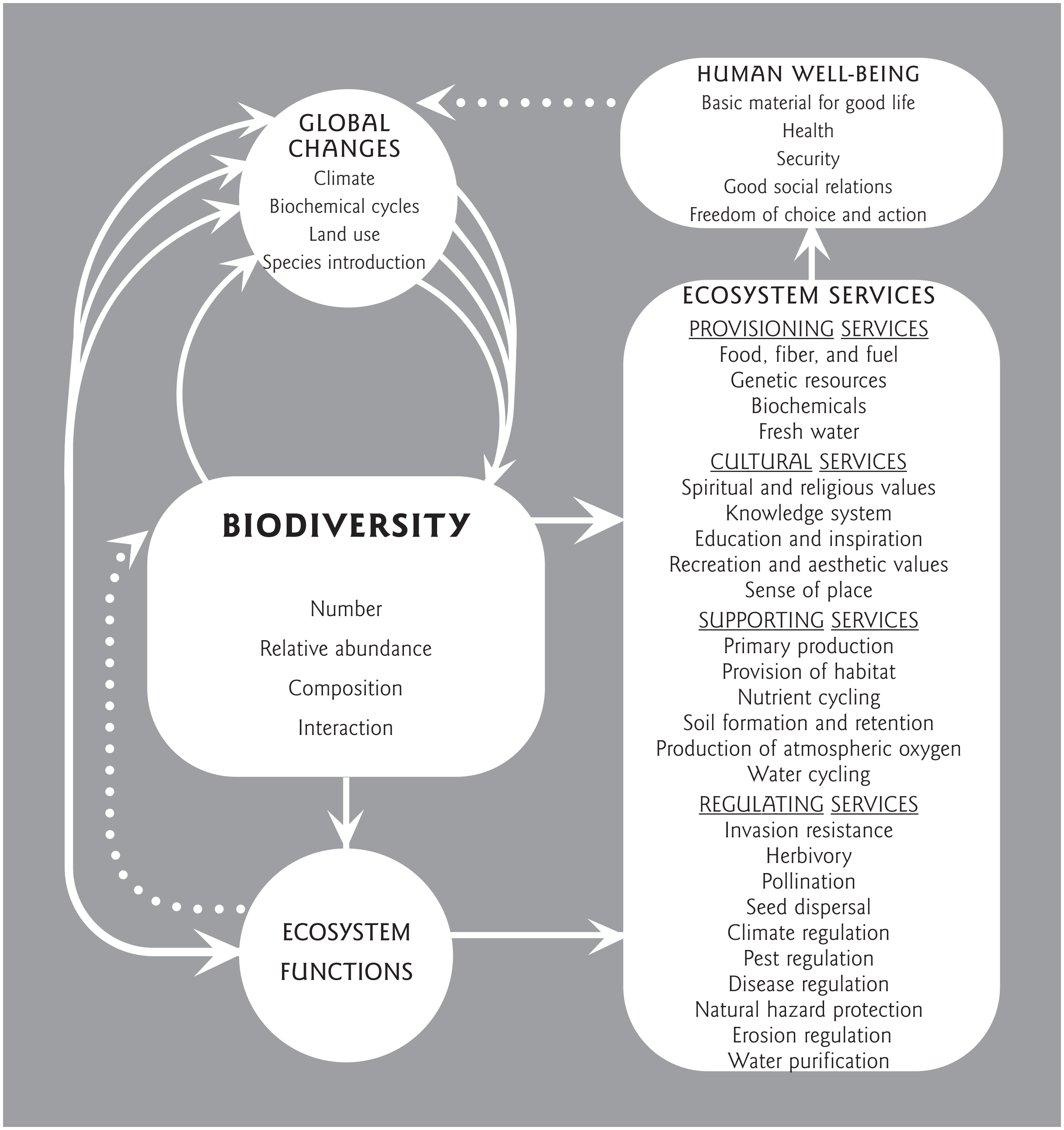
EDITORS : LOUISE JACKSON, KAMAL BAWA, UNAI PASCUAL, AND CHARLES PERRINGS

PREPARED BY THE agroBIODIVERSITY SCOPING COMMITTEE

APPROVED BY THE SCIENTIFIC COMMITTEE OF DIVERSITAS

DIVERSITAS
an international programme
of biodiversity science

Box P.1 :
*Biodiversity, ecosystem functioning, ecosystem services and human well-being. Biodiversity is both a response variable that is affected by global change drivers and a factor that modifies ecosystem processes and services and human well-being. Figure source: Millennium Ecosystem Assessment (2005).*



# PREFACE

While species extinction is a matter of increasing concern, changes in biodiversity in the world's agricultural landscapes have largely escaped attention. Yet, agriculture is fundamentally linked to biodiversity. "Biological diversity" or biodiversity[1] has formed the basis for human food production systems for millennia, and plays an important role in the provisioning services, *i.e.*, production of foods, fuels, and fibers, that agriculture supplies. Biodiversity in agriculture also provides cultural services that form key elements of the agricultural knowledge base, and define spiritual, religious, and aesthetic values for human societies. In a wider context, biodiversity serves important functions that enhance the environmental resource base upon which agriculture depends, e.g., regulating and supporting services such as water purification, nutrient cycling, and soil formation.

Population growth, changes in food demand, conversion to modern, high-input agriculture, land use changes, and the globalization of agricultural markets have caused rapid loss of agricultural biodiversity, and of biodiversity in wildland ecosystems. Despite the importance of biodiversity for agriculture, ecologists and conservation biologists have tended to place greatest emphasis on the negative agricultural impacts on wild biodiversity that have resulted from modern agricultural intensification and expansion. In fact, a dichotomy has arisen between agriculturalists and conservation biologists, due to the growing demand for food, creating a significant impact of agriculture on wild land ecosystems, as has been demonstrated in the recent Millennium Ecosystem Assessment[2]. Resolving this dichotomy is imperative, in order to conserve biodiversity for its highest potential benefit to agriculture and for the Earth's life-support system.

Agricultural landscapes are part of our natural capital, and the flow of services that they provide is the 'interest' on that capital. Just as investors choose a portfolio of produced capital to maintain the return on that capital over a range of market risks, so society needs to choose the mix of genes, species, communities, and ecosystems to maintain the flow of ecosystem services over a range of environmental and social risks. This requires understanding the risk implications of changes in that mix that will help to design adequate strategies for agricultural management and conservation biology in order to maintain an ecologically acceptable level of biological diversity on this planet.

To inform decision makers, new scientific approaches are needed to address the trade offs between food production, biodiversity conservation, ecosystem services and human well being in agricultural landscapes.

This international programme of biodiversity science, DIVERSITAS, has identified a science agenda for biodiversity use in agricultural landscapes, to inspire and facilitate a new generation of research on this topic. This science agenda recognises that a fundamentally new approach to the science and management of agricultural landscapes is needed and that agricultural landscapes need to be considered as systems providing a range of services in addition to food, fuel and fibres.

This document, the science plan and implementation strategy of a new DIVERSITAS cross cutting theme called "agroBIODIVERSITY" is the result of a number of meetings and discussions over the past year, involving scientists of diverse backgrounds, disciplines and countries. We are grateful to the US National Academy of Sciences for providing a seed grant that has enabled this work to be initiated. This document is by no means an end in itself, but is meant to evolve as new knowledge is generated. We hope that it will contribute, in the context of the post Millennium Assessment era, to a new generation of scientific work, and a new way to consider biodiversity in agricultural landscapes.

**Louise Jackson, Kamal Bawa, Unai Pascual and Charles Perrings**
agroBIODIVERSITY

**Michel Loreau**
Chair, Scientific Committee DIVERSITAS

**Anne Larigauderie**
Executive Director, DIVERSITAS

[1] *The UN Convention on Biological Diversity defines biological diversity as "the variability among living organisms from all sources including...terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are a part: this includes diversity within species, between species and of ecosystems".*

[2] *Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.*

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Biodiversity loss in agricultural landscapes affects not just the production of food, fuel, and fiber, but also a range of ecological services supporting clean water supplies, habitats for wild species, and human health. The world's population of 6.3 billion people is projected to grow to 9 billion by 2050. To meet the increased demand for food, more land will be converted to agriculture, and agricultural intensification will increase, thereby increasing the pressure on biodiversity in natural ecosystems. Given the expected growth in human population and predicted environmental change, research is needed predicted effects on environmental change, research is needed that shows how the utilization and conservation of biodiversity can provide ecosystem services to satisfy both current and future needs.

The goal of the agroBIODIVERSITY science plan and implementation strategy is to establish the scientific basis needed to address the trade-offs between food production, biodiversity conservation, ecosystem services, and human well being in agricultural landscapes. Three key research foci of the agroBIODIVERSITY Science Plan integrate the biological and social sciences:

**(1)** To assess biodiversity in agricultural landscapes and the anthropogenic drivers of biodiversity change;

**(2)** To identify the goods and services provided by agrobiodiversity at various levels of biological organization, e.g., genes, species, communities, ecosystems, and landscapes;

**(3)** To evaluate the socioeconomic options for the sustainable use of biodiversity in agricultural landscapes.

Innovative biodiversity-rich farming systems can potentially be high-yielding and sustainable, and thus support persistence of wild species by limiting the adverse effects of agriculture on habitats. Adoption of farming practices that utilize and conserve biodiversity may ultimately improve environmental quality and limit agricultural expansion. Conservation of biodiversity and human knowledge from traditional agroecosystems is an urgent priority, to support human societies that rely on its cultural services, and for its potential for solving agricultural problems, now and in the future.

Implementation of the agroBIODIVERSITY Science Plan will involve collaboration between geneticists, ecologists, anthropologists, and economists, to cross ecosystem boundaries to understand the environmental and social drivers of biodiversity change, ecosystem services provided by biodiversity in agricultural landscapes, and how to use this information for policy-relevant strategies to meet human needs. Innovative methods for data handling and analysis across disciplines are required, as are protocols for integrating formal and informal knowledge. Workshops, publications, and projects by international networks of scientists will result in various scientific products that will increase useful knowledge for a variety of stakeholder groups.

Examples of activities will include:

- Assemble and synthesize current knowledge,
- Develop new approaches, methods, and models for assessing biodiversity in agricultural landscapes, and for determining issues that affect the sustainable use and conservation of biodiversity in agriculture
- Establish international networks that promote research and capacity building among researchers involved in biodiversity science in agricultural landscapes
- Conduct research linking the biophysical and socioeconomic sciences to develop new knowledge that will support decisions for biodiversity utilization and conservation in agricultural landscapes
- Produce synthetic outcomes of research activities and promote the development of policy-relevant materials related to sustainable use of biodiversity
- Lead outreach efforts to show the successful outcomes of approaches that link biophysical and socioeconomic sciences for sustainable use of biodiversity in agricultural landscapes.

bioDISCOVERY
a core project of DIVERSITAS

ecoSERVICES
a core project of DIVERSITAS

bioSUSTAINABILITY
a core project of DIVERSITAS

# DIVERSITAS – AN INTERNATIONAL PROGRAMME OF BIODIVERSITY SCIENCE–

Since its inception in 1991, DIVERSITAS has focused on identifying global concerns related to biodiversity science and on coordinating efforts from around the world to address these issues. In 2001, a second phase of the Programme was launched with the aim of further refining its three main objectives:

- Discovering biodiversity and predicting its changes.
- Assessing impacts of biodiversity changes on ecosystem functioning and services.
- Developing the science of the conservation and sustainable use of biodiversity.

In 2003, DIVERSITAS hosted a series of scoping meetings to produce a science plan and implementation strategy for each of these Core Projects. In recognition of their primary goals, participants chose to identify the Core Projects by the following names: bioDISCOVERY (in prep.), ecoSERVICES (Bulte, Hector and Larigauderie 2005), and bioSUSTAINABILITY (Raffaelli, Polasky, Holt and Larigauderie 2004).

This document constitutes the first in a series of science and implementation strategies of DIVERSITAS cross cutting networks, focusing on a particular theme or ecosystem, and encompassing some of the themes of each of the three core projects.

## THE BIODIVERSITY CHALLENGE

Biodiversity underpins the Earth's life-support system. Both natural and managed ecosystems deliver important ecological services such as the production of food and fibre, the capacity to store carbon and to recycle nitrogen, and the ability to change in response to climate and other disturbances. Nevertheless, changes in the structure and function of ecosystems resulting from biodiversity alterations and loss can reduce the availability of vital services and affect the aesthetic, ethical and cultural values of human societies.

It is well recognized that the Earth is a complex and sensitive system regulated by physical, chemical and biological processes – and influenced, as never before, by human activities. Of serious concern is that the planet is experiencing unprecedented rates of species extinctions and shifts in ecological processes, the consequences of which could be numerous and far-reaching for human societies. Unfortunately, our ability to predict the outcome of interactions between natural processes and human activities is limited. Better understanding of the consequences of biodiversity change will require an integrative approach drawing on the strengths of both natural and social sciences. Measuring and describing biodiversity associated with genes, species and ecosystems must continue, but must be coupled with efforts that determine how humans can be motivated to conserve and to use biodiversity in sustainable ways. Without question, the most pressing challenge is to establish a scientific foundation for appropriate actions aimed at maintaining an ecologically acceptable level of biological diversity.

Meeting these challenges is the main objective of DIVERSITAS, an international programme of biodiversity science, which aims to provide the scientific basis for the conservation and sustainable use of biodiversity by integrating biodiversity science across biological and social disciplines (Box I.1). This document, the agroBIODIVERSITY Science Plan and Implementation Strategy proposes an international framework to develop policy relevant knowledge on agricultural biodiversity. As it is a DIVERSITAS cross-cutting network, this document is based on many priorities identified in the Science Plans and Implementation Strategies of the DIVERSITAS Core Projects: bioDISCOVERY (in prep.), ecoSERVICES (Bulte et al. 2005) and bioSUSTAINABILITY (Raffaelli et al. 2004).

## DIVERSITAS

DIVERSITAS is an international, non-governmental programme, established under the auspices of ICSU[3], IUBS[4], IUMS[5], SCOPE[6] and UNESCO[7], that aims to address the complex scientific questions posed by the loss of and change in global biodiversity. By connecting individuals across natural and social science disciplines, it facilitates research that extends beyond national or regional boundaries to address issues of global concern, thereby adding value to research projects being undertaken around the world.

In accordance with the mandate developed by its sponsoring bodies, the mission of DIVERSITAS is two-fold:

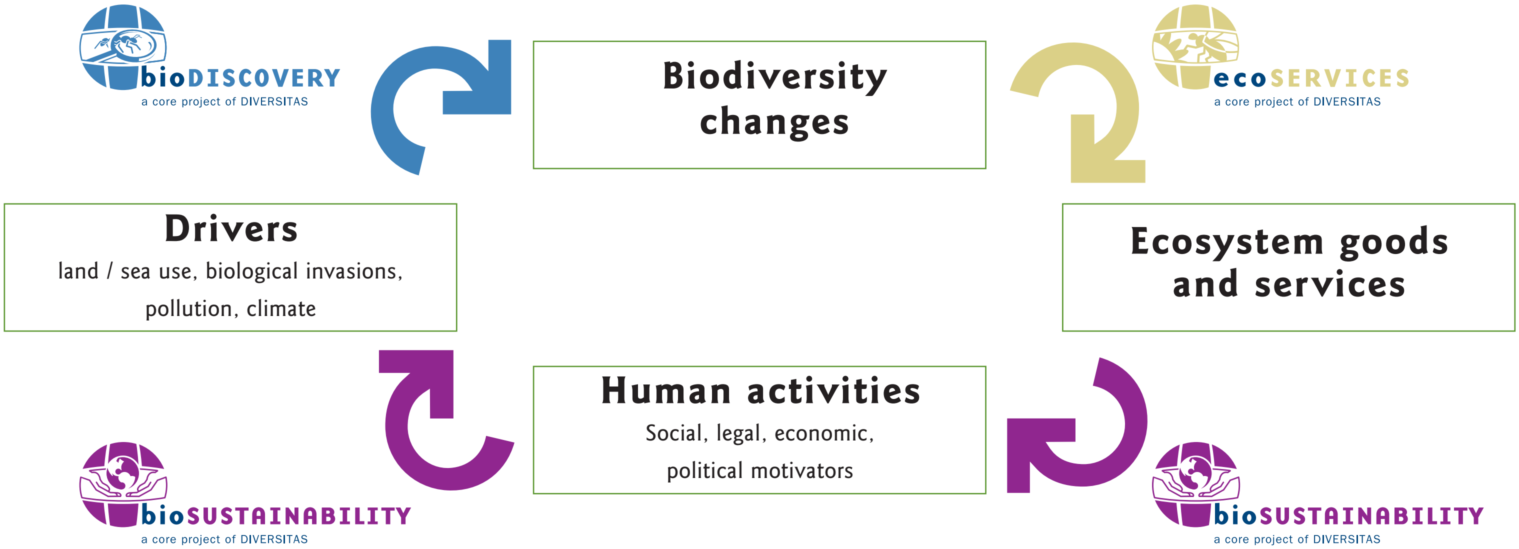
- To promote an integrative biodiversity science, linking biological and social disciplines in an effort to produce socially relevant new knowledge.
- To provide the scientific basis for the conservation and sustainable use of biodiversity.

### ■ Scientific Core Projects

The primary means by which DIVERSITAS carries out its mission is through catalysing research aligned with its three Scientific Core Projects (Loreau and Larigauderie 2002 - DIVERSITAS Science Plan). Collectively, DIVERSITAS Core Projects form an integrated programme that can be illustrated by a cycle (Box I.1):

- bioDISCOVERY focuses on biodiversity change, asking how much biodiversity exists on the planet, how it is changing, what are the fundamental ecological and evolutionary processes causing the changes, how are these processes controlled, and what are the mechanisms of action of the drivers underlying changes in biodiversity from local to global scale.
- ecoSERVICES examines the impact of these biodiversity changes on ecosystem functioning and services.
- bioSUSTAINABILITY analyses the repercussions to society of considering or neglecting goods and services provided by biodiversity. It also investigates human activities and, in particular, the social, legal, economic and political motivators that could have an impact on the drivers of biodiversity change. Results will be used to guide conservation measures and sustainable use of biodiversity.

- [3] *International Council for Sciences*
- [4] *International Union of Biological Sciences*
- [5] *International Union of Microbiological Societies*
- [6] *Scientific Committee on Problems of the Environment*
- [7] *United Nations Educational, Scientific and Cultural Organisation*




## Cross-cutting Networks

DIVERSITAS also establishes Cross-cutting Networks, on specific topics or ecosystems, which embrace issues addressed in all three Core Projects:

- Global Mountain Biodiversity Assessment (GMBA) addresses mountain biodiversity issues. www.unibas.ch/gmba/
- Global Invasive Species Programme (GISP) addresses issues related to invasive species. www.gisp.org
- freshwaterBIODIVERSITY focuses on issues related to freshwater biodiversity.
- agroBIODIVERSITY investigates relationships between biodiversity and agriculture.

In addition, two other networks on biodiversity and health, and on marine biodiversity are being developed

*Box I.1*
*Each DIVERSITAS Core Project targets specific issues, yet the new knowledge acquired in any given area will support development of the field of biodiversity science as a whole.*

## Earth System Science Partnership

Recognising the links between biodiversity and other areas of global concern, DIVERSITAS is a founding member of the Earth System Science Partnership (ESSP; www.ess.org). In addition to DIVERSITAS, this network includes three other programmes that focus on global issues such as climate change and human impacts on the planet:

- International Geosphere-Biosphere Programme (IGBP; www.igbp.kva.se)
- International Human Dimensions Programme on global environmental change (IHDP; www.ihdp.org)
- World Climate Research Programme (WCRP; www.wmo.ch/web/wcrp)

Established in 2001, ESSP supports the integrated study of the Earth system: its structure and functioning; change occurring within the system; and the implications of change for global sustainability. ESSP currently oversees four Joint Projects:

- Global Environmental Change and Food Systems (GECAFS; www.gecafs.org) develops strategies to address food provision concerns while also analyzing the environmental and socioeconomic consequences of adaptation and mitigation .
- Global Carbon Project (GCP; www.globalcarbonproject.org) investigates carbon cycles and energy systems to develop policy-relevant knowledge that encompasses natural and human dimensions, as well as their interactions.
- Global Water System Project (GWSP; www.gwsp.org) examines how humans are altering the global water cycle, the associated biogeochemical cycles, and the biological components of the global water system as well as human response to these changes.
- Global Environmental Change and Human Health project (www.diversitas-international.org/essp_global) investigates how environmental change worldwide affects human health and well-being, with the aim of developing policies for adaptation and mitigation. This project is under development.

## National Committees and Regional Networks

One of DIVERSITAS' primary objectives is to create a worldwide network in support of biodiversity science that fosters integration across disciplines and establishes links at regional and international levels. Two types of bodies play important roles in the achievement of this objective: National Committees and Regional Networks.

National Committees enlarge DIVERSITAS' scientific and policy networks, thereby helping to establish crucial links between national biodiversity programs and international framework activities. They also make it possible to implement and, where necessary, to adapt the DIVERSITAS Science Plan to local and regional concerns. Because many issues related to biodiversity transcend national boundaries, it is often essential for several countries to collaborate in scientific research and policy development.

# INTRODUCTION :
## Challenges for agriculture and biodiversity

We are in an era of rapid ecological, social, and economic change, and the pace of this change will accelerate during the next several decades. The world's population of 6.3 billion people is projected to grow to 7.5 billion by the year 2020 and to 9 billion by 2050 [(8)]. By 2050, food consumption must double to meet human needs. To meet this increasing demand for food, production systems are expected to become increasingly dependent on inputs of fertilizers, pesticides, and water. Irrigated lands will likely increase by 1.3-fold by 2020, and 1.9-fold by 2050. Pasture lands are also increasing, with an expected doubling in area by 2050. In 50 years, global agricultural land area is projected to increase by 18%, with a loss of $10^9$ hectares of natural, wildland ecosystems.

These trends will further increase the pressure on biodiversity in natural ecosystems, already under stress from human disturbances such as climate change. Ironically, since the advent of agriculture, biodiversity has provided the raw material for new innovations in agriculture, critical ecosystem services, and options for an uncertain future. Yet at this time in human history, we face the prospect of agricultural landscapes that are biodiversity-poor, with increasing threats to wild biodiversity. Humanity faces a challenge of meeting its growing needs for food and fiber from a resource that it is threatening to destroy. Given the expected growth in human population and predicted environmental change, how can biodiversity sustain agriculture and the agroecosystem services upon which humans depend, and how do we conserve this biodiversity for current and future needs?

Modern agriculture is currently one of the greatest extinction threats to biodiversity in both agroecosystems and in wildlands, and holds thus the key to the conservation of world's remaining biodiversity. Innovative biodiversity-rich farming systems can potentially be high-yielding and sustainable, and thus support persistence of wild species by limiting the adverse effects of agriculture on wildland habitats. Adoption of farming practices that utilize and conserve biodiversity may ultimately improve environmental quality and limit agricultural expansion.

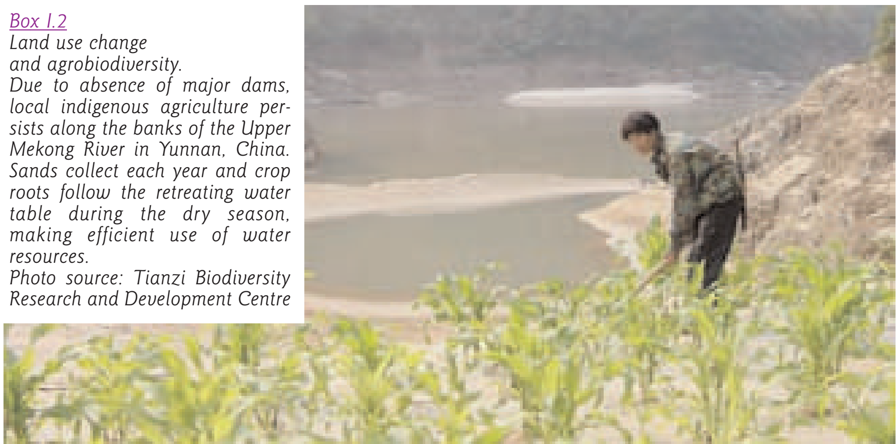
The mission of DIVERSITAS is to promote an integrative biodiversity science that links biological, ecological, and social disciplines to provide the scientific basis for the sustainable use and conservation of biodiversity. Here, the focus is on agriculture, with greatest emphasis on farming, but including pastoralism, fishing, and forestry in managed, human-dominated ecosystems as well. The specific challenges for agriculture are to answer the following questions:

**1)** What types of biodiversity are available for increasing agricultural sustainability, and how is this biodiversity affected by rapid social and environmental change?

**2)** How does biodiversity enhance the goods and services supplied by agricultural landscapes at all levels of biological organization, e.g., genes, species, communities, and ecosystems?

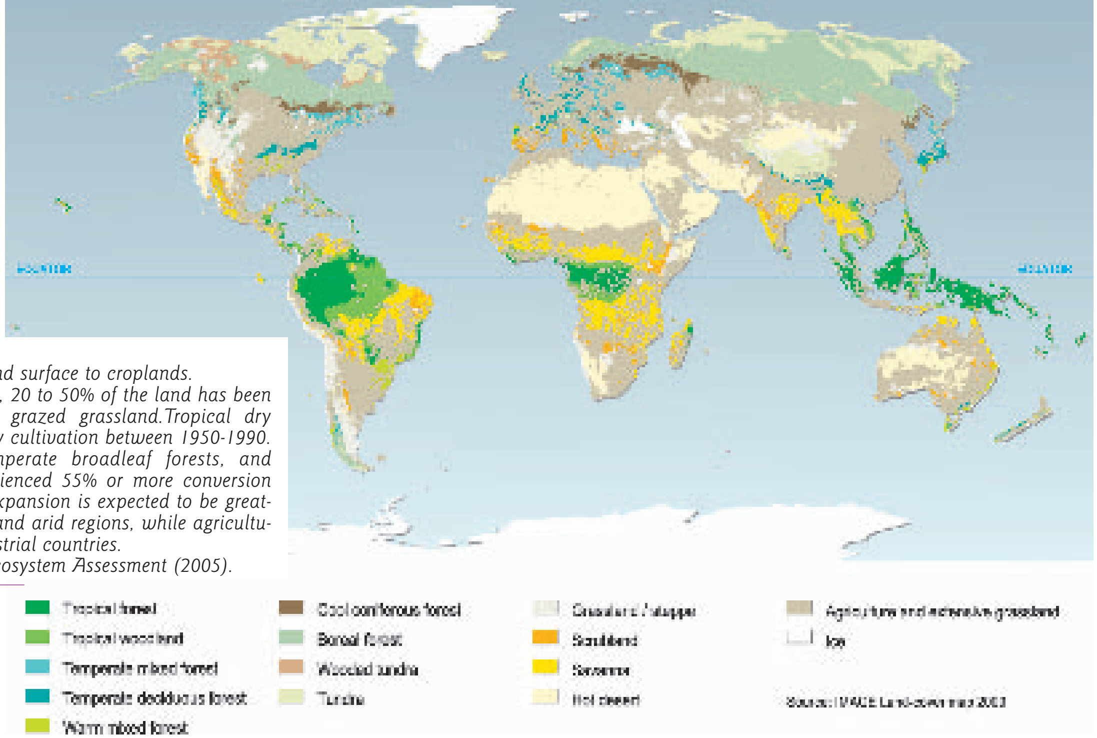
**3)** How can society assure the sustainable use of biodiversity in agricultural landscapes, and the equitable sharing of the benefits of conservation?

To accomplish this mission, an interdisciplinary research framework is needed to monitor biodiversity, to understand ecosystem services provided by biodiversity, and to guide decision making and policies regarding biodiversity in agricultural landscapes. This requires collaboration between biological and social scientists, with knowledge inputs from agricultural producers. The effort will build on international treaties and organizations that have already been instrumental in conserving biodiversity (See Appendix).



*Box 1.2*
*Land use change and agrobiodiversity.*
*Due to absence of major dams, local indigenous agriculture persists along the banks of the Upper Mekong River in Yunnan, China. Sands collect each year and crop roots follow the retreating water table during the dry season, making efficient use of water resources.*
*Photo source: Tianzi Biodiversity Research and Development Centre*

● (8) *Tilman, D., K.G. Cassman, P.A. Matson, R. Naylor, and S. Polasky. 2002. Agricultural sustainability and intensive production practices. Nature 418: 671-677.*




*Box 1.3*
*Conversion of the Earth's land surface to croplands.*
*In 9 of the 14 global biomes, 20 to 50% of the land has been converted to croplands or grazed grassland.Tropical dry forests were most affected by cultivation between 1950-1990. Temperate grasslands, temperate broadleaf forests, and Mediterranean forests experienced 55% or more conversion prior to 1950. Agricultural expansion is expected to be greatest in developing countries and arid regions, while agricultural area will decline in industrial countries.*
*Figure source: Millennium Ecosystem Assessment (2005).*

## CONTEXT

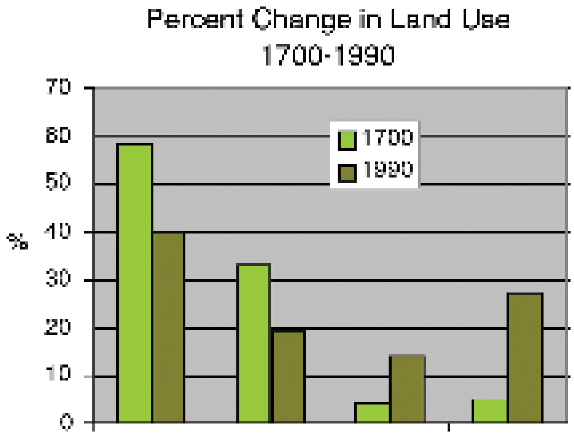
Agricultural biodiversity or, as referred to in this document, agrobiodiversity, performs functions and delivers services that sustain agriculture and the resources upon which agriculture depends. Agrobiodiversity refers to all crops and animal breeds, their wild relatives, and the species that interact with and support these species, e.g., pollinators, symbionts, pests, parasites, predators, decomposers, and competitors, together with the whole range of environments in which agriculture is practiced, not just crop lands or fields. It encompasses the variety and variability of living organisms that contribute to food and agriculture in the broadest sense, and that are associated with cultivating crops and rearing animals within ecological complexes. It comprises genetic, population, species, community, ecosystem, and landscape components and human interactions with all these. It also includes many habitats and species outside of farming systems that benefit agriculture and enhance ecosystem functions. Examples include:

- genetic and population characteristics of traditional varieties, breeds, and of related wild species, that are important for human adaptation to socioeconomic and environmental change;
- community assemblages that limit pest damage to crops thereby reducing inputs of pesticides and off-farm impacts, and the habitat on which they depend;
- ecosystem functions such as nutrient cycling and retention that are derived from spatial and temporal biodiversity via rotations, fallowing, and tillage; and
- landscape-level interactions between agricultural and non-agricultural ecosystems that enhance resource availability for agriculture.

Nearly half of the world's population lives in rural areas and depends directly on agricultural systems. It is estimated that about 60% of the world's agriculture (approx.three million ha) consists of traditional subsistence farming systems in which there is a high diversity of crops and species grown and a high diversity in the ways in which they are grown, such as polycropping and intercropping. These systems encompass an enormous amount of the planet's agrobiodiversity, yet much of it has not been well-documented in terms of species composition or function. Modernization of agriculture is due to many factors including rapid population growth, breakdown of traditional institutions, and stronger market forces, exacerbated by the role of agribusiness and international trade pressures. An immediate effort must be made to conserve the biodiversity and human knowledge from traditional agroecosystems so that it is available for solving agricultural problems, now and in the future, and to support human societies that rely on its cultural services.

Agricultural intensification and expansion of agriculture adversely impacts the biodiversity on- and off-farm, thereby promoting species extinction in managed and constricted wildland habitats. Abandonment of degraded lands, desertification, and agricultural encroachment on forest margins will increase, with further loss of biodiversity and its services. Agricultural intensification, as defined here, refers to the use of nonrenewable, purchased inputs,

Box 1.4. *Estimated changes in global land use between 1700 and 1990.*
*Percent Change in Land Use, based on estimates by Lambin et al. (2003), there has been a 350% increase in cropland in the last 300 years, with a concomitant decrease in forest and steppe. 38% of land area on earth is now agricultural or pastoral (Wood et al. 2000).*




such as pesticides and fertilizers, substitution of mechanization and fossil fuels for human labor, and high capital invested per unit of land. To combat the adverse impacts of agricultural intensification and expansion, a transition has been set into motion worldwide toward sustainable agriculture, which is one that "will over the long term[9] :

- satisfy human food and fiber needs
- enhance environmental quality and the natural resource base upon which the agricultural economy depends
- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls
- sustain the economic viability of farm operations
- enhance the quality of life for farmers and society as a whole."

Biologically, there is much potential for increasing the utilization of agrobiodiversity for sustainable agriculture. The agricultural sciences have shown for decades that plant breeding can introduce genes to increase the quality of agricultural production, though recent advances with genetically modified organisms (GMOs) are very controversial. Crop diversity can clearly enhance nutrient use efficiency, and a diverse soil community may govern tighter nutrient cycling, control pests and diseases and improve soil structure ('let the soil work for us'). Ecological research has shown that biodiversity can increase the productivity of ecosystems. The structure of agricultural landscapes, i.e. mosaics of agricultural and nonagricultural ecosystems, now is recognized as important for the utilization and conservation of both on-farm and off-farm biodiversity. Economists have shown how investment in agrobiodiversity reduces both the environmental and market risks faced by agricultural producers, and so enhances well-being.

The economic value of changes to enhance agrobiodiversity and its services is rarely reflected in current market transactions, and is not taken into account by decision-makers. In many countries, users of biological resources in agroecosystems have little incentive to maintain sufficient diversity to meet the needs of agricultural production because markets for agricultural inputs and outputs do not reflect the full social opportunity costs. Economists refer to this as the problem of market failure, and to the resultant loss of biodiversity as an external effect of agricultural markets that creates excessive social costs. Many policies, particularly in agriculture, exacerbate the problem by modifying agricultural prices in ways that increase the gap between privately and socially optimal prices.

Research that integrates the natural and social sciences is needed to explore the importance of agrobiodiversity for sustainable agriculture, its services, and the socioeconomic trade offs involved in its use and conservation. The challenge is to find ways to meet our immediate needs for food, fuel, and fiber while conserving sufficient biodiversity to assure our capacity to respond to climate and other anthropogenic environmental change. Moreover, to alleviate poverty in a rapidly growing world population using a finite set of rapidly eroding biological assets, we need to be able to identify the trade offs involved in alternative land uses much more effectively than has been done in the past. This requires a scientific approach that is driven by human needs, recognizes the interdependence between human behavior and ecosystem processes, and delivers a deeper understanding of the role of biodiversity in satisfying those needs.

## STRUCTURE OF THE agroBIODIVERSITY SCIENCE PLAN

For research on agriculture and biodiversity, a cross-cutting approach is adopted to integrate the three core projects of DIVERSITAS. This recognizes the need to adopt an integrated interdisciplinary research framework to understand genetic, ecological, and economic aspects of conservation and use of biodiversity in agriculture.

Discovering biodiversity and predicting its changes (bioDISCOVERY) is the essence of Focus 1 in this document. This focus seeks to assess how much biodiversity is present, develop the scientific basis for monitoring biodiversity, promote the establishment of biodiversity observatories, and understand and predict biodiversity changes.

[9] *1990 Farm Bill [US Government 1990].*

Assessing impacts of biodiversity changes (ecoSERVICES), involves aspects of ecosystem functioning and ecosystem services. Focus 2 strives to expand the science of biodiversity and ecosystem functioning to larger scales and over a greater breadth of the biological hierarchy. The goals are to develop an effective means for linking changes in ecosystem structure and functioning to changes in ecosystem services, to assess human response to changes in ecosystem services and feedbacks into ecological systems; and to examine the impacts of biodiversity change on human well-being.

For developing the scientific foundation of conservation and sustainable use of biodiversity (bioSUSTAINABILITY), Focus 3 develops new knowledge to guide policy and decision-making. Its main objectives are to evaluate the effectiveness of current measures for the sustainable use of biodiversity, to study the social, cultural, political, and economic drivers of biodiversity loss, to investigate social choices for optimal levels of biodiversity use and the ecological and socioeconomic trade-offs that exists in agroecosystems at the local, regional, and global levels.

| Variable | Actual (world) | Average annual rate of change * |
|---|---|---|
| **World population**, 2003 (million) | 6,301 | 1.72% |
| Agricultural population (as % of total) | 41.17 | 0.88% |
| Developed countries (million) | 1,329 | 0.72% |
| Agricultural population (as % of total) | 6.84 | -2.41% |
| Less Developed Countries (LDCs) (million) | 4,972 | 2.07% |
| Agricultural population (as % of total) | 50.35 | 1.16% |
| | | |
| Total cropped and arable land (billion ha): 1961-2002 | 1.53 | 0.30% |
| Developed Countries (billion ha): 1992-2002 | 0.63 | -0.51% |
| LDCs (billion ha): 1961-2002 | 0.90 | 0.68% |
| | | |
| Food production per capita, (index) 1961-2003 | ** | 0.65% |
| Developed countries | ** | 0.47% |
| LDCs | ** | 1.25% |
| Total food production (index) 1961-2003 | ** | 2.38% |
| Developed countries (index) | | 1.20% |
| LDCs (index) | | 3.36% |
| | | |
| Cereal production (Billion MT, 2003) | 2.07 | 2.15% |
| Developed countries (Billion MT, 1961-2003) | 0.84 | 2.47% |
| LDCs (Billion MT, 1992-2003) | 1.23 | 1.36% |
| | | |
| Cereal yields (ton/ha, 2003) | 3.08 | 2.03% |
| Developed countries (ton/ha, 1961-2003) | 3.63 | 1.58% |
| LDCs (ton/ha, 1961-2003) | 2.80 | 2.24% |
| | | |
| Fertilizer intensity, 1961-2001 (kg/ha) | 90.1 | 3.59% |
| Developed countries | 79.9 | 1.00% |
| LDCs | 98.6 | 7.79% |
| | | |
| Global fertilizer consumption (1961-2002) | | |
| Nitrogenous Fertilizers (million Mt) | 84.74 | 5.11% |
| Phosphate Fertilizers (million Mt) | 33.55 | 2.90% |
| Potash Fertilizers (million Mt) | 23.27 | 2.59% |
| | | |
| Workers/ha agricultural land, 1961-2001 | 0.87 | 0.81% |
| Developed countries | 0.07 | -2.22% |
| LDCs | 1.42 | +0.71% |
| | | |

*Box 1.5*
*Trends in agricultural productivity and use of resources in the last 40 years. Source: Food and Agriculture Organization of the United Nations (FAO), FAOSTAT on-line statistical service at http://apps.fao.org. FAO: Rome, 2004.*
*Last accessed in February 2005.*
**calculations based on FAOSTAT data;*
***actual figures not available.*

## *Box 1.6*

## Examples of recent scientific advances in biodiversity science and their relevance to agriculture.

Future biodiversity research will be assisted by a number of recent scientific developments. The genomic structure for several major crop species and their wild relatives is now being described, and this provides a wealth of information and analyses that can be used for describing biodiversity at the genetic level and its use in crop production (Tanksley and McCouch 1997; Cooper et al. 2001; Gustafson et al. 2004). Recent agronomic research has emphasized systems analysis to show the benefits of biodiversity-based practices such as cover crops, intercrops, rotations, and hedgerows for agricultural productivity and environmental quality (McNeely and Scherr 2004). New ecological research has shown that greater numbers of species result in higher productivity of grassland ecosystems, which is relevant not only for pastures, but for other types of agriculture (Loreau et al. 2002). Using satellite imaging systems, the distribution of ecosystems in agricultural landscapes can now be described with high resolution, yielding information on how to better manage agricultural species, invasives, and wild species (Walsh and Crews-Meyer 2002). New efforts to merge biological and economic approaches are generating information on how policies can affect the conservation and use of agrobiodiversity for enhancement of human well-being (Millennium Ecosystem Assessment 2005).

## *Box 1.7*

## Ecological and socioeconomic analogies for agricultural transition.
## Source: A.M. Izac.

While various authors have provided definitions of sustainability that encompass biophysical, biological and socioeconomic factors, relatively few attempts have been made at integrating key concepts from ecology and economics to better understand, analyze, and manage biodiversity in agroecosystems. Resilience appears to be a useful concept for ecologists and economists. It refers to the capacity of a system to adapt to external changes by either returning to its original state or by evolving into a state preferable to the initial one. A basic hypothesis, shared by ecologists and economists, is that biodiversity has a number of functions which contribute to the resilience of agro-ecosystems. For instance, soil biodiversity (earthworms and termites, in particular) can enhance soil fertility which enables the rehabilitation of degraded soils. Another example is that crop and tree biodiversity in agroecosystems enhances the ability of farmers to remain economically viable by diversifying their revenues under uncertain market conditions with respect to volatile market price changes of inputs, crops or tree products.

A research agenda attempting to address these core issues for ecologists and economists alike would focus on the identification of the key functional (ecological and socioeconomic) roles played by biodiversity, with evaluation of possible scenarios for improving the management of these key functions in agroecosystems, where feasible, in response to environmental or economic stress. Policy recommendations for enhancing biodiversity management and the resilience of agroecosystems could then be developed on the basis of a better understanding of the ecological and economic principles at play and of the feasibility of improvements in different types of agroecosystems (e.g., highly diverse and complex in the tropics and with no external support vs. more simplified by humans in temperate areas and with a high level of financial support through subsidies).

## Box 1.8

An example of the integrated, interdisciplinary approaches required to address issues that cut across three core projects of DIVERSITAS is provided by the work of natural and social scientists associated with the Ashoka Trust for Research in Ecology, and the Environment (ATREE), Bangalore, India.Source: K. Bawa.

*Figure C: Enhancing biodiversity in agroforestry systems in BRT Wildlife Sanctuary to increase productivity of finger millets and maize, fosters sustainability, and reduces dependence upon wild species such as P. emblica (i.e., Amla or Emblic) which is harvested for wood and its medicinal fruits.*

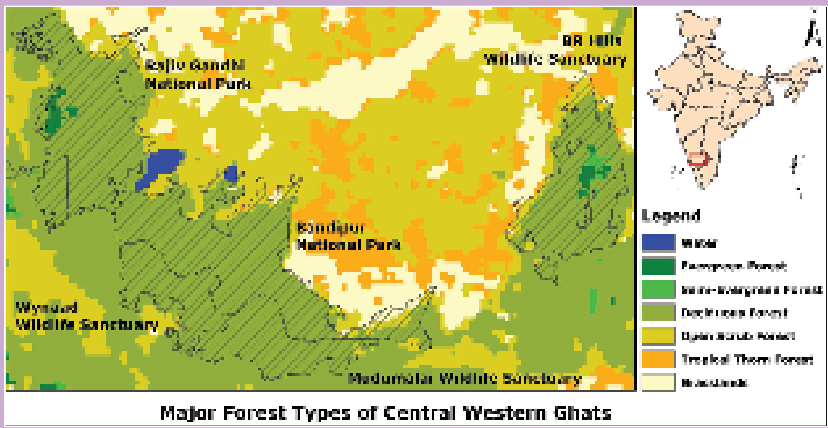



*Figure A: A remotely sensed image showing ecosystem diversity in three protected areas in India, with agricultural production primarily outside the protected areas.*

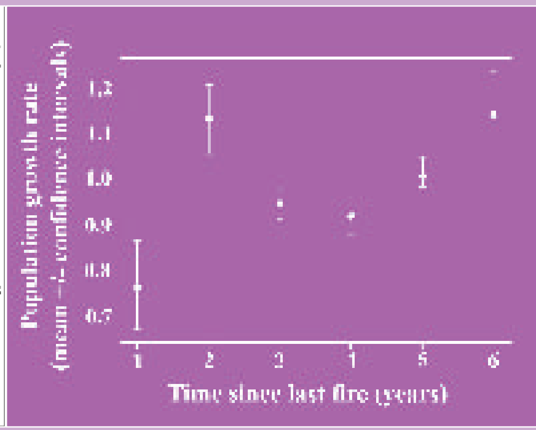



*Figure B: Population growth rates of one of the non-timber forest product species, Phyllanthus emblica, as impacted by fire in BRT Wildlife Sanctuary (shown in Figure C), India.*

ATREE scientists are working to promote conservation of biodiversity at multiple scales at several sites covering agroscapes and forest landscapes using a diverse array of approaches. In one of the programs, focused on conservation and livelihoods in the Biligiri Rangaswamy Temple (BRT) Wildlife Sanctuary, the first objective is to describe system parameters relating to both ecological and interacting social systems (for example, genetic, species, and ecosystem diversity; land use and land tenure; and household determinants of resource use).

The second objective is to examine the impact of human societies on ecosystem structure and function (for example the effects of collection of non-timber forest products, agricultural production for local consumption, fire, and invasive species on biodiversity at the population and ecosystem level, the impact of land use change on ecosystem services, and the effectiveness of protected area network as well as current management practices and polices on conservation of biological diversity).

The third objective is to design and implement management and policy interventions to mitigate human impacts and promote sustainable use of resources.

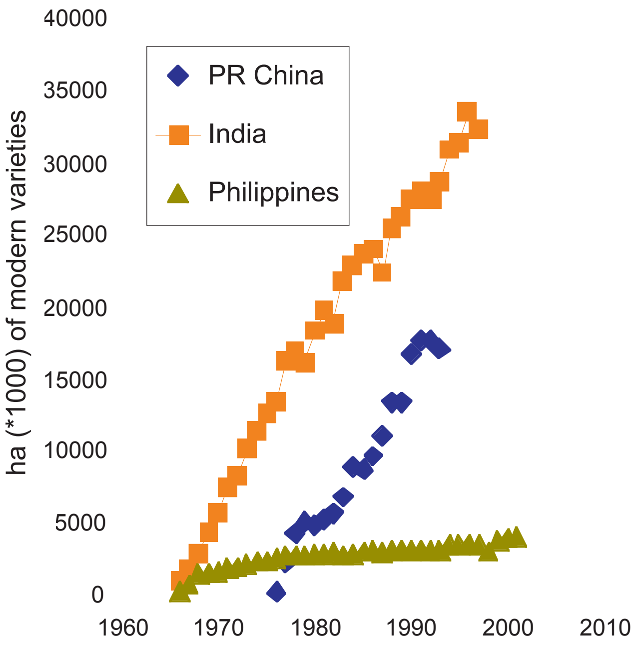
The management interventions consist of enhancing biodiversity and productivity in agroecosystems to reduce pressure on forest biodiversity, provision of micro-credit, and promotion of micro-enterprises based on biological resources, initiating governance reforms for sustainable use of forest resources in various organizations. The project uses a participatory approach for research and action, combines principles and approaches of ecology and economics, fosters social equity in sharing of biodiversity benefits, and brings stakeholders together to define and resolve conservation problems. Lessons and experiences from the project form the basis of policy and institutional reforms.

## ■ FOCUS 1 :

### Determining the factors that increase biodiversity in agricultural landscapes and anticipating the impacts of social and environmental change

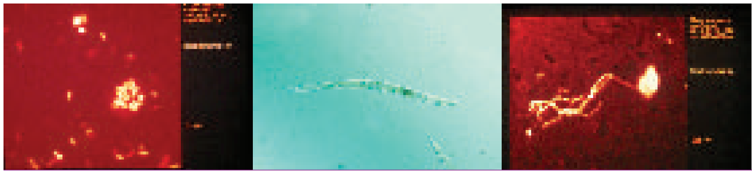
For millennia, agricultural production has depended on the diversity that exists at the level of genes, species, communities, and ecosystems. Genetic diversity, the genetic material that can be exchanged between populations, has formed the basis of crop improvement since the beginning of agriculture that today feeds more than 6 billion people worldwide. Landraces and wild relatives of agricultural species have been a source of genes for improved stress tolerance, disease and pest resistance, and enhanced nutrition. Agricultural intensification, driven by social forces at various spatial scales, has led to an enormous loss of genetic diversity as local breeds, varieties, and landraces have been replaced by modern high-yielding breeds and cultivars. It has also resulted in major shifts in communities of other organisms such as symbionts, soil biota involved in nutrient cycling, pollinators, and invasive species and pests. Habitat loss caused by agriculturally induced problems, such as erosion and deforestation, has reduced biodiversity in adjacent ecosystems. Toxicological impacts on biota, including humans, create large economic and social costs, which, like many other adverse effects, are not usually factored into the cost/benefit analysis for adopting intensive agriculture.

Programs to assess, measure, and monitor the biodiversity that is of high priority to production and sustainability of agricultural systems are needed. There is little information about the diversity that is at risk, even in regions of biodiversity 'hotspots'. Assessments of changes in biodiversity at all ecological levels from genes to landscapes will show the factors that promote both the invasion of new pests, pathogens and competitors and the loss of native species. The analysis of the rates and consequences of biodiversity loss must grapple with local issues such as agricultural growth, environmental sustainability, and poverty alleviation, as well as global factors such as climate change and changing markets. This will allow us to target taxa and situations that are in greatest need of conservation, and then manage to avoid biodiversity losses, or to restore biodiversity for its various services (see Foci 2 and 3).




*Box 1.1. Adoption of modern varieties of rice in Asia. Nearly 75% of the rice production area in Asia is planted to modern varieties (World Rice Statistics 2002). Much of this is lowland rice, where genetic diversity was originally very high, and now is greatly reduced due to adoption of modern varieties with a narrow genetic base. At present there are more than 90,000 rice accessions (most of which are traditional varieties belonging to Oryza sativa) in the IRRI genebank. The Philipines quickly converted its production to modern varieties as it is the center of international rice breeding programs. In contrast, India and China are continuing to increase the land area in modern varieties, partly in response to local breeding programs.*

*Box 1.2.* *Soil biodiversity: much of the soil biota remains to be identified.*
*Soils are thought to harbor the majority of global biodiversity and to govern major components in the cycling of materials, energy, and nutrients. For example, a hectare of grassland may account for the decomposition and processing or organic matter in amounts over 50,000 kg ha $^{-1}$ yr $^{-1}$. However, much of the world's soil biodiversity remains to be discovered, especially in tropical regions.Left to right: Bacteria, nematode, fungi.*
*Photo source: P. de Ruiter.*



## SPECIFIC TASKS FOR FOCUS 1 ARE:

### **Task 1.1**. Develop standards to monitor agrobiodiversity using ecological, anthropological and economic criteria

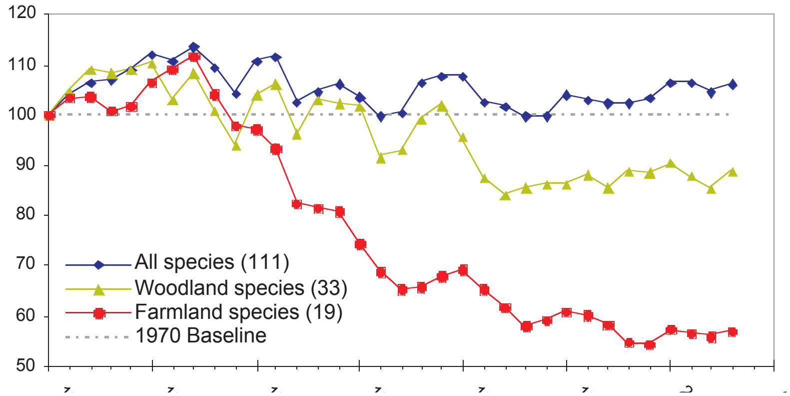
During the past few years there has been an increase in programs for the assessment and monitoring of biodiversity in agricultural landscapes. For example, inventories and surveys of biodiversity across agricultural and non-agricultural ecosystems are using indicators that are relevant to socioeconomic policies. Geographic information systems (GIS) can compile data on responses of biodiversity to factors such as habitat and climate change, land management, environmentally toxic materials, agricultural markets, and cultural change.

An international set of standards is needed for data collection, so that a common framework can be developed for inventories and comparisons across taxa, cropping systems, habitat complexity, ethnobotanical attributes, and economic conditions. In conjunction with bioDISCOVERY, monitoring programs will be directed toward linking patterns of biodiversity change to causal factors. Such linkages are necessary to develop effective strategies to avoid biodiversity loss and/or restore biodiversity. New methods need to be developed to analyze changes in patterns of biodiversity from ecological,

anthropological, and socioeconomic points of view. Ecological criteria for such standards should include measures of genetic diversity, life form, species richness, community structure, and other simple biophysical parameters for characterizing agroecosystems. Anthropological data on relevant human knowledge, gender and culture, food preferences, and spiritual attributes need to be collected. Economic criteria that show the value of biodiversity also require further development, including the assessment of the external costs imposed on society from increased intensification in agroecosystems and expanding land conversion to agriculture.

Development of databases and new methods for the quantitative analysis of patterning of biodiversity that integrate natural and social sciences at various scales are high priorities. Improvement of predictive models for impacts of loss of community, ecosystem, and cultural diversity would be another outcome of this activity, as well as models that explore strategies to restore needed biodiversity levels.

*Box 1.3.*
*Effects of gene flow between crop landraces and wild relatives.Wild and domesticated beans are growing in close-range sympatry in a Mexican milpa field of corn, squash, and beans. Introgression between wild and domesticated beans has been found to be asymmetric, being higher (from 3 to 4 fold) from domesticated to wild populations. This result points to a displacement of genetic diversity in wild populations due to gene flow from the domesticated populations (Papa and Gepts 2003).*
*Photo Source: R. Papa*




*Box 1.4. Bird species decline due to agricultural intensification.* *Marked declines in bird species populations across Britain are due to agricultural intensification (Donald et al. 2001). Many upland grassland bird species are especially impacted (Henderson et al. 2004). Figure is from DEFRA (2004). The index is the percentage change in bird species in various categories relevant to a 100% baseline value for 1970. Above are two farmland-dependent bird species that have suffered recent population declines in Britain as a result of farm management practices.*

**Task 1.2.** Evaluate how genetic resources and population diversity can increase agricultural productivity and other aspects of human well-being, especially in relation to contemporary land use changes

Agricultural intensification has led to a reduction in genetic diversity by a) the reduced area occupied by landraces, b) disruption of adaptive evolutionary processes through the widespread use of varieties based on a single genotype, and c) the decreased size of wildland habitats containing wild relatives (see Boxes 1.1 to 1.5). Landraces in traditional agricultural systems are especially susceptible to agricultural intensification as they are easily replaced by modern high yielding varieties. The introduction of genetically modified organisms poses new challenges with potential to further influence evolutionary forces (e.g. Box 1.3). More effort must be placed on determining the amount and value of diversity in landraces and wild relatives of crops and breeds, and the modification of this diversity by the introduction of modern varieties, land use changes, and cultural behavior such as seed exchange networks. Access to genetic resources is extremely important and needs clarification. The current system of intellectual property rights (IPRs) for genetic resources in agriculture is highly complex, variable among different countries and to some extent contradictory (e.g. Plant Breeders Rights vs. Patenting). International initiatives (e.g. ITPGRFA; See Appendix) to facilitate access to genetic resources, must ensure the fair and equitable sharing of the benefits arising from their use.

Theoretical approaches in population genetics and molecular evolution should form the basis for experimental studies of population structure and evolutionary dynamics. Putative neutral and selective markers, genetic maps, and linkage disequilibrium studies are now available for many crop species and wild relatives, and can be combined with ecological and anthropological measurements to predict viable population structures and breeding options for greater adaptation and resilience to stress (See Focus 2). Candidate gene analysis may be another forthcoming approach. A synthesis of case studies is needed that shows the dynamic nature of gene pools in response to *in situ* conservation of landraces, and during the improvement of landraces for yield reliability, e.g., by participatory research between scientists and farmers.

Analysis of genetic diversity of associated, noncommodity biota in agroecosystems will be useful in identifying potential for increasing ecosystem services (see Focus 2). This includes genetic diversity of soil biota such as mycorrhizae, rhizobia, or ammonia oxidizers, or beneficial insects such as pollinators and natural enemies of pests. Molecular methods will allow the 'fingerprinting' of distinct populations using large sample sizes, to permit the evaluation of diversity, and its relation to land management practices.

### **Task 1.3.** Investigate how biodiversity at the community and ecosystems level can contribute to sustainable agriculture

For most of the agroecosystems in the world, little is known about the biotic communities that provide vital ecosystem services. Maintenance of biotic communities depends on habitat availability in the agroecosystem, dispersal of organisms, and the spatial configuration of source areas. Much is to be learned from traditional agroecosystems on the composition and structure of communities and their ecosystem services, and on how this is changing in response to emergent market and other institutional conditions, intensification, loss of natural habitats, and climate change.

A long-standing tradition of biodiversity-related research exists in the agricultural sciences, e.g., crop rotations, cover crops, intercrops, integrated pest management, and biocontrol agents, to promote ecosystem services with minimal environmental impact. Less-studied are the cultural and socioeconomic barriers to adoption of these practices, which often cannot be simply quantified on the basis of economic use value, and require more complex analytical approaches.

Examples exist where innovative cropping systems have replaced intensive agriculture, by relying on increased biodiversity to provide ecosystem services such as nutrient cycling and pest management, instead of fertilizers and pesticides. Assessment of trade offs in agricultural productivity, economic profitability, and environmental and human impacts in relation to biodiversity change during such transitions would help to generate approaches for increasing agricultural productivity in a sustainable fashion.

### **Task 1.4.** Identify populations, species and ecosystems in most urgent need of conservation efforts during transitions in agricultural landscapes

Agrobiodiversity that is critical for crop breeding and maintenance of ecosystem services (see Focus 2) is unevenly distributed across taxa, ecosystems, and landscapes. Clearly, taxa and ecosystems with high potential for conservation should be those with the greatest expected potential for providing genetic diversity for crop improvement and for ecosystem services. In the absence of direct scientific information on genetic diversity or ecosystem function, theoretical guidelines and predictive frameworks must be developed to target diversity for *ex situ* as well as *in situ* conservation.
Guidelines and predictive models at the genetic and population levels need to integrate biological and socioeconomic forces regulating gene flow, drift, and selection. *Ex situ* conservation measures, especially those by gene banks and botanic gardens, must consider evolutionary dynamics within and among related populations, and the sampling required to capture variation across habitats and landscapes. At the species and ecosystem levels, an understanding of biological interactions and the structure of trophic interactions and food webs would hold the key to the identification of appropriate targets. Other criteria involve value for environmental quality such as watershed functions and mitigation of climate change. In all cases, economic and cultural factors driving change would have to be incorporated into biophysical sampling and modeling exercises.

*Box 1.5*

## Enhancing the contribution of neglected and underutilized species to food security, and to incomes of the rural poor. Source: S. Padulosi, IPGRI.

*Figure C: Andean scrublands: Poor communities in Ayacucho (Perú) have traditionally depended on Opuntia (Opuntia ficus indica) plants for cash income and subsistence food (fruit) and fibers. Source: L.C. Rodríguez*

*Figure A: Andean grains: diversity of quinoa (Chenopodium quinoa) from Bolivia. Source: W. Rojas*

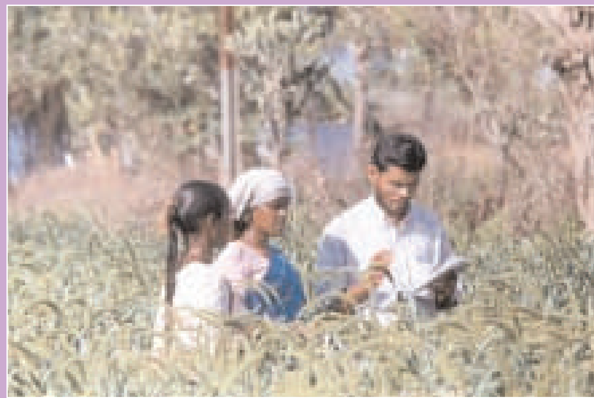


*Figure B: Foxtail millet (Setaria italica): participatory selection in India. Source: M.S. Swaminathan Research Foundation*

Globally, food and nutritional security and economic growth depend increasingly on a declining number of plant species. Humankind has, at one time or another used more than 7,000 plant species for food. On the other end, agricultural research, has concentrated only on very few of them, leaving the rest largely in a state of neglect and/or underutilization. Over half of the protein and food energy we consume is now met by just three crops: maize, wheat, and rice. The narrowing base of global food and nutritional security is limiting livelihood options for people, particularly the rural and urban poor.

Plant biodiversity – including neglected and underutilized species (NUS) - plays an important role in providing household food security but its wider use for tackling nutritional deficiencies and poverty is yet to be fully realized. The successful promotion of biodiversity calls for major commitment at national and international level, in order to tackle all those obstacles that limit its full deployment for improving people's livelihood. Such interventions, often seen as part of a new "evergreen revolution" should encompass diverse fields of research and development, ranging from surveying/ collecting/ conserving/ genetic diversity and safeguarding associated indigenous knowledge to development of effective agronomic practices, improvement of post harvest/processing/adding value technologies, marketing, and commercialization of end-products and the implementation of enabling policies. It is the full realization of the whole chain of events -from sowing to marketing- that would indeed ensure that biodiversity benefits reach ultimately target users, particularly the rural and forest poor of this world in an effective and sustainable way.

The International Plant Genetic Resources Institute (IPGRI) is involved actively in a number of projects addressing NUS, including a major UN global effort targeting Andean grains, finger millets and medicinal and aromatic plants and a German-supported initiative to promote international synergies and partnership specifically on underutilized species.

## ■ FOCUS 2 :

Using biodiversity in agricultural landscapes to enhance the provisioning of ecosystem goods and services

The worldwide interest in developing sustainable agricultural systems is motivated by concerns about environmental impact, e.g., pesticides, acidification, and eutrophication, long-term resource availability for food production, and social quality of life. Although agrobiodiversity clearly can enhance ecosystem functioning and services, e.g., pollination and pest control, nutrient cycling, greenhouse gas exchanges, water use efficiency, soil structure formation, and resistance and resilience of communities to disturbance, these can be site specific, and the adoption of biodiversity-based practices by agriculturalists is often slow or difficult to achieve. Focus 2 addresses how biodiversity influences agricultural processes in ways that can be managed to support the process of sustainable development in agriculture. It follows up on the recommendation made in the Convention on Biological Diversity (CBD) to utilize an 'ecosystem approach' to address the issue of biodiversity and ecosystem functioning in agro ecosystems. Both scientific and practitioner (including indigenous) knowledge is necessary in this approach.

An understanding of the socioeconomic value of biodiversity that underpins ecosystem services is essential for adoption of biodiversity-based management practices. There are several ways of addressing this, including farmer-scientist participatory research. On-farm participatory approaches combine an understanding of biodiversity and its services with cultural practices and economic behaviour of land users. Most work on the relationship between diversity and ecosystem functioning is carried out at small spatial scales and is concerned mostly with species diversity within ecosystems. At the landscape level, materials and energy flow across ecosystems and this flow maintains essential ecosystem functions. A major challenge in Focus 2 is therefore to extend studies concerned with the role of biodiversity in ecosystem functioning from small spatial scales to large spatial scales, and to integrate biological and social science research across these diverse scales.

### SPECIFIC TASKS FOR FOCUS 2 ARE :

**Task 2.1.** Understand social and economic value of ecosystem services provided by biodiversity in agricultural landscapes, and study options provided by biodiversity for alternative management regimes

Three different types of economic value of ecosystem services can be distinguished: direct use, indirect use, and non-use (or existence) values. Biological resources have use value to people either directly through their consumption and generation of income, or indirectly through the ecological services they provide. Direct use values include food, fiber, fuel, biochemicals, genetic material, and medicinal and other pharmaceutical products. The value of aesthetic and recreational experiences also falls in this category. Indirect use values of agrobiodiversity include the value of ecosystem services that support agriculture (e.g., nutrient cycling). Other more subtle values include the value of knowing that biodiversity exists now and for future generations. The quantification of the value of biodiversity in agricultural landscapes is difficult, as many sets of uses by different social groups must be considered, yet this is essential for assessing the potential benefits of biodiversity in alternative uses.

Since farmers are the managers of natural resources in an agroecosystem context, the challenge is to build on their experience and innovation to conserve biodiversity for the provision of valuable services and goods to society. Farmer participation with scientific researchers offers the opportunity to test the mechanistic processes by which biodiversity affects ecosystem function in real-world agroecosystems under the environmental regimes to which organisms have been selected, and in the context of actual socioeconomic constraints that affect farmers' decision making. Anthropology and economics help to understand how the choices that farmers make about conservation of biodiversity are affected by cultural, political, historical and current constraints, needs, and objectives. These choices may differ in the agroecosystems where the crops have

Box 2.1. *Flower insectary strips as pollen and nectar sources for beneficial insects in organic production in the Salinas Valley, California, USA. Photo source: E. Brennan.*

evolved historically through processes of human and natural selection vs. agroecosystems for which newly designed strategies for sustainable management are being created.

The adoption of biodiversity-based agricultural practices usually requires adaptive management, before the full value of a changeover can be assessed. Therefore, biodiversity management in agroecosystems must involve a learning process, which helps to adapt methodologies and practices to the ways in which these systems are being managed, with appropriate back-up by, and feedback from research. Once the value of a potential change in the stock of agrobiodiversity is identified, it is then possible to assess the costs and benefits of alternative land use and management options from a social point of view. This adaptive knowledge can help policy makers to make better informed decisions about how a desired level of biodiversity conservation can be achieved with limited financial, human and technical resources under specific social and cultural contexts (See Focus 3 and Box 2.2).

**Task 2.2.** Evaluate previous land use effects on biodiversity and ecosystem function, and thus ability to transition to new agricultural management options for increased sustainability

There is accumulating evidence that after a major change in land use, such as the conversion from grassland to cultivation, the agroecosystem is not well adapted to perform its 'new' function. This may be primarily due to at least partly irreversible processes that prevent restoration (hysteresis). Also, the direct and indirect linkages between aboveground and belowground ecosystems may hamper the effects of biodiversity restoration measures. Aboveground biodiversity is dominated by a few species of agricultural interest, yet the vast belowground biodiversity must also adapt following a cropping system change, and more so if soil cultivation is altered. Soil organisms of certain life-history strategies will not, or very slowly, colonize the new habitat or recover from the disturbance. Conversion from grassland to arable land leads to a sudden, drastic reduction in soil biodiversity, whereas recovery in the other direction, from arable land to grassland, is much slower or not demonstrable at all within several years after the change. Soil biodiversity is subject to considerable legacy effects, with potentially important effects on agroecosystem functioning in terms of incidence of pests and diseases and their biological control, and nutrient loss and retention.

A major change in management can result in economic problems during the transition period, e.g., initiation of organic management usually requires at least 5 years for soil fertility, soil structure and soil health to allow target productivity. The costs of transitioning to alternative practices are often site specific, and represent unknown risks and a deterrent for agriculturalists to make changes.

A better understanding of hysteresis and legacy effects will provide a more complete set of options for restoring biodiversity and its services, not only in agroecosystems but in ecosystems negatively impacted by agriculture. Wherever land use change in agriculture is desirable from a social point of view, options should be identified and evaluated to offset farmers´ temporary costs of transitioning against societal gain (see Focus 3).

*Box 2.2. Adaptive management is promoted when scientists and land users work together on research to facilitate the transition to alternative agricultural strategies. Shown is participatory sampling of soil macrofauna (TSBF methodology) in farming systems of Tanzania in the belowground biodiversity (BGBD) project of TSBF-CIAT (http://www.ciat.cgiar.org/tsbf_institute/csm_bgbd.htm). Photo source: G.G.Brown.*

### **Task 2.3.** Use biodiversity at different scales to support adaptation and resilience (e.g. tolerance, disease resistance, and risk mitigation) in agroecosystems

Agricultural scientists have typically relied on biodiversity for breeding improved cultivars and breeds, although there has been more recent attention on biodiversity for the functioning of food webs and nutrient cycling. Often research is conducted at small scales, and landscape-level functions of biodiversity are less understood. Social scientists mostly work at larger scales than most agricultural scientists, and the result is often a disconnect between research in the biological and social sciences.

At the genetic level, breeders rarely know the precise genetics of important traits for resistance to pests, diseases, and environmental stress, despite the wide adoption of crops and breeds with introgressed traits from wild relatives and other germplasm. Readily available genetic sequence information, and genetic and physical maps open a new perspective for providing agricultural goods and services via gene transfer for stress tolerance and disease resistance.

Combining genetic and ecophysiological approaches will clarify the mechanisms behind adaptation of landraces to stressful environments, or in response to inputs. This will also help explain why modern varieties bred in high-input conditions can have reduced performance in low-input environments. A better understanding is needed of the factors that determine the capacity for having positive interactions with soil-borne organisms and the ability to compete with weeds. Genetically heterogeneous populations such as landraces or mixtures can provide services such as pathogen reduction, and stabilize yields with lower pesticide inputs, yet the generality of these results and the ecological mechanisms are not yet clearly understood.

One avenue to increased resilience is that crop diversity may promote diversity in microbial and faunal populations, supporting stable changes in soil organic matter, and diversity in shoot and root herbivore organisms and

their predators. Decomposition and processing of organic matter inputs are affected by the diversity of soil organisms, and the outcome is important for the stabilization of organic matter, which is considered a key aspect of sustainable soil management. More diverse plant communities, such as agro forestry systems, may decrease the sensitivity of crops to pests, and alter the availability of resources such as water and nutrients for crop uptake, but mechanisms again are not well-understood.

At the landscape level, agricultural services derived from biodiversity in wildland ecosystems include, for example, pollination and pest suppression by insects that traverse both agricultural and wildland habitats (see Box 2.1), and provision of high-quality water resources from hydrological corridors in which diverse vegetation removes excess nutrients and trap sediments. Landscape-level processes are now increasingly recognized as an important element for sustainable agriculture, and for the loss of wild species in agricultural landscapes with fragmented habitats. Understanding the role of biodiversity in supplying services across the boundaries between agricultural and non-agricultural ecosystems will help to develop strategies for agricultural zoning, preserves, and parks.

## ■ FOCUS 3 :

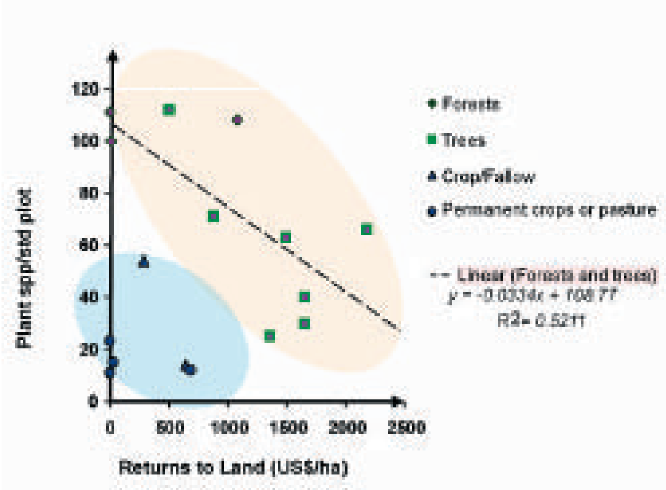
### Ensuring that society supports the use of biodiversity for sustainable agriculture and equitable sharing of the benefits of conservation of agrobiodiversity

Biodiversity in agricultural landscapes is strongly affected by the production and consumption decisions of people inside and outside those landscapes. These decisions are determined by economic signals such as the relative market prices of agricultural and other goods and services, and the transfers (e.g., taxes, subsidies aid flows) offered under various national and regional agricultural policies, and culturally driven behaviour. There is growing evidence that market prices for goods and services that depend on biodiversity in agricultural landscapes are below their true value or social opportunity cost, and that this has led to insufficient biodiversity conservation. There is also evidence that many agricultural policies merely exacerbate the problem. That is, far from internalizing the biodiversity externalities of agricultural production, many agricultural policies have driven a deeper wedge between the prices that people pay for foods and fibers, and the total costs to society for the production of these commodities, including the full ecological costs to society of biodiversity loss.

The change in biodiversity in agricultural landscapes varies greatly and according to the type of agricultural environment (e.g., highland vs. lowland) and type of farm (e.g., commercial vs. subsistence-oriented), and scale (e.g., corporate, industrial vs. family farm). Understanding the intertwined role of cultural (e.g., ethnicity, gender roles), economic (e.g., incentives offered by market prices and transfers), demographic and institutional factors behind changes in agrobiodiversity presents a major challenge. Social institutions, policies, property rights regimes, markets and policies are key factors to understanding these changes.

Changes in biodiversity in specific agricultural landscapes take place against the backdrop of the increasingly tight integration of the world's food production system.

*Box 3.1.*
*Tradeoffs between land use management, plant species richness, and profitability. Relationship between plant species richness (number of plant species per standard 40 m X 5 m plot) and returns to land (net present value) for forest-derived land use systems in benchmark areas in three tropical continents (Van Noordwijk et al. 2001). Tree-crop based systems are far richer in plant species than systems based on annual food crops. Yet, within these tree crop systems and forests, plant species richness is associated with lower returns to land. So, shifting from annual food crops or pasture to tree crops may lead to gains in environmental benefits as well as profitability. Within the tree crop systems, more intensively managed systems give higher returns to land, but lower plant species richness.*




The markets that drive local production decisions are world markets. The technologies adopted in individual countries are global technologies. One consequence of this, already noted, is that crop and livestock genetic diversity worldwide has been reduced as agriculturalists have abandoned traditional landraces and livestock breeds in favor of the global market leaders. Understanding this process and the implications it has for the correlation between risks across agricultural landscapes is a high priority.

What is driving biodiversity loss in agricultural landscapes? What implications does it have for human well-being? What may be done to assure the sustainable use of biodiversity and the equitable sharing of its benefits? Interdisciplinary research can identify the institutional, market, and policy reforms needed to induce agriculturalists and other users of agroecosystem goods and services to take account of the social costs of their actions. This requires a better understanding of the factors driving the private decisions made by producers and consumers and the social costs of biodiversity loss in agricultural landscapes. It also requires research into the trade offs between the provision of agricultural products and of other ecosystem goods and services both within and between agricultural landscapes.

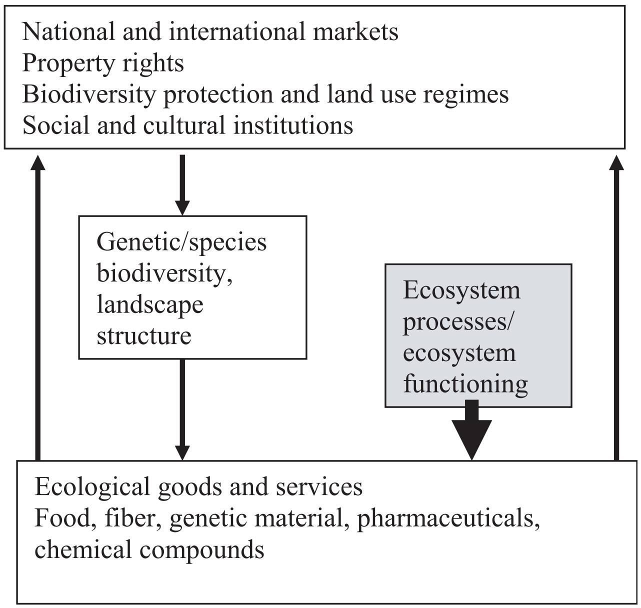
*Box 3.2.*
*Deforestation in the Brazilian rainforest.*
*From Brazil comes an illuminating example of possible pervasive effects of government failures: There is a general exemption from taxation of agricultural income and a de-facto land tenureship right for forest-land clearance for agriculture. This has provided strong incentives for agricultural encroachment into wildlands causing loss of wildland species.*

## SPECIFIC TASKS FOR FOCUS 3 ARE :

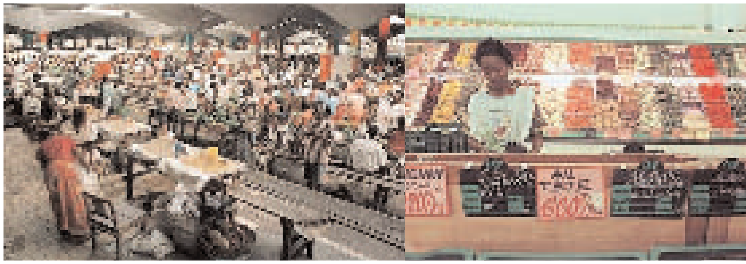
### **Task 3.1.** Assess and predict factors driving anthropogenic changes in biodiversity in agricultural landscapes

Of the many factors behind biodiversity change in agricultural landscapes the growth in demand for food, fuel, and fiber is pre-eminent. This is in part determined by increased human population pressure, and by changes in the distribution of population due to migration and differential rates of growth in urban and rural areas. Migration often responds to economic opportunities, but can also be a consequence of factors such as environmental degradation, poverty, political instability, and warfare. This task will explore the implications of demographic changes for the structure of demand for agricultural products and other services of agricultural landscapes, such as watershed protection, habitat provision, microclimatic stabilization etc. It will identify the consequences of expected changes in consumption growth per capita in different regions, and the increasing concentration of human populations in urban and peri-urban areas.

*Box 3.4. Direct and indirect effects of biodiversity loss on the production of goods and services.*




Growth in demand may be expected to change the relative prices of the outputs of agricultural landscapes, and hence the production choices by farmers. But agricultural market prices are often distorted – not just by market imperfections (e.g., by monopoly or oligopoly in agrobusiness), but also by institutional factors (e.g., weak governance institutions) or policy failures. Over-exploitation of socially valuable biodiversity due to agriculturalists' private decisions are said to be an external effect of agricultural markets that do not operate adequately, or that fail to allocate resources efficiently. For example, geneflow from agricultural to wild organisms is an externality generated by the use genetically engineered crops.



*Box 3.3. Rise of supermarkets in developing countries*
*Supermarkets in Africa, Asia, and Latin America are rapidly transforming the food retail sector (Weatherspoon and Reardon 2003). Supermarket procurement systems will mean changes in crop biodiversity, livelihoods of small producers, and urban markets. Photo source: Africaphotos.com http://africaphotos.com/*

In some cases, the lack of secure land tenure contracts, missing or largely imperfect credit, and food and labor markets can induce agriculturalists to make decisions that overexploit biodiversity.

This task will identify key market, institutional and policy failures in market prices and transfers that affect biodiversity in agricultural landscapes. It will then seek to understand the relationship between changes in relative prices, land use and biodiversity, in order to predict the biodiversity implications of both changes in demand at global and sub-global levels, and the use of corrective economic incentives based on sound policy and institutional conditions. In addition, farmers' responses to different types of risks associated with increased involvement in new agricultural markets for

*Box 3.5 Economic incentive measures for agrobiodiversity use and conservation (Emerton 2000).*

| | Direct incentives | Indirect incentives | Disincentives |
|---|---|---|---|
| Property rights | **Examples:** Ownership, management, access, and use rights over biodiversity. Joint, collaborative and co-management of biodiversity. Leases, concessions, licences, permits and franchises to manage, use, harvest and prospect biological resources. | | **Examples:** Exclusion, alienation from land and biodiversity. Enforcement and penalties for unsustainable or illegal biodiversity use. |
| Markets and charge systems | **Examples:** Improvement of existing biodiversity markets and prices., development of new biodiversity markets and charges – tourist levies, entrance fees, user fees, prospecting fees, royalties. Tradable quotas, permits, rights and licenses. | **Examples:** Development of alternatives to biodiversity markets and products. Eco-labelling and accreditation of sustainable biodiversity products. | **Examples:** Bans on biodiversity-impacting products or markets. Biodiversity impacting product quotas or limits. |
| Fiscal instruments | **Examples:** Subsidies to biodiversity conserving activities, technologies and products. Tax relief or differential taxes on land uses, technologies and products. Credits and offsets for biodiversity conserving activities. | | **Examples:** Biodiversity-impacting product taxes or surcharges. Differential land use, technology and product taxes. |
| Bonds and deposits | | | **Examples:** Security deposits, restoration bonds, assurance bonds, conditional resource security |
| Livelihood support | **Examples:** Improving efficiency, scope and sustainability of biodiversity utilisation. | **Examples:** Rural development, livelihood diversification and improvement, away from biodiversity. | |

inputs (e.g., energy, seed, and chemicals) and portfolio outputs must be assessed. Local culture affecting resource use practices and incentives to conserve different elements of biodiversity will be considered and factored in. Models must be developed to estimate and predict the consequences for biodiversity in specific agricultural landscapes of changes in the demographic and economic drivers of land use.

### Task 3.2. Evaluate the social cost of biodiversity loss in agricultural landscapes

This task will assess the cost of biodiversity loss in agricultural landscapes in terms of (a) changes in ecosystem services, (b) changes in agricultural outputs, (c) changes in other values attached to those landscapes. There are a number of methodologies available to estimate the value of biodiversity in providing the ecological regulatory, support and provisioning services implied by (a) and (b). These are generally variants of production function valuation methodologies, and will be used in this task to infer a value for biodiversity loss in agricultural landscapes from the role of biodiversity-supported ecosystem services in the production and consumption of marketed goods and services. Different methodologies are required to estimate non-use values. These variants of direct elicitation methodologies will be used to estimate the value of biodiversity that is not directly or indirectly used in the production of goods and services.

The reciprocal effects of agrobiodiversity on agricultural production and biodiversity conservation policies may be summarized relatively simply (Box 3.5). While the direct connections between market failures, loss of biodiversity,

*Box 3.6. Innovative approaches and locations for crop production include roof tops of urban buildings. Green or living roofs in urban areas could become important for future crop production, especially for local consumption of vegetables, as well as habitat for native bees, birds, and plant species. Roof design is geared toward reducing contamination of storm water drainage with nutrients and other contaminants. Shown is the design for the green roof of the California Academy of Sciences in San Francisco, California, USA, now under construction.*
Photo Sources: PG&E/USGS and California Academy of Sciences.

and the production of food and fiber are reasonably well-understood, the indirect connections through ecosystem process and functioning are not.

The values to be estimated range from localized economic outcomes for the agricultural producer, including effects on agricultural yields, human health and nutrition, to out-sourced effects such as the conservation of biodiversity with future economic potential and the welfare derived by people from knowing that biodiversity is conserved. For example, most modern crop varieties and many livestock strains contain genetic material incorporated from wild relatives, or from crops and livestock still used by traditional agriculture. At least half of the increase in agricultural productivity in the last century has been attributed to artificial selection, recombination, and gene transfer procedures. The value of wild relatives can be partially derived from the value of the crop varieties they have supported. Similarly, while breeding programs currently use only a small amount of the genetic resources that are conserved *ex situ* and *in situ*, future technologies may increase the value of these resources. Gene transfer both within species and between unrelated species increases the flexible use of genetic resources, and therefore the derived value of those resources, but also hold potential risks. For techniques that involve genetic engineering, cultural and spiritual issues also influence social perceptions about the value of introducing these genotypes into different types of agricultural landscapes.

The production function valuation methodologies require a collaborative approach between ecologists and social scientists to accurately identify the role of biodiversity in supporting the goods and services that people are willing to buy (see Focus 2). Predictive, mechanistic models need to be developed for the feedbacks between human behavior and changes in the production of goods and services in agriculture through changes in agrobiodiversity. The same models will subsequently be used to evaluate the biodiversity impacts of current policies, institutions, and social conditions, and to help design alternative policies for the sustainable use and conservation of agrobiodiversity and the equitable sharing of its benefits.

### **Task 3.3.** Assure the sustainable use of biodiversity in agricultural landscapes and the equitable sharing of its benefits

Land users' private decisions affect on-farm biodiversity, especially crop and livestock diversity, soil biodiversity, and insect populations, but also the off-farm elements of agricultural landscapes, such as natural remnants, protected areas, and watersheds. Generally, management of agroecosystems reflects the private rate of return on alternative uses, and this may be correlated negatively with biodiversity in agricultural landscapes, especially those where intensive agriculture occurs.

Short-term financial returns, however, do not reflect all the total benefits of biodiversity conservation. For instance, the market or financial rate of return from using biodiversity-rich farming systems may be lower relative to other crops, but the real economic return can be understated if positive environmental outcomes are not considered, e.g., mitigation of pesticide use or erosion. When markets do not reflect the real cost of such effects, markets are said to fail and become a primary cause of biodiversity loss in agriculture. Furthermore, misguided environmental and economic policies (e.g., subsidies for capital intensification in farming) can have pervasive effects

*Box 3.7. Complexity of the agricultural landscape in the Hill Lands of Sri Lanka near Kandy, and impacts on human livelihoods.The land use of the upper slopes is dominated by illegal cultivation of tobacco by poor farmers displaced by large water reservoirs in the valleys. Deforestation is rife. The consequence to the steep upper lands is severe erosion, run-off, and nutrient losses. However, these losses are trapped by rice paddies on the lower slopes, enabling a massive expansion in rice production and dry season vegetables on terraces. Often it is the very same farmers who lose sediments from the upper parts of the landscape and harvest them lower down for productive purposes. Nearby, a third land utilization type is the Kandy Home Gardens, a multi-story, agroforestry system, which is both extremely diverse and productive. The loss of forest biodiversity and the trade-offs made at the landscape level by farmers gaining a livelihood have major implications for sustainability and the re-fashioning of complex land use systems (Clark et al. 1998). Photo Source: M. Stocking.*

on agrobiodiversity by reinforcing the negative role of market failures. This occurs because agriculturalists react strongly to market and policy forces. For instance, poor and vulnerable producers may have no choice but to overexploit biodiversity in the short-term, given sudden increases in the financial profitability from more intensive land use options. Furthermore, this is exacerbated when people in extreme poverty discount potential declines in future welfare as immediate survival becomes the most important objective.

Article 11 of the Convention on Biological Diversity calls for contracting parties to "adopt economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity." Institutions can create, deliver and monitor better incentives to promote the sustainable use and conservation of biodiversity in agroecosystems, that otherwise would not be provided through farmers' private incentives, at various governance levels. Incentives need to be cost-effective and socially acceptable in order to encourage longer term investment in agrobiodiversity conservation, and reconcile other objectives related to agricultural growth, food security and farmers' livelihood systems. An incentive for biodiversity conservation can be defined as[10]: "A specific inducement designed and implemented to influence government bodies, business, non-governmental organisations, or local people to conserve biological diversity or to use its components in a sustainable manner. Incentive measures usually take the form of a new policy, law or economic or social programme."

At national and regional levels, biodiversity and its services may be enhanced by the establishment of: (i) property rights, such as land development rights and zoning that allow the use and control of the various components of biodiversity, (ii) market measures that encourage benefit sharing systems that are socially acceptable by local biodiversity users (iii) the use of subsidies and taxes, (iv) design of bonds and deposits systems to provide liability when land use activities can negatively impact agrobiodiversity, and (v) livelihood support systems that enable producers to conserve on-farm biodiversity, for instance by providing loans for soil conservation investments to increase services derived from soil biodiversity. A combination of such measures along with direct protection constitutes a biodiversity conservation strategy.

The research problem this creates lies in the fact that the effectiveness of different strategies can be quite location specific. Direct incentives can encourage the conservation of the flow of ecosystem services provided by agrobiodiversity (e.g., compensation payments for organic farming, wildlife friendly farming, or more generally payments for environmental services). Indirect incentives which generate general enabling conditions, such as land use rights, can alter the economic behavior of agriculturalists towards greater conservation. Alternatively, disincentives can be devised to penalize land users for certain types of behavior that favor agrobiodiversity degradation. The task will evaluate the cost effectiveness of alternative strategies for internalizing the biodiversity externalities of agriculture and, using case studies, will identify the sensitivity of choice of strategy to local institutional, economic, political, and cultural conditions.



*[10] This is the definition of incentives for biodiversity conservation used by the Convention on Biological Diversity (UNEP/CBD/COP/3/24). The CBD calls for "adopting economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity (Art. 11, CDB 1992).*

# IMPLEMENTATION STRATEGY

# IV

agroBIODIVERSITY activities will implement the Science Plan through interdisciplinary and international activities coordinated by an International Project Office (IPO). The key deliverables will include scientific reviews, research networks, case studies and new ways of modeling and synthesizing information. It is anticipated that more activities will emerge, for example, agenda-setting workshops, networks of scientists, and proposals for research.

## INITIAL TIMETABLE OF ACTIVITIES FOR AGROBIODIVERSITY

### ■ FOCUS 1 :

Determining the factors that increase biodiversity in agricultural landscapes and anticipating the impacts of social and environmental change (bioDISCOVERY)

| | Phase 1 years 0-2 | Phase 2 years 3-5 | Phase 3 years 6-10 |
|---|---|---|---|
| **Task 1.1** Monitor agrobiodiversity with standards that address genetic, ecological, anthropological and economic issues to create frameworks for data acquisition and analysis | | | |
| • Review existing literature on agrobiodiversity indicators | ------------- | ------------- | |
| • Hold workshop for use of databases and quantitative analysis of agrobiodiversity (with Core Project 1) | ------------- | ------------- | |
| **Task 1.2.** At the level of genetic and population diversity, evaluate genetic resources to increase agricultural productivity and other aspects of human well-being, especially in relation to contemporary land use changes | | | |
| • Review case studies on dynamics of gene pools for crops and livestock, and wild relatives | ------------- | | |
| • Analyze population diversity in noncommodity biota in agricultural landscapes | ------------- | ------------- | |
| • Conduct research linking genetic and population diversity with ecosystem services (with Focus 2) | | ------------- | ------------- |
| **Task 1.3.** At the level of communities and ecosystems, understand the biodiversity that is available for sustainable agriculture, now and in the future | | | |
| • Review levels of biodiversity in agroecosystems across land use gradients | ------------- | | |
| • Establish international research to examine factors that promote the use of biodiversity for sustainable agriculture (see Focus 2 and 3) | | ------------- | ------------- |
| **Task 1.4.** Target populations, species and ecosystems that most strongly need conservation, and aid their survival in changing environments by using our understanding of evolutionary, ecological, and economic processes | | | |
| • Hold workshop to develop guidelines and predictive models based on information and theory | | ------------- | |

### ■ FOCUS 2 :

Using biodiversity in agricultural landscapes to enhance the provisioning of ecosystem goods and services (ecoSERVICES)

| | Phase 1 years 0-2 | Phase 2 years 3-5 | Phase 3 years 6-10 |
|---|---|---|---|
| **Task 2.1.** Understand social and economic value of ecosystem services provided by biodiversity in agricultural landscapes, and options provided by biodiversity for alternative management regimes | | | |
| • Develop strategies to obtain total economic value of biodiversity in agricultural landscapes | ------------- | | |
| • Hold workshops to better understand adaptive management to utilize agrobiodiversity | | ------------- | |

| | | | |
|---|---|---|---|
| **Task 2.2** Evaluate previous land use effects on biodiversity and function, and thus ability to transition to new agricultural management options for increased sustainability | | | |
| • Explore legacy effects especially regarding soil biodiversity and provisioning services | | ------------- | ------------- |
| **Task 2.3.** Use biodiversity at different scales to support adaptation and resilience (e.g. tolerance, disease resistance, and risk mitigation) in agroecosystems | | | |
| • Review literature and case studies | ------------- | | |
| • Establish international research to examine factors that promote the use of biodiversity for sustainable agriculture (with Focus 1 and 3) | | ------------- | ------------- |

## ■ FOCUS 3 :

Ensuring that society supports the use of biodiversity for sustainable agriculture and equitable sharing of the benefits of conservation of agrobiodiversity (bioSUSTAINABILITY)

| | | | |
|---|---|---|---|
| **Task 3.1.** Assess and predict factors driving anthropogenic changes in biodiversity in agricultural landscapes | | | |
| • Review relationships between changes in relative prices, land use, and biodiversity | ------------- | | |
| • Develop models to predict global implications of utilization of biodiversity in agriculture, and effects of corrective economic incentives | | ------------- | |
| **Task 3.2.** Evaluate the social opportunity cost of biodiversity loss in agricultural landscapes | | | |
| • Evaluate strategies for joint valuation of agrobiodiversity between ecologists and social scientists to accurately identify use values, and socioeconomic outcomes (with Focus 2) | ------------- | ------------- | |
| • Develop predictive models for the feedbacks between human behavior and changes in the production of goods and services in agriculture through changes in agrobiodiversity | | | ------------- |
| • Hold workshops to present research on evaluating social opportunity costs | | | ------------- |
| **Task 3.3.** Assure the sustainable use of biodiversity in agricultural landscapes and the equitable sharing of its benefits | | | |
| • Review the cost effectiveness of alternative strategies for internalizing the biodiversity externalities of agriculture | ------------ | ------------- | |
| • Identify the sensitivity of choice of strategy for agrobiodiversity utilization to local institutional, economic, political, and cultural conditions | | ------------- | |
| • Establish international research to examine factors that promote the use of biodiversity for sustainable agriculture (with Focus 2 and 3) | ------------- | ------------- | ------------- |

## DIALOGUE AND CAPACITY BUILDING

| | | | |
|---|---|---|---|
| **IPO establishment** | ------------- | | |
| **Provide scientific syntheses and recommendations for the CBD** | ------------- | ------------- | ------------- |

## getting started

Several activities have already been initiated, and are proposed in the initial timetable during Phase I of the project (see timetable above; Year 0-2). An IPO will be established, and a scientific committee will be formed. Research projects identified in Tasks 1.3, 2.3, and 3.3 will cross-cut the three core project areas of DIVERSITAS insofar as possible. For Phase II (Years 3-5), delivery of the first short-term and medium-term results will occur, and Phase III (Years 6-10) will focus on synthesis and publications.

## Immediate Activites for agroBIODIVERSITY

| Task | Activity | Dates/Locations |
|---|---|---|
| Tasks 1.3, 2.3, 3.3 | Workshop to address research priorities for international project on agrobiodiversity and sustainable agriculture | November 2005, Oaxaca, Mexico |
| Tasks 1.1, 2.1, 3.1 | Symposium on biodiversity in agricultural landscapes at the DIVERSITAS Open Science Conference | November 2005, Oaxaca, Mexico |
| Tasks 1.1, 2.1, 3.1 | Review articles for a special issue of *Agriculture,Ecosystems and Environment* on biodiversity in agricultural landscapes | January 2006 |
| Other | Establishing International Project Office | |

## Management Structure and Execution

The work of agroBIODIVERSITY is guided by a Scientific Committee (SC) comprising scientists who demonstrate expertise in the various research areas of the three Foci. This Committee will be appointed by the DIVERSITAS Scientific Committee. Duties of the SC-agroBIODIVERSITY include:

- Provide scientific guidance and oversee the development, planning, and implementation of agroBIODIVERSITY
- Encourage national governments and funding agencies to support research at the national, regional, and international levels, relevant to the overall goals of agroBIODIVERSITY
- Seek collaboration with the DIVERSITAS Core Projects (bioDISCOVERY, ecoSERVICES, bioSUSTAINABILITY) and with other international programs
- Take on responsibilities within the work program of agroBIODIVERSITY

## International Project Office (IPO)

agroBIODIVERSITY will be supported by an IPO which will be responsible for raising funds for proposed activities, organizing these activities, and seeking involvement from the wider scientific community. The IPO will also work to establish links with relevant international programs. In addition, it will communicate results of activities through various media including the website.

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## Partnerships

The activities carried out by agroBIODIVERSITY will be carried out in close partnership with those of the three core projects of DIVERSITAS, bioDISCOVERY, ecoSERVICES and bioSUSTAINABILITY. agroBIODIVERSITY will interact with a number of international organizations, such as the International Plant Genetic Resources Institute (**IPGRI)**, the **CIRAD** (Centre de coopération Internationale en Recherche Agronomique pour le Développement), the Food and Agricultural Organization of the United Nations (**FAO**), and the UNESCO Man and the Biosphere (**MAB**) programme.

agroBIODIVERSITY anticipates opportunities for contribution to the relevant international conventions, such as the Convention on Biological Diversity (**CBD**), and assessments, such as the ongoing International Assessment of Agricultural Science and Technology for Development (**IAASTD**).

## Getting involved

As outlined in the inside back cover of this publication, there are many ways to participate in DIVERSITAS—as an individual scientist, by establishing a National Committee, or as a funder.

The DIVERSITAS International Secretariat, and the agroBIODIVERSITY community encourage scientists to propose additional activities that support the goals of this Science Plan including:

- Proposals for collaborative research;
- Workshops;
- Syntheses.

agroBIODIVERSITY also welcomes requests for endorsement of activities that embrace its goals. Such proposals should be submitted to the DIVERSITAS Secretariat in the early planning stages of the event or initiative.

# CONCLUDING REMARKS

# V

The agroBIODIVERSITY Science Plan focuses on utilization and conservation of biodiversity as agriculturalists and social institutions strive to meet the demands for increased sustainability (productivity, environmental quality, and human well-being) that are needed to support the growing global human population. Biodiversity loss in the world's agricultural landscapes requires immediate attention for the following reasons:

■ 1 : The under-utilization of the vast majority of species holds the promise of innovations in food, fiber, and fuel production and, hence, calls for a halt to the current mass extinction of species. In other words, biodiversity is not simply a threat to agriculture, it is also a key to its sustainability.

■ 2 : The over-utilization of just a few species (genotypes) in agriculture calls for diversification to stop massive production failures and pesticide inputs, toxicological effects on non-target biota, and the risks for human health. In other words, biodiversity-rich agriculture is not simply a threat to wildland biodiversity, it also can increase the chances of its survival.

■ 3 : The failure to recognize the important role of biodiversity in agricultural landscapes means that insufficient attention has been paid to the risks associated with the loss of important ecosystem services. In other words, biodiversity in agricultural landscapes provides numerous services that increase the ability of the Earth's biota, including humans, to respond successfully to climate and other anthropogenic environmental change.

To address these issues, we describe an approach whereby scientists from different disciplinary backgrounds work together, with knowledge inputs from agricultural producers, towards a truly integrative biodiversity science. Integrating formal and informal knowledge and jointly setting the research agenda will help to find a socially optimal solution where agricultural, environmental, and social trade offs are explicitly accounted for. This will not allow the total preservation of biodiversity, nor the escalation of intensive agricultural production, but may lead to realistic and sustainable options.

The tasks in this Science Plan will improve the understanding and integration of biological and socioeconomic proses that will support the Earth's life support systems during our current period of rapid environmental change. Strong efforts are being made to resolve the dichotomy between agriculture and conservation biology. The knowledge achieved by innovative interdisciplinary approaches will serve as guidelines for policy makers for appropriate solutions for managing biodiversity and its services in agricultural landscapes.

This research agenda of agroBIODIVERSITY is motivated by the desire to bridge traditional disciplines and crosscut the three core projects of DIVERSITAS (bioDISCOVERY, ecoSERVICES, bioSUSTAINABILITY) to utilize and conserve biodiversity for human well-being. International collaborations will achieve this goal, ensuring that biodiversity in agricultural landscapes is better understood and more widely used in a diverse set of communities around the world.

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# APPENDIX : AGRICULTURAL PRIORITIES FOR BIODIVERSITY-CONSERVATION

VII

## INTERNATIONAL TREATIES

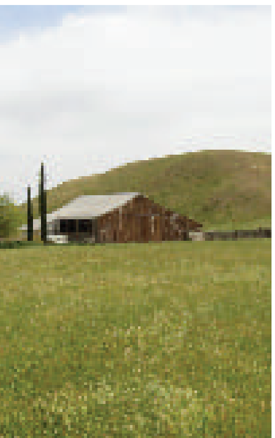
Three major international treaties are directly concerned with the conservation and sustainable use of biological diversity in an agricultural context.

1 : **The Convention on Biological Diversity (CBD)** which entered into force on 29 December 1993, and which has been ratified by 168 countries (June 2004). Its three main objectives are:

- the conservation of biological diversity
- the sustainable use of its components, and
- the fair and equitable sharing of the benefits arising out of the utilization of genetic resources

One of the thematic programmes of the Conference of the Parties to the Convention is on Agricultural Biodiversity which was the subject of Decision III/11 'Conservation and sustainable use of agricultural biological diversity' and subsequent Decisions IV/6, V/5, VI/5 and VII/3. The work programme focuses on:

- assessing the status and trends of the world's agricultural biodiversity and of their underlying causes, as well as of local knowledge of its management.
- identifying and promoting adaptive-management practices, technologies, policies and incentives.
- building capacity to strengthen the capacities of farmers, indigenous and local communities and other stakeholders to manage agricultural biodiversity sustainably
- supporting the development of national plans or strategies for the conservation and sustainable use of agricultural biodiversity



Within the agricultural work programme, cross-cutting initiatives include the International Initiative for the Conservation and Sustainable Use of Pollinators and an International Initiative for the Conservation and Sustainable Use of Soil Biodiversity. The programme also studies the impacts of trade liberalization on agricultural biodiversity.

In addition, a number of other items on the COP's agenda address key cross-cutting issues of relevance to all thematic areas. Those of particular concern for agricultural biodiversity are:

- access to Genetic Resources and Benefit-sharing, Traditional Knowledge, Innovations and Practices and Sustainable Use of Biodiversity. Decision VII/9 on access and benefit-sharing as related to genetic resources adopted at the seventh meeting of the Conference of the Parties addresses, amongst other issues, the Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of Benefits Arising out of their Utilization.
- capacity-building for access and benefit-sharing.
- the negotiation of an international regime on access to genetic resources and benefit sharing.
- the development of a programme by FAO and IPGRI with other agencies on biodiversity and nutrition

In April 2002, the Conference of the Parties to the CBD agreed on a Global Strategy for Plant Conservation, whose ultimate objective is to halt the loss of biological diversity. This includes a number of time-bound quantitative targets relevant to conservation and sustainable use of agricultural biodiversity, notably:

**(i)** Development of models with protocols for plant conservation and sustainable use, based on research and practical experience

**(ii)** At least 30 per cent of production lands managed consistently with the conservation of plant diversity;

**(iii)** 70 per cent of genetic diversity of crops and other major socio-economically valuable species conserved, and associated indigenous and local knowledge maintained;

**(iv)** 30 per cent of plant-based products derived from sources that are sustainably managed.

2 : **The Global Plan of Action (GPA) for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture,** agreed on, at the International Technical Conference on Plant Genetic Resources held in Leipzig, 17–23 June 1996, sets out a global strategy for the conservation and sustainable use of plant genetic resources for food and agriculture with an emphasis on productivity, sustainability. It has 20 priority activity areas arranged in four main groups:

- *In situ* conservation and development
- Supporting on-farm management and improvement of plant genetic resources
- Assisting farmers in disaster situations to restore agricultural systems
- Promoting *in situ* conservation of wild crop relatives and wild plants in food production

The Global Plan of Action covers a number of multidisciplinary areas such as *in situ* conservation of wild plants and crop relatives in natural ecosystems that extend the traditional activities of sustainable agriculture and plant genetic resource conservation and whose successful implementation will require the development of new partnerships with a range of intergovernmental and non-governmental organizations as well as with indigenous and local communities.

## 3 : **The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)** which entered into force on 29 June 2004.

Through the Treaty, countries agree to establish an efficient, effective and transparent Multilateral System to facilitate access to plant genetic resources for food and agriculture, and to share the benefits in a fair and equitable way. The Multilateral System applies to over 64 major crops and forages. Relevant activities include:

- Article 5 – Conservation, Exploration, Collection, Characterization, Evaluation and Documentation of Plant Genetic Resources for Food and Agriculture:

**(a)** Survey and inventory plant genetic resources for food and agriculture, taking into account the status and degree of variation in existing populations, including those that are of potential use and, as feasible, assess any threats to them;

**(b)** Promote the collection of plant genetic resources for food and agriculture and relevant associated information on those plant genetic resources that are under threat or are of potential use;

**(c)** Promote or support, as appropriate, farmers and local communities' efforts to manage and conserve on-farm their plant genetic resources for food and agriculture;

**(d)** Promote *in situ* conservation of wild crop relatives and wild plants for food production, including in protected areas, by supporting, *inter alia*, the efforts of indigenous and local communities;

**(e)** Cooperate to promote the development of an efficient and sustainable system of *ex situ* conservation, giving due attention to the need for adequate documentation, characterization, regeneration and evaluation, and promote the development and transfer of appropriate technologies for this purpose with a view to improving the sustainable use of plant genetic resources for food and agriculture;

**(f)** Monitor the maintenance of the viability, degree of variation, and the genetic integrity of collections of plant genetic resources for food and agriculture.

- Article 6 – Sustainable Use of Plant Genetic Resources

This may include:

**(a)** pursuing fair agricultural policies that promote, as appropriate, the development and maintenance of diverse farming systems that enhance the sustainable use of agricultural biological diversity and other natural resources;

**(b)** strengthening research which enhances and conserves biological diversity by maximizing intra- and inter-specific variation for the benefit of farmers, especially those who generate and use their own varieties and apply ecological principles in maintaining soil fertility and in combating diseases, weeds and pests;

**(c)** promoting, as appropriate, plant breeding efforts which, with the participation of farmers, particularly in developing countries, strengthen the capacity to develop varieties particularly adapted to social, economic and ecological conditions, including in marginal areas;

**(d)** broadening the genetic base of crops and increasing the range of genetic diversity available to farmers;

**(e)** promoting, as appropriate, the expanded use of local and locally adapted crops, varieties and underutilized species;

**(f)** supporting, as appropriate, the wider use of diversity of varieties and species in on farm management, conservation and sustainable use of crops and creating strong links to plant breeding and agricultural development in order to reduce crop vulnerability and genetic erosion, and promote increased world food production compatible with sustainable development; and

**(g)** reviewing, and, as appropriate, adjusting breeding strategies and regulations concerning variety release and seed distribution.

## INTERNATIONAL ORGANIZATIONS

**The Food and Agricultural Organization of the United Nations (FAO)** provides a global, neutral forum for debate and discussion of all issues related to food, agriculture, forestry and fisheries. FAO's goal is to alleviate poverty and hunger by promoting sustainable agricultural development, improved nutrition and food security, and the access of all people at all times to the food they need for an active and healthy life. It provides intergovernmental fora where biodiversity-related policy is discussed and relevant agreements negotiated and adopted by member countries. Examples of such agreements are the International Plant Protection Convention, the Code of Conduct for Responsible Fisheries and the International Treaty on Plant Genetic Resources (see above).

FAO assists in the implementation of the Global Plan of Action on Plant Genetic Resources and the Global Strategy on the Management of Farm Animal Genetic Resources, adopted by the Commission on Genetic Resources for Food and Agriculture (CGRFA) in 1998 by 160 countries. It manages a broad range of programmes and activities to enhance sustainable agricultural systems and management practices, for example the promotion of mixed agricultural systems such as rice-fish farming and agroforestry; participatory training for integrated pest management; advice on soil and water conservation; and technologies for use and maintenance of natural and low-input grasslands. FAO also addresses legal and economic aspects of agricultural biodiversity. It plays a leading role in support of the multiyear work programme in agricultural biodiversity of the CBD (see above).

**The International Plant Genetic Resources Institute (IPGRI)** seeks to advance the conservation and use of genetic diversity for the well being of present and future generations. It works to strengthen international collaboration, support the development of strong national genetic resources programme and to improve our knowledge and procedures for the conservation and use of genetic resources. Based in Rome with over 200 staff in over 15 offices worldwide, IPGRI carries out its research work through collaboration with institutes and genebanks throughout the world. It focuses on research that can support the implementation of such international agreements as the Global Plan of Action and the Global Strategy for Plant Conservation and provides direct inputs to the Commission on Plant Genetic Resources, the Secretariat of the CBD and other international bodies.

**The Ecosystem Conservation Group (ECG) ad hoc Working Group on *in situ* Conservation of Plant Genetic Resources.** The ECG was established in 1974 and brings together United Nations agencies such as UNESCO, UNEP, FAO, secretariats of biodiversity-related conventions and non-United Nations international institutions such as IPGRI and IUCN to advise its member organizations on the development and implementation of relevant ecosystems and genetic resources conservation activities and promote thematic joint programming. It established an ad hoc Working Group on *in situ* Conservation of Plant Genetic Resources which at its first meeting in 1986 reviewed on *in situ* conservation activities and needs, especially in the context of the FAO Commission on Plant Genetic Resources, the UNESCO Action Plan on Biosphere Reserves and the IUCN Bali Action Plan. Its work plan included the preparation of an information document on *in situ* conservation published in 1989.

The Man and the Biosphere (MAB) programme of the United Nations Educational Scientific and Cultural Organization (UNESCO) is focusing on new approaches for facilitating sustainable development, through promoting conservation and wise use of biodiversity. By taking advantage of the transdisciplinary and cross-cultural opportunities of UNESCO's mandate in the fields of education, science, culture and communication, MAB is promoting both scientific research and information gathering, as well as linking with traditional knowledge about resource use. It cooperates with a number of other agencies, including IPGRI which is helping it to integrate agricultural biodiversity concerns into the programme.

# ACKNOWLEDGMENTS

# VIII

The editors of the agroBIODIVERSITY Science Plan and Implementation Strategy would like to thank the people who have contributed their ideas and time to assemble this document, and in particular the members of the Scoping Committee, as well as reviewers and members of the DIVERSITAS Scientific Committee.

Special thanks are to Vernon Heywood, Toby Hodgkin, Anne-Marie Izac, and Stefano Padulosi for preparing side-bar boxes and the appendix for the Science Plan.

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In addition, the editors would like to thank the DIVERSITAS staff, especially Anne Larigauderie and Anne-Hélène Prieur-Richard for their enormous help and enthusiasm for the project. Funding for the development of the agroBIODIVERSITY Science Plan was provided by a grant from the US National Academy of Sciences and by DIVERSITAS through core funding originating from the following:

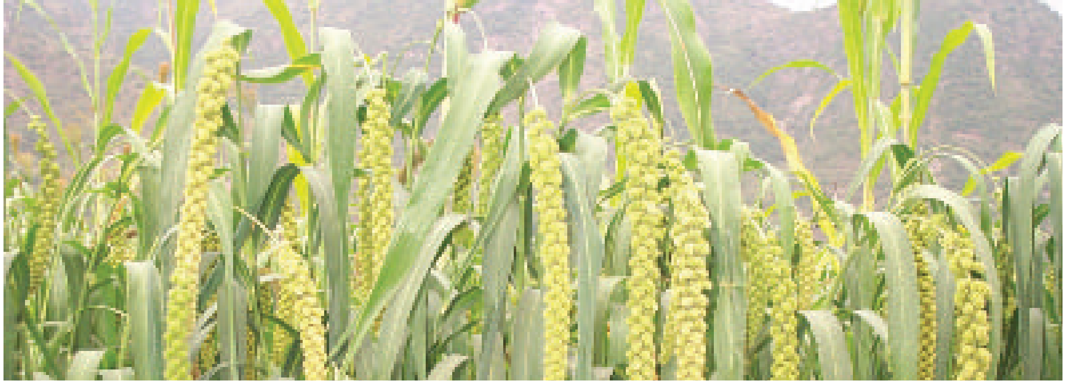
- German Federal Ministry of Education and Research (BMBF)
- German Research Foundation (DFG)
- French Ministry of Foreign Affaires (MAE)
- International Council for Science (ICSU)
- International Union of Biological Sciences (IUBS)
- International Union of Microbiological Societies (IUMS)
- National Council on Science and Technology (CONACYT), Mexico
- National Science Foundation (NSF), USA
- Natural Environment Research Council (NERC), UK
- Netherlands Organisation for Scientific Research (NWO)
- Research Council of Norway
- Royal Netherlands Society of Arts and Sciences (KNAW)
- Swedish Natural Science Research Council (NFR)
- Swiss National Science Foundation (SNF)

DIVERSITAS expresses its gratitude to all of the above organisations, as well as to the International Group of Funding Agencies for global change research (IGFA), for their help in securing these national contributions.

# LIST OF ACRONYMS

# IX

| | |
|---|---|
| CBD | Convention on Biological Diversity |
| CIRAD | Centre de coopération Internationale en Recherche Agronomique pour le Développement |
| ESSP | Earth System Science Partnership (DIVERSITAS, IGBP, IHDP, WCRP) |
| FAO | Food and Agriculture Organization of the United Nations |
| GCP | Global Carbon Project (DIVERSITAS, IGBP, IHDP, WCRP) |
| GECAFS | Global Environmental Change and Food Systems of ESSP |
| GISP | Global Invasive Species Programme (CAB International, DIVERSITAS, IUCN, SCOPE) |
| GMBA | Global Mountain Biodiversity Assessment (DIVERSITAS) |
| GWSP | Global Water System Project (DIVERSITAS, IGBP, IHDP, WCRP) |
| IAASTD | International Assessment of Agricultural Science and Technology for Development |
| ICSU | International Council for Science |
| IGBP | International Geosphere-Biosphere Programme |
| IGFA | International Group of Funding Agencies for Global Change Research |
| ITPGRFA | International Treaty on Plant Genetic Resources for Food and Agriculture |
| IHDP | International Human Dimensions Programme on Global Environmental Change |
| IUBS | International Union of Biological Sciences |
| IUMS | International Union of Microbiological Societies |
| IPGRI | International Plant Genetic Resources Institute |
| MEA | Millennium Ecosystem Assessment |
| SC | Scientific Committee |
| SCOPE | Scientific Committee on Problems of the Environment (ICSU) |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNESCO-MAB | Man And Biosphere programme of UNESCO |
| WCRP | World Climate Research Programme |



# PHOTOS AND ILLUSTRATIONS CREDITS

**Front cover :** Cover photographs were taken and kindly provided by Marc B. Schenker, M.D., from University of California at Davis, and are part of a collection at www.marcschenker.com website. Shown are horse-plowing in Chile, wheat harvesting in India, transplant production in Guatemala, and tractor cultivation in Chile.

**Page 1:Safflower (***Carthamus tinctorius***) flower,** IPGRI

**Page 4:** Corn diversity from Peru, Felipe Barrios Masias

**Page 6, 10, 38, and inside back cover:** Vegetables, Anne Larigauderie

**Page 10:** Tianzi Biodiversity Research and Development Center

**Page 2 and 11:** Millennium Ecosystem Assessment (2005)

**Page 14:** Field of mustard, Louise Jackson

**Page 15:** *Ashoka Trust for Research in Ecology and the Environment (ATREE)*, Kamal Bawa

**Page 17:** *Bacteria, nematode, fungi*, Peter de Ruiter; *Mexican milpa field*, Roberto Papa

**Page 18:**

<u>Bird on left :</u>
*Turdus torquatus (*Ring ouzel*)*, Weitze Janse;

<u>Bird on right :</u>
*Emberiza citrinella (*Yellowhammer*)*, Mark Caunt; Graph from DEFRA, UK.

**Page 19:** Strawberry cultivation in Sinai, Egypt, Anne Larigauderie

**Page 20:** *Chenopodium quinoa* (Andean grains; Fig A), W. Rojas; *Setaria italica* (Foxtail millet; Fig B), M.S. Swaminathan Research Foundation ; Andean scrublands (Fig C), L.C. Rodriguez.

**Page 22:** Celery and flowers in Salinas Valley, California, E. Brennan

**Page 23:** Adaptive management, TSBF-CIAT, G.G. Brown

**Page 25:** Supermarkets, Africasphotos.com

**Page 27:** California Academy of Sciences, PG&E/USGS

**Page 28:** Agricultural landscapes in Sri Lanka, Michael Stocking

**Page 29:** *Nolina durangensis*, Mexico, Anne-Hélène Prieur-Richard

**Page 32:** Sheep in Southern France , Jean-Michel Dreuillaux

**Page 35:** California poppies, barn, Louise Jackson

**Page 37:** Wild finger millet from the Kinari Forest, Kenya, IPGRI

**Page 40:** Millet (*Setaria italica*), China, IPGRI.

# GETTING INVOLVED...

The success of DIVERSITAS is directly related to the voluntary involvement of scientists and organisations from around the world. The following paragraphs briefly describe the primary means of contributing to this dynamic network of integrated biodiversity science. More detailed information is available in the Getting involved section of our web site: www.diversitas-international.org

## as a Scientist

DIVERSITAS invites individual scientists to make the Secretariat aware of their ongoing research and to suggest ways to integrate local and international initiatives. The DIVERSITAS Secretariat, as well as the Core Project and Cross-cutting Network offices, welcome proposals for collaborative activities (research projects, workshops, syntheses, etc.) that support the implementation of the DIVERSITAS Science Plan.

## as a National Committee

DIVERSITAS encourages the establishment of National Committees as a means of building a truly international network to support integrated biodiversity science. These Committees play an important role in linking national and international programmes, as well as interacting with policy makers and other stakeholders in their home countries.

## as a Funder

Funding DIVERSITAS initiatives provides an excellent opportunity for individuals and organisations to demonstrate a strong commitment to conservation and sustainable use of biodiversity—issues that often have strong appeal for their own stakeholders and audiences. DIVERSITAS welcomes the opportunity to collaborate with private industry, non-governmental/inter-governmental organizations, foundations and associations.

# OUR MISSION

**DIVERSITAS**
**is an international, non-governmental programme with a dual mission:**

- To promote an integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge.
- To provide the scientific basis for the conservation and sustainable use of biodiversity.

ICSU
IUBS
IUMS
SCOPE
UNESCO

**Through its Scientific Core Projects and Cross-Cutting Networks, DIVERSITAS encourages global investigation of three key aspects of biodiversity research :**

**bioDISCOVERY**
Assessing current levels of biodiversity; developing the scientific basis for monitoring and observation; understanding and predicting changes.

**ecoSERVICES**
Expanding biodiversity science to larger scales and over a greater breadth of the biological hierarchy; linking changes in ecosystem structure and functioning to changes in ecosystem services; assessing human responses to changes; examining the impacts of biodiversity change on human health.

**bioSUSTAINABILITY**
Developing new knowledge to guide policy and decision making that support sustainable use of biodiversity; evaluating the effectiveness of current conservation measures; studying the social, political and economic drivers of biodiversity loss, as well as social choice and decision making.

DIVERSITAS
an international programme
of biodiversity science

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