Agriculture

Integrating Conservation Biology and Agricultural Production

Executive Summary of International Workshops

Public Service Research and Dissemination Program
University of California, Davis
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Editors

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PREFACE

Agricultural scientists and conservation biologists need to communicate with each other. Often they have not because of differences in perspective and priorities, and because of conflicts, some perceived and some real. However, the two groups have many common fundamental goals; but these goals can be achieved only if those whose professional occupation is conservation of biological diversity and those who manage much of the world's land and water supply can reach consensus and a common means of communication. We believe this volume, and the workshops on which it is based, represent one of the first formal efforts to initiate the kind of communication needed between these two groups. We hope it proves to be a positive step towards more effective conservation of the world's biological diversity.

Differences in perspective arise from many causes. Farmers are most concerned about a relatively narrow range of species, the domesticated animals and plants they raise and harvest; conservation biologists are concerned with biological diversity. The agriculturist's time perspective tends to be the few generations it may take to modify a species to perform in a new environment or to produce a new product; the conservationist's is over evolutionary time. The farmer must produce a reasonable net return from crops and animals under current supply and demand constraints or risk losing land and a way of life; the conservation biologist faces no personal monetary consequence. Farmers feel that certain species, livestock predators for example, should be excluded from some regions to free agricultural production of this constraint; conservation biologists tend to argue for restoration and conservation of most pre-agricultural biota.

The common interests of the two groups include permanent maintenance of the planet's capacity to produce an abundant variety of high quality food and a diverse, aesthetically pleasing and healthy environment. Farmers have been effective, practicing conservationists for centuries while articulation of conservation issues is a recent event. Agriculture has been highly successful in increasing production efficiency, but at the expense of renewable resources. However, the desire to pass on to their children and grandchildren a farm at least as productive as the one they inherited is a deeply ingrained ethic among farm people throughout the world, today as in past generations. Similarly, conservation biologists wish to insure the existence of extensive biological diversity for future generations.

Conservation biologists and agriculturists have much to offer each other. The conservationist brings professional knowledge of ecology and evolution. Their perspectives on the interactions within biological systems, and on evolutionary processes constantly affecting organisms, can help identify or predict, and thus help avoid, threats to the stability of agriculture and other life support systems before the effects are evident to those not so trained.

Agriculturists have practical and scientific knowledge of how to manage soil, water, and other resources to produce food and fiber essential to a rapidly expanding human population. Their working knowledge of soil-plant-animal interactions and how to make things grow and reproduce can be invaluable to biological conservation projects, including restoration and relocation activities necessitated by human population expansion or global climate change.

These and many other areas of overlapping interests and complementary expertise argue for increasing communication between agriculturist and conservation biologists in the hope of developing methods for the conservation of resources critical to all. This summary of workshop discussion provides examples of both overlapping expertise and common interests and attempts to demonstrate that communication without conflict is not only possible but essential. Responsibility for the contents of this summary lies solely with the workshop chairman.

We are indebted to many individuals for the successful completion of this project. The participants at the two workshops gave unselfishly of their time and showed considerable patience in responding to the wishes of the workshop chairman. The work group chairpersons and rappatours are given special recognition for their diligence and creativity. Finally, the members of the advisory committee and the program staff provided guidance and support far beyond the normal call to duty.

Graham A.E. Gall
November, 1989

INTRODUCTION

Two workshops were organized to explore what might result from structured interaction among agricultural and conservation minded biologists and social scientists. In fact, the second workshop occurred as an outgrowth of the first; after four days, participants agreed that there was common ground and they needed an opportunity to explore it.

In some respects, preparation of this executive summary carries an element of risk. However, it is hoped that objectivity has been achieved and that statements found controversial will generate discussion and dialogue rather than outright rejection.

Since its beginning about ten thousand years ago, agriculture has spread steadily around the world to become the dominant form of land management on all continents. It has been estimated that human beings have co-opted about 40% of terrestrial biological productivity.

Until very recently, agricultural practice had not been a concern of biologists interested in conservation. However, the realization in the 1960's that agricultural activities were having a negative impact on wildlife resulted in conservation biologists adopting a very pessimistic view of agriculture. The result was antagonism between farmers and conservationists.

Clearly, the differences in perspectives and priorities of agriculture and conservation biology stem from many causes, some perceived, some real. But it is also abundantly clear that conservation biologists and agriculturists have much to offer each other and that dialogue between the two groups is long overdue.

Broad definitions of the two disciplines, agriculture and conservation biology, are adopted.

> **Agriculture, broadly speaking, is the practice of harvesting plants, animals, and microorganisms and modifying both the organisms and the systems in which they live in order to yield products and services.**

Conservation biology is the study of organisms and life processes and the development of strategies for maintaining biological diversity.

Commonality

Pressing issues concerning global biological resources demonstrate the not so widely recognized common ground for conservation biologists and agriculturists.

The continually increasing human population and global environmental changes are going to strain the limited earthly resources needed to sustain food and fiber production as well as the health and well being of all living things.

Agriculture has been highly successful in increasing production efficiency, but economic and social pressures have taxed available renewable resources.

To insure sustainability of agricultural systems, agriculture must strive to achieve a new balance between production methods and production efficiency.

The level of terrestrial, as well as aquatic, biological productivity dedicated to the support of human beings is steadily rising.

The survival of many of the species with which we share the earth is in jeopardy if population growth continues - or even if it remains at its present level.

The most obvious common ground for agriculturalists and conservation biologists is the very shrinking earth on which we all live.

Consensus

It is our belief that the workshops out of which this summary evolved represent one of the first formal efforts to initiate crucial discourse between agricultural and conservation biologists. It is our hope that this beginning will be a positive step toward more effective conservation of this world's abundance and rich variety.

Much research is needed in order to identify areas of potential interaction between agriculture and conservation biology. But even now it is clear that both groups have much to offer each other.

Because of increasing demands by a growing human population, conservation biologists recognize that parks and reserves will inevitably be too small to carry the full burden of efforts to preserve and maintain biological diversity.

> Ways could be found to design and exploit agricultural systems so that they provide habitats for species other than the target species.

Agriculture can play a unique role in conservation biology because of the scale at which conservation research could be carried out in agricultural systems. Cooperative use of private and public resources would make possible intensive studies on a scale much larger than that normally possible under research projects supported by scientific funding sources.

> Ways can be found to encourage interactive and disciplinary research on farming systems that will capitalize on the cooperative nature of agriculture.

The long-term viability of agriculture depends, in part, on its ability to respond to change, most particularly climate change caused by increases in atmospheric gases. Other changes are certain to come because of population growth, political and economic shifts, new energy strategies, or the completely unexpected and surprising.

> Conservation biology can strengthen the ability of agriculture to respond effectively to these changes by providing the conceptual and actual frameworks needed to develop new local, regional and global systems.

Section 1: Background

THEORY AND CONCEPTS

Differences in the theory and practice of agriculture and conservation biology can be examined in light of parallel differences between the "process-functional" and "population-community" approaches used in ecology. To begin, it is important to note some basic differences in the way agriculture and conservation biology describe the structure and dynamics of ecosystems.

Agriculture (especially as practiced in developed nations) is concerned with the economics of production of a particular commodity and is dependent on the manipulation and management of labor and material to optimize production quantity and quality. The emphasis on energy flow and the cycling of materials parallels the "process-functional" approach to describing ecosystem dynamics where energetics and biogeochemistry are the central focus of research.

Conservation Biology emphasizes communities as networks of populations subject to evolutionary forces and linked by such processes as competition, predation, and mutualism. This parallels the "population-community" approach in describing ecosystems.

> The divergence of the two approaches used to describe ecosystems arises in part from the difficulty of fully defining the complexity of systems.

Approaches

In an effort to reconcile the "process-functional" and the "population-community" approaches to ecosystem description, it has been suggested that the complexity of ecosystems can be represented as a "dual hierarchy" of organization. The argument is based on the notion that in trying to relate biotic and functional components, it is impossible to obtain a simple one-to-one "mapping" of one onto the other.

The difficulty of attempting to view a complex system within the unidimensional framework of a single observation set and the relevance of descriptions of "dual hierarchies" to a discussion of agriculture and conservation biology can best be illustrated by a hypothetical example.

> *To maximize productivity, a farmer adopts a "process-functional" approach by carefully monitoring and regulating the cycling of nutrients in a given agroecosystem. Crop yields respond nicely to the farmer's efforts.*
>
> *Reasoning that productivity could be increased even more by putting more land under cultivation, the farmer removes hedgerows and fence-lines that divide the fields, eliminating the habitat for a beneficial parasite of a nasty crop pest. With the parasites gone, the pest population explodes and productivity declines catastrophically despite all efforts by the farmer to maintain productivity.*
>
> *The farmer's agroecosystem is now responding to a new biotic constraint not considered in the original observation set.*

In this context, biological diversity provides what is called "functional redundancy" for a given agroecosystem.

> Functional redundancy occurs when a particular process is performed by more than one species of organism.

Implicit in the concept of functional redundancy is the idea that several species performing the same function buffer that process against effects of variation in population size for any one species in the functional group.

To illustrate this idea, we return to the hedgerow/parasite example.

Our farmer appreciates the importance of pest parasites in maintaining crop yield, and his observation set now includes some population parameters.

However, the farmer may care only that there is some sort of parasite in the fields, and not about the diversity of species within this functional group.

Discovering that maintenance of a number of different parasite species may enhance the stability of crop pest control causes the farmer to expand the population observation set even further because diversity within the parasite group has become relevant to the farmer's functional goal of increased crop yields.

Hence, parasite diversity itself has become important to the farmer.

At this point, it is important that agriculturists and conservation biologists understand the interrelationships their respective expertise.

> Conservation biological theory needs to be sensitive to the contrast between observation sets and the functional goals of agriculture. If possible, aspects of biotic diversity should be related to functional processes in agroecosystems.

> Agricultural practice needs to be responsive to maintaining or increasing biotic diversity even though in some cases increased diversity may not directly enhance agriculture's functional goals of increased yields or sustainability.

Biological Diversity

Measurements and perceptions of biological diversity in both conservation biology and agriculture depend on a complex interaction of observation sets with levels of organization that can span several temporal and spatial scales. A general characteristic of a diversity hierarchy is that it has a nested structure with lower levels of diversity aggregated to make up higher levels of diversity.

Diversity Within Species

Patterns of genetic diversity at the population level are often characterized by the way genetic variation is allocated among and within populations.

Some species maintain most of their diversity among local populations, the members of which are themselves quite homogeneous. In contrast, other species are characterized by large amounts of genetic variation within local populations and exhibit little differentiation among populations.

How genetic diversity is structured has obvious implications for efforts in both conservation biology and agriculture to preserve species-wide levels of genetic diversity. For example, to conserve much of the genetic variation in a self-fertilizing plant species, efforts should be concentrated on obtaining germplasm from as many different populations as possible as opposed to a large collection from a few populations.

Diversity Within Habitats

The number of species within a local habitat or agricultural field (the theoretician's idealized "point in space") is called alpha diversity. A large amount of theoretical and experimental work in ecology has focused on how alpha diversity can be maintained by mechanisms of competitive coexistence.

In biological communities, the component species tend to play distinct ecological roles, although certain sets of species in a community may nonetheless be quite similar from a functional point of view.

> *Consider grassland as an example. The plants, herbivores, and carnivores clearly fill distinct roles in natural systems. Yet within each of these levels in the food chain, the species composition also differs to varying degrees. Range managers, through proper grazing practices, promote complementary mixes of grasses and forage species to maintain cover on different micro-sites and in different seasons, thus providing a sustained and nutritionally balanced diet for livestock.*

The potential for non-equilibrial, competitive coexistence of species depends on factors that slow down rates of competitive displacement or exclusion. Species diversity within pastures or natural grasslands is increased by reducing competition for light by mowing or grazing. In conservation biology, it is becoming more generally recognized that certain rare or endangered plant species are poor competitors and may require specific types of disturbance (e.g., fire or gopher mounds) in order to persist.

Diversity Among Habitats

Rate of change in species composition resulting from the turnover of species as one moves along an environmental gradient, or among different communities in a landscape, is called between-habitat or beta diversity.

In natural communities, the rate at which species composition changes along a spatial dimension often reflects the intensity of a gradient for some important physical factor. In oak-woodland range in the foothills of California, there is a distinct change in the plant community as one moves from open grassland to areas under oak canopy.

In more intensive agricultural systems one might consider beta diversity as being represented by the crop species change occurring among different fields, although the spatial distribution of species in this system is obviously very artificial.

Landscape Diversity

Landscape or gamma diversity results from combining both the within-habitat (alpha) and between-habitat (beta) diversities contained within a region. At this level in the diversity hierarchy, it is easy to demonstrate why considerations of scale are so important in describing biological diversity.

A homogenization of both flora and fauna at regional levels by cosmopolitan, "weedy" species is a serious concern of conservation biologists and is even occurring on a continental and a global scale. Processes occurring at this landscape or "mesoscale" level are at present poorly understood because they occur at spatial and temporal scales that are usually not considered by ecologists.

Initially, according to the idea of functional redundancy, it was thought that greater diversity would act to stabilize community or ecosystem dynamics. Later work with model ecosystems suggested that as both the number of interacting components and the intensity of interaction among components increased, the stability of the system actually decreased.

There is little good evidence from either natural or agricultural systems that diversity per se promotes stability. It has been suggested that the way interacting species within a community are constrained by each other in a nested structure, and the relative strength of interactions among species, are more important determinants of stability than just species numbers.

Agricultural Sustainability

In an attempt to incorporate competing definitions of agricultural sustainability, Lowrance and coworkers[1] have proposed analyzing agriculture as a hierarchical system.

> **At the smallest spatial scale, the individual field, agronomic sustainability is concerned with maintaining "acceptable" levels of production over a long period of time.**
>
> **At the next larger spatial scale of the farm, consisting of fields aggregated into an organizational unit, microeconomic sustainability depends on the ability of the farmer to shift production practices among fields. For example, fields with poor agronomic sustainability may be converted to more profitable non-agricultural uses.**
>
> **At the next higher spatial level, different farms are grouped together, along with areas of land not under cultivation, to form an agricultural landscape. The ability of the environment to provide life support "goods and services" is the focus of attention.**
>
> **At the largest spatial scale, macroeconomic sustainability addresses the potential constraints of monetary and fiscal policy at a national and international level. At this global level, governmental policy and macro-economic forces dictate the types of agricultural systems that develop within a country.**

The organization of these concepts of sustainability within a spatial and temporal hierarchy is reminiscent of the hierarchical structure of biotic diversity. The parallel nested structure of both biotic diversity and sustainability suggests that bringing together these two focal concepts from agriculture and conservation biology might best be done by using concepts from hierarchy theory.

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[1]Lowrance, R., P.F. Hendrix, and E.P. Odum. 1986. A hierarchical approach to sustainable agriculture. Amer. J. Alternative Agriculture 1:169-173.

Research Needs

1. Studies are needed to determine how genetic diversity is structured at the population level.

2. Studies of spatial and temporal organization need to be made at the mesoscale level in order to begin to understand the potential interface between agriculture and conservation biology.

3. Farm scale studies need to be initiated that assess theory and concepts for alternative systems through computer analysis and field studies.

4. Advanced theory needs to be developed relating landscape architecture, structure of biological diversity, and agricultural practices.

CONSERVATION OF GENETIC RESOURCES

The two basic and complementary approaches to conserving biological diversity are usually referred to as *in situ* and *ex situ* conservation.

> ***In situ*** **conservation has been defined as "the continuing maintenance of a population within the community of which it forms a part, in the environment to which it is adapted" (Commission on Plant Genetic Resources, Item 5, 11-15 March 1985). This method of conservation has typically been carried out in protected public lands.**
>
> ***Ex situ*** **conservation is the conservation of organisms outside their natural habitat. For plants, most** ***ex situ*** **conservation is carried out under refrigeration in special facilities popularly known as "gene banks". Zoological gardens often provide** ***ex situ*** **conservation of animals.**

Conservation biology and agriculture both have their own perspectives on the kind and amount of manipulation a given system can or should tolerate, and both have their own perspectives on what purpose that manipulation should serve.

Agriculture views genetic resources as a source of genetic diversity for selection in existing populations, or for use in future animal and plant breeding programs. The commitment here is to conservation efforts that include collection, characterization, secure storage or growing conditions, and evaluation for morphological, agronomic and economic traits.

Conservation Biology sees the price of breeding plants and animals as a reduction in genetic variability which sacrifices long-term advantages for the immediate benefit of genetic uniformity and predictability.

This line of thought would prefer to see biological diversity continue to evolve on a grand scale, rather than managed as genetic resources for agricultural and industrial progress.

Walter Truett Anderson stated in his To Govern Evolution[2]:

> "The steady trend of history has been toward the creation of artificial environments: cities, cultivated farms, managed wilderness areas, constructed waterways, and now reconstructed natural ecosystems. As our environments become more artificial, we live through new patterns of interaction that are unavoidably political. The same process that causes an escalation of intentionality also causes a collapse of privatism. Not only do boundaries between nations mean less, but so do boundaries between ecosystems and cultures - and so does the distance between the individual and the biosphere."

The issue which should bring together conservation biologists, who want to protect the genetic resource bases, and agriculturists, who feel a special responsibility to help feed the growing population, is the reality of human pressure on land resources.

How much wilderness and habitat can be protected to ensure *in situ* genetic resource conservation, and how much preservation of genetic diversity can be achieved using *ex situ* means?

Land will continue to be used for agricultural production; and land will continued to be developed for economic growth and human settlement.

Manipulating genetic variability through breeding for high yields and disease and pest resistance is one way of maximizing food production on cultivated lands and providing some protection for

[2] Anderson, W.T., 1987. To Govern Evolution. Harcourt Brace Jovanovich, Inc., Boston.

marginal lands. Without increased yields, much more land would be required to meet current food demands. Since there is relatively little uncultivated prime land, expanding acreage would require bringing into production the marginal, more environmentally fragile land, much of which currently provides habitat for many species.

The diversity of species used in agriculture is another area of common ground for agriculture and conservation biology. Currently, agriculture depends on a handful of domesticated plants and animals - as much as 80 percent of the world's food supply may be based on fewer than two dozen species of plants and animals. Other species potentially could be sources of food and fiber. There are alternative agricultural systems that promote diversity and could provide increased food production.

Resource Conservation Systems

Plants

Until recently, the world's ability to collect and preserve plant genetic resources was limited. Few countries had the capacity to store crop seeds for long periods.

The International Board for Plant Genetic Resources (IBPGR) emerged in 1974 from a group of meetings sponsored by the Food and Agriculture Organization of the United Nations. Since it began, IBPGR has worked to stimulate and help establish a global network of gene banks. Today, more than 50 gene banks are operating in the world; well over half of these are located in the developing countries. In most cases, these gene banks operate under a set of guidelines developed by IBPGR and its international collaborators.

In the United States, the U.S. National Plant Germplasm System (NPGS) has been in effect since the enactment of the Agricultural Marketing Act in 1946, which authorized regional centers to maintain and develop plant germplasm. Today, the NPGS coordinates Federal, State and private sector efforts in the collection, maintenance and preservation of plant germplasm for potential future use, primarily in improving agricultural and industrial crops. Both base and working collections are maintained for all important crop plants in the U.S.

Animals

Currently, there is no organized international or national program to sample, evaluate, and utilize the genetic diversity in animal genetic resources which are important as food and fiber worldwide.

In the U.S., animal products provide consumers with 70 percent of their protein as well as significant amounts of essential vitamins and minerals. It is thought that for several species, the genetic diversity available in the U.S. may not be adequate for future breeding efforts.

> Establishing a program to coordinate the management of animal germplasm resources would be in our national interest. This program could include sampling, evaluating, preserving, and using these resources globally.
>
> A first step toward this would be to establish a National Animal Germplasm Resources Board to provide counsel to the Secretary of Agriculture.

Of greatest concern in protecting germplasm resources are those breeds that are in danger of deterioration or extinction, and those that have large genetic differences which could be important to future breeding efforts.

Microorganisms

Internationally, microbial germplasm is maintained through the Microbiological Resources Centers (MIRCENs). This global network is comprised of 17 academic and/or research institutes in developed and developing countries. The work is carried out within the framework of UNESCO's regular program activities and in cooperation with the international scientific community. The U.S. Department of Agriculture maintains microbial germplasm collections ranging in size from 6 cultures of mycoplasm to 77,000 fungi, actinomycetes and bacteria.

> Of immediate concern is the necessity of educating ourselves and government policy makers about our dependence on biological diversity.

Research Needs

1. Studies are needed to determine the compliment of cultivated and uncultivated areas and how to manage uncultivated lands adjacent to cultivated lands to minimize negative impacts from pests and diseases.

2. Studies are needed on the management of whole landscapes in order to provide cropland for food production, the existence of forests and pastures, and assess the effectiveness of large reserve programs.

3. Studies are needed to determine the impacts of continuously increasing agricultural production and the environmental impacts when agricultural productivity cannot meet human needs.

4. Data needs to be assembled and collated on the distribution and habitat requirements of the wild relatives of cultivated plants and domestic animals so that those areas most in need of preservation and management can be identified and appropriate action taken to establish them as "genetic reserves".

GLOBAL ENVIRONMENTAL CHANGE

At some time in the next century, there will be twice as many people on the earth as there are today. We are unable to equitably distribute food to the earth's population now.

If environmental conditions were to remain optimal, there is no assurance that we could provide the necessities for more people. But what if future conditions are not optimal?

A succession of environmental events over the last few years has led to a dramatically increased awareness in the scientific community, and the public, of the issue of global environmental change. The discovery of the ozone hole over Antarctica, the reactor accident at Chernobyl (whose airborne radioisotopic signature was transmitted around the globe), the 1987-88 drought, the weather extremes of the 80s, and the chemical priming of the arctic polar vortex for the appearance of still another ozone hole, dramatized the fact that global environmental change can happen quickly, can involve all nations, and can contain hidden surprises.

> The issues central to agriculture and conservation biology relate directly to the question of global climate change, specifically global warming.

Our ability to continue to feed ourselves is intimately related to our ability to respond to anticipated environmental changes. Habitat available for the worlds creatures may be disrupted by global changes and also diminish as more land is required to support a growing human population.

There is still vigorous debate in the scientific community about the evidence of global warming and what its impacts might be. But there is increasing agreement that global environmental change, as a result of human activity on the earth, is occurring and that we must begin to monitor it and develop plans in order to mitigate its effects.

Atmosphere

Evidence that fossil fuel burning may be a serious cause of global climate change first emerged from accurate measurements of the atmospheric concentration of carbon dioxide at remote, globally representative locations.

It has been determined, through detailed analysis of trace gas concentrations of prehistoric air locked in ice core samples, that the atmospheric concentration of carbon dioxide has increased from about 280 ppm to the current value of 350 ppm since the beginning of the Industrial Revolution.

Currently, scientists estimate that by the middle of the 21st century, the level of carbon dioxide emissions will be double what it is now.

> The consensus of climate modeling groups is that a doubling of CO_2 would lead to a 2° to 4° C increase in the average global air temperature and an increase of about 10% in mean global precipitation.

It must be noted that the concentration of several other greenhouse gases in combination are as important as CO_2 alone. This means that the predicted doubling effect could occur well before the middle of next century, perhaps by as early as 2030.

Several crucial questions are now matters of intense scientific investigation. Examples include:

Have these climate changes, specifically global warming, in fact been detected?

What might be the nature of changes brought about by global warming?

How extensive might changes caused by global warming be?

What would be the response of earth's various ecosystems if global temperature increases and CO_2 doubles?

What is the sustainability of agriculture if global temperature increases and CO_2 doubles?

There are no certain answers to these questions at this time.

The Greenhouse Effect

It is now more and more widely accepted that as a result of the accelerated use of fossil fuels and other human activities, the emission of infrared-absorbing, heat-trapping greenhouse gases is steadily increasing. This appears to be changing the composition of the atmosphere which is expected to alter the earth's climate, with major economic, social, political, and environmental consequences, in the coming century.

> Potential changes could effect earth's aridity, agriculture, forest growth, precipitation, and sea level.

Predictions hold that a buildup of greenhouse gases results in the sun's energy being retained within the earth's atmosphere causing a consequent rise in earth's average temperature. There is much uncertainty about the magnitude of the temperature changes. However, models currently in use predict a sequence of secondary effects.

Climate Scenarios

Ideally, the climate modeling community would be able to provide reliable, spatially detailed predictions of the climate variables needed to assess changes in farm output, the productivity and sustainability of ecosystems, the behavior of watersheds, and air quality changes in specific air sheds for a time when it is predicted the CO_2 concentration will double (e.g., 2030-2070).

Unfortunately, present models lack many crucial attributes, including appropriate coupling of the oceans, detailed topography, improved treatment of cloud processes, and adequate spatial resolution.

> Flawed and limited as they might be, climate scenarios are essential to facilitate thinking about global climate change.

One scenario currently in use for discussions of potential impacts in California consists of two parts. The first part of the scenario deals with the first decade of the 21st century; the second part deals with the years 2030-2070.

Years 2000-2010

Temperature: Increase in average annual global temperature of 0.5^0 C (above average 1951 - 1980 level).

Seasonal Changes: Drier in autumn, wetter in winter and spring.

Years 2030-2070

Temperature: Increase in average surface temperature of 2^0 to 4^0 C (above average 1951 - 1980 level).

Seasonal Changes: Change in precipitation of +10% globally and $\pm$ 20% in California.

Rise in snow level of 100 m for each 1^0 C increase in temperature.

Storm tracks move poleward consistent with a projected poleward shift of climatic zones.

Sea Level: Increase in average sea level of 0.2 - 1.0 m.

Air Pollution:	Increase in the peak surface-air concentrations of ozone downwind of urbanized areas of 10 - 20% because of increased surface temperature and higher global background of tropospheric ozone.
Other:	Increase of 50% in the UV flux to the Earth's surface.

Anticipated Changes and Effect on Agriculture

Scientists are less certain about the spatial distribution and specific effects of a potential environmental change than they are that warming will probably occur by sometime in the next century.

Any change in climate could produce shifts in agricultural production and affect our ability to feed ourselves.

Climatic change also could have drastic effects on the suitability of habitats for the biological diversity currently occupying a region.

Warming will not occur evenly over the earth and the effects are not expected to be uniform. The peculiarities of topography and air/water circulation patterns will be strong factors in determining how a given area responds to climate change.

Scientists generally agree that warming will be more significant at high latitudes; in the polar regions, as sea ice and snow cover retreats, surface reflectivity will be reduced, allowing additional absorption of solar radiation to further warm these regions.

At mid-latitude continental regions, warming might agree roughly with the predicted global average change.

At equatorial latitudes, changes may be somewhat less than the global average.

Anticipated global climate changes could be extreme compared to recent natural temperature fluctuations. And these changes could occur suddenly, exceeding the ability of species to adapt.

Some examples of expected effects of global climate change are:

Regional alterations in rainfall pattern. Some areas might see a substantial increase in precipitation while others might see a substantial decrease causing loss of soil and vegetation.

Regional storm patterns and severity could be altered, changing soil chemistry and ecosystem stability.

Increased CO_2 may speed the growth of certain plant species at the expense of others, thus destabilizing ecosystems.

Rises in sea level could disturb coastal ecosystems.

To put the current warming estimates into perspective, it is expected that an average increase of 3°C would present us with an earth warmer than at any time in the last 100,000 years. An increase of 4°C would warm the earth to its level of 40 million years ago.

The developed countries of the industrial world have been the main source of greenhouse gases. Consequently, they bear the main responsibility for addressing the issues posed by global environmental change.

Until recently, short term modulations and discomforts caused by weather have always occurred in the context of a basically stable world climate. International cooperation to delay the arrival and lessen the impact of global environmental change may well be a factor of our common realization that the world as we have known it is about to change in ways we cannot predict or control.

Research Needs

1. Existing data bases must be evaluated to determine what data are available now and what data are needed to help estimate the magnitude, direction, and timing of climate change, and its regional impacts.

2. The current performance and status of representative worldwide ecosystems must be documented so that future studies will be able to determine if climate changes are influencing the biological world.

3. Studies are needed to determine the resilience of natural and agricultural ecosystems to changes in global climate factors.

4. Studies are needed of the potential of tree planting as a means of sequestering carbon dioxide and to reduce the rate of increase in atmospheric concentrations.

GENETIC OPPORTUNITIES

Alterations in global climate and sea level could have a major impact on the future geographic distribution of agricultural activities. The demand for agricultural products is likewise changing at ever increasing rates.

The genetic interdependence of domesticated plants and animals and their wild relatives is increasing as we recognize the wealth inherent in hitherto unincorporated natural germplasm.

With rapid progress in genetic engineering and the foreseeable ability to move genes between unrelated species, the apparent conflict between agriculture and biological conservation disappears.

> If the primary imperative in the management of agricultural lands is the provisioning of the human species, sustainable agricultural systems must be developed that produce double or triple today's yields.

The populations and species that carry the genes upon which future agriculture depends are rapidly disappearing at just the historical moment at which we are developing the tools to use them.

Genetic Conservation and Biotechnology

Sustaining the productivity of agricultural, forest, and aquatic species requires the continued application of traditional genetic methodologies and the rapid deployment of new biotechnologies based on molecular genetics.

> At least half of the increases in productivity realized this century are directly attributable to simple selection, recombination, and traditional intraspecific gene transfer procedures.

Molecular genetics and genetic engineering have a great deal to offer agriculture in ways that will both reduce negative environmental impacts and enhance sustainable productivity over present-day levels.

Genetic engineering involves altering the genome of an organism by adding new genes or changing existing genes. Gene transfer, gene recombination, gene expression, and protein secretion all can be manipulated using relatively simple techniques.

> **It is important to note that genetic engineering will not be a substitute for traditional breeding methods since many traits of importance are under the control of multiple genes scattered throughout the genome.**

Because of real and perceived risks associated with the release of genetically engineered organisms, it is essential that there be careful case-by-case evaluation of the potential ecological consequences of releasing exotic or genetically modified organisms into the environment. The problems caused by the rabbit in Australia or the lamprey in Lake Michigan may be minor compared to the potential damage of poorly conceived uses of genetically modified organisms.

Another set of biotechnologies of importance to agriculture involve embryo transfer and livestock germplasm improvement. Frozen semen already permits the rapid movement of introduced genotypes on a worldwide basis. Interspecific gene transfer has been successful in laboratory trials; its potential to modify animal populations is so far unfathomed.

Genetic engineering is also playing a larger role in increasing animal productivity by improving vaccines and pharmaceuticals. Hybridoma technology, which results in the generation of monoclonal antibodies by cell fusion procedures, is demonstrating increasing usefulness in diagnosing specific diseases as well as in disease prevention and treatment.

Ex-situ Conservation

Technologies for the collection, storage, evaluation, movement, and utilization of germplasm are still in their infancy. The potential role of germplasm captured and conserved today is enormous. Future breeders seeking to improve a species' adaptability, resistance, or productivity will be thwarted in their efforts if their natural genetic raw materials are lost by extinction and mismanagement.

> The technologies for maintaining genetic diversity of economically important animals and plants are completely inadequate given the predictable environmental changes and the current rate of loss of overall biodiversity.

Since the late 1970's there has been increased recognition of the need to coordinate and implement the ex situ conservation of genetic resources of priority plant species other than major food crops. In 1984 the I.U.C.N. and W.W.F. launched the Plants Conservation Program designed to "assert the fundamental importance of plants in all conservation activities."

In the future, agriculture should not be dependent on stocks and strains of plants and animals that are in reality highly inbred, genetic deadends.

Livestock, crop and forestry population and their ancestral species must be managed so as to insure their ability to evolve under environmental and human pressure.

The basic science of evolution is still inadequate to effectively address questions critical to both agriculture and conservation biology.

A perennial question seeks to establish the adaptive significance of variation (molecular, chromosomal, phenotypic); this in turn raises many methodological questions regarding sampling, assays, statistics, and natural selection tests. Yet, this question should be raised repeatedly so as to go beyond the general statistics of diversity or heritability measures.

Conservation of Populations

In the last decade, the new applied science referred to as conservation biology has begun to quantify the concepts of minimum viable population (MVP) size, MVP area, and other demographic measures of the fitness or relative well-being of populations.

Local extinction of components of a metapopulation are now viewed as normal occurrences, and research focuses on the relative contributions to such extinctions of genetic, demographic, and habitat-fragmentation processes.

> Agriculture recognizes populations as wild species, subspecies, landraces, breeding lines, varieties, stocks, strains, and cultivars.
>
> Conservation biology recognizes groups of organisms as demographic units and evolutionary taxa: populations and species.

Biologically, species are groups of populations that share a genetic and evolutionary cohesion based on the ability of individuals to discriminate between their own kind and members of other species.

It is essential that a common and effective method of characterization and classification emerge for management and conservation.

We simply cannot evaluate the genetic variation and population structure of the approximately 30 million species on the planet today. Instead we must develop ways of prioritizing species for attention based on various generalizations that have emerged over the last decade.

Research Needs

1. For a better understanding of gene effects (epigenetic effects, pleiotropy, and genotype-environmental interactions), mapping and estimating the number of both structural and regulatory loci is essential.

2. Surveys are needed to determine genetic variation in agricultural species and their wild relatives as well as those wild plants and animals that are already the focus of conservation activities.

3. A system needs to be developed for prioritizing the numerous rare and endangered species for attention based on different types of rarity and probable rates of extinction. Special attention should be given to the identification of ecological "key-stone species" in natural communities.

4. Methods are needed to pool data from technologically different assays of genetic variation to improve conservation decisions, both *in-situ* and *ex-situ*.

5. Methods must be found that can be used to establish the adaptive significance of variation and provide a new synthesis of quantitative genetics of interest to both breeders and conservation biologists alike.

6. There is an urgent need for the biological community to define a generalized methodological and biological classification system suitable for all biological management and conservation activities.

Section 2: Opportunities

ARABLE LANDS

Intensive farming of arable land dominates agriculture in most parts of the world. Consequently, farming practices and methods of operation can significantly affect the landscape.

A common feature of all farming operations is the sequential process of planting a crop, harvesting a product, disposing of residues, manipulating the soil, and replanting the same or a different crop.

> Examination and modification of farming practices provide a unique opportunity for agriculture and conservation biology to serve the common purpose of providing habitat for non-agricultural species and enhancing the sustainability of agriculture.

Global Issues

Modern agriculture has a major responsibility in managing biological resources. Many food plants are cultivated in areas far removed from their native ranges. Agricultural products are shipped extensively in a global network. Animal and plant diseases can be spread readily, especially as a result of extensive human travel and crop shipments.

Many animals migrate across national boundaries and are often dependent on agricultural land at some time during their migration. Chemicals used on croplands may spread, via air and water, throughout the globe.

There is increasing evidence that North American and European birds that migrate to the tropics are suffering more serious reductions in their populations than are resident or short distance migrants.

Economic and cultural bases for achieving the best mixes of plant species, appropriate methods of crop site preparation and management, and ideal locations of plantings, are essential to sound land management.

Such research can be done inclusive of all conservation objectives rather than exclusively in consideration of biodiversity and species extinction.

Since agriculture provides, or has an impact on, much of the available habitat, effective management must be achieved through adoption of compatible farming operations, not through regulation.

International conventions and treaties exist to protect some migratory and aquatic species, to regulate trade in rare and endangered species, and to control international transport of pollutants by air and water. However, these treaties deal primarily with direct harvesting and exploitation of species, not with the habitats they require for existence.

The Individual Field

The field as considered here is a piece of land managed under a continuous cropping cycle. The most common cycle is an annual one with a new crop planted each spring. However, some forage and tree crops are generally maintained for more than one year.

A series of standard operations are performed on a field during each cycle. Each operation can be considered for its potential impact on both species habitat and agricultural production.

Land preparation after harvest is of significant concern. Methods can range from leaving residues on the ground, to harvesting the residues for fiber, to burning residues as a means of pest control.

The method and timing of tillage have important implications for habitat maintenance, control of soil erosion, water conservation, and soil management. Clearly, tillage methods that leave crop residues at or near the soil surface during critical seasons can have significant positive impacts for animals and microorganisms.

Water management is critical to both plant productivity and survival of non-target species, with irrigated fields providing the greatest flexibility. Removal of excess water is essential for good plant growth and the control of pests such as mosquitoes. Diversion of excess water for riparian habitat must be balanced against salt accumulation.

Fertilizer applications are routine and can produce negative outputs as well as enhance crop productivity. Changing the rate or the timing of plant growth in pasture fields can influence the suitability of the habitat for birds. Soil microbes may also be modified due to changes in nutrient balance of soils.

Harvesting methods, and the timing of the harvest, can have a significant impact on wildlife. Harvesting by machine before birds have completed nesting will reduce bird populations. Fall planting for summer harvest can remove seed residues that may be important to winter survival of animals and birds.

Soil animals, including earthworms and other decomposers, and larvae of many insects, are critical to the continued healthy life of the soil. But as yet, little is known about the effect on them of various tillage methods.

Farm Scale Issues

Increased availability of improved varieties, superior breeds, chemical pesticides, herbicides, and fertilizers, and modern machines have revolutionized farming operations since World War II. As a result, farm size has increased, field boundaries have been removed, marginal lands have been developed for production, and the diversity of farming operations has decreased.

The long term effects of these changes on the environment and biological resources has not been adequately examined. In addition, the organization of fields in relation to crop rotations and other land uses should be designed for production efficiency and long-term sustainability.

The mix of crops present within a given farm at any one time can greatly influence the contribution of farming practices to conservation biology.

For intensively managed farms, the size of the farm, the field boundary areas, the size of buffer zones, and the local mosaic organization of land all have major effects on the suitability of the environment as habitat for non-target organisms.

Edge Effects

Structural boundaries between plant communities or between other physical features in the landscape produce "edges" or "ecotones" in the environment. Aldo Leopold[3] was the first to write about this so-called "phenomenon of edges" and the beneficial "edge-effects" on wildlife populations, especially game animals.

Biological diversity in natural environments appears to be directly proportional to the quantity of edges.

Agricultural systems that contain substantial numbers of edges tend to provide more diverse habitats for conservation of natural systems.

Edges maximize the habitat diversity for mobile species and allow wildlife to use portions of otherwise unsuitable areas by providing escape cover. Edges provide habitat for early successional plant species and serve as corridors to foster migration and colonization.

Field edges can have negative effects on agricultural production. They tend to reduce field size and constrain flexibility of farming operations. The edge habitat may also harbor pests and weeds, but effective biological and cultural practices can be utilized to minimize these negative impacts.

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[3] Leopold, A. 1933. Game Management. Charles Scribner and Sons, New York.

Buffer Zones

Wherever land preserve, reserve, or created habitat boundaries meet intensive agricultural land, buffer zones are usually required for the protection of both resources. In addition, buffer zones, or strips in agricultural land, can serve as corridors for animal movement and plant dispersal.

> Corridors are needed to connect natural areas across large tracts of agricultural land. Buffer zones can function both as a refuge and a corridor for native plants and animals.

Buffer zones and corridors can also be provided by highway landscapes and irrigation canals and drainage sloughs through appropriate management of these sites. Currently, vegetation along roadways and canals is often kept under control with herbicides or may be composed entirely of exotic plants that provide poor habitat for wildlife.

Local Mosaics

Creation and maintenance of on-farm mosaics require economic incentives for farmers. For instance, the diversity of mosaics would be increased if selective cutting of trees for firewood and collecting fees for hunting and fishing were encouraged and permitted.

Alternative farming systems, such as multicropping (raising more than one crop in the same plot simultaneously), intercropping, and polyculture, need to be investigated not only from the perspective of economic value, but also for their value to the local biota.

> Enhancing farmland aesthetics is a way to increase on-farm habitat diversity as well as attractiveness.

The farmstead is typically a complex habitat, with large trees, bushes, garden, and lawn. If a farm has a woodlot or pond, aesthetic opportunities are greatly expanded and could be shared with the general public.

Many elements that improve farm aesthetics (crop diversity, hedgerows, strips) may also improve farm economics for the long-term by providing more diverse sources of income.

Intensive Animal Production

An important trend in animal production in recent decades has been the expansion of systems in which animals are grown at densities much higher than those the resources of the area can sustain. The difference is made up by importing large quantities of feed and disposing of waste.

Although these systems usually cover rather small areas, they may have effects well beyond their boundaries. These systems can be sources of pollution of streams, ground water, and adjacent lacustrine and marine areas. For newly domesticated animals, there is the danger of interaction with wild relatives, resulting in the spread of diseases and interbreeding.

The integration of animal production with the local farm mosaic has been lost as a consequence of social and economic conditions. An objective evaluation of the role of animal production and the influence of local, state, and national policies may reawaken interest in animal systems.

Regional Issues

Habitat Diversity and Patchiness

For biological conservation and increased diversity generally, it is desirable to have as many different kinds of habitat available as possible. Application of this idea is simply an extension of the notion of the farm mosaic already discussed, with two important differences. First, the range of habitat types is likely to be much greater and, second, considerably larger patches of each habitat type may be present.

The point about larger patches is especially important on a regional scale because larger species of animals and plants and mobile animals and birds generally need larger areas of habitat to maintain viable populations.

In areas dominated by agricultural use of land, an overall strategy might be simply to retain, or even create, a diversity of habitat types. If there are one or more endangered species that require a specific habitat type or a specific management practice, special treatment may be needed.

Providing specialized habitat within agricultural land may require some form of compensation payments to landowners if economic productivity of the land is reduced.

The system of Sites of Special Scientific Interest (SSSI) in Britain is designed to do just this for species and habitats as an alternative to reserve acquisition or other agreement.

Water Management

Three aspects of water management effect wide areas: surface drainage, land use planning for watersheds, and managing ground water.

> All agriculture relies on water. Much of it falls as rain, but many areas rely on streams and rivers.

The quality of stream and river water depends on what is occurring higher in the watershed. The higher areas of a watershed are often the most vulnerable and there are now an increasing number of schemes designed to protect origin watersheds.

Ground water has become an important resource for agriculture. It has the potential of being over-drafted and of being contaminated from surface run-off and seepage from agricultural fields.

High quality surface drainage also can provide important sources of water for downstream sections of wildlife habitat, and ground water recharge.

Agriculture Adjacent to Urban Areas

In the developed world, people increasingly have more leisure time and want to spend it in the countryside. Agriculture must come to terms with this, especially in those areas adjacent to cities where the potential pressure is greatest.

Often there is pressure to reduce the intensity of farming in areas of high aesthetic and recreational appeal. Some farmers adapt by incorporating recreational facilities, either as an integral part of the farm itself or as a separate area set aside for this purpose.

> Agriculture bears some responsibility for providing society with a pleasing and enjoyable landscape. Greater consideration of the societal needs of urban populations could greatly enhance society's appreciation of agriculture.

Agriculture Adjacent to Parks and Reserves

A topic crucial to the theme of this report is the consideration of the area around reserves and other protected areas. What, if any, particular needs or practices can or should be adopted both to minimize damage to agriculture by animals and plants in a wildlife area and to eliminate adverse effects of agriculture on the area being preserved?

In the United States, national parks were established primarily in uninhabited wilderness areas, and to some extent this is true elsewhere in the world. In Europe, national parks have, of necessity, been placed in areas already occupied and used by people for a variety of purposes other than recreation. In some tropical countries, many areas desirable as parks and reserves are occupied by people.

It is politically impossible, and perhaps biologically undesirable, either to fail to establish parks under such circumstances, or to attempt to evict people already living there.

National parks and reserves must be responsive to the particular circumstances of their location if ecosystems are to be preserved. Both the park and the surrounding land must be considered a larger management unit in which both co-operate for the maintenance of viable populations of species within the preserve.

Even in the United States, there is increasing recognition that parks must be managed in a larger context because most of them are too small to protect populations of some species living in them. It is not clear that agricultural operations must be removed to maintain effective preserves.

Pest Control and Pest Management

One of the major conflicts between agriculture and conservation biology concerns the nature of pests because what is a pest to the farmer can be wildlife to the conservationist.

A farmer confronted by potential or actual pests can elect one or more of several options, including: use of resistant cultivars of the crop; planting crops at a time of year to avoid the pests; planting crops in rotation to avoid a build-up of pests; physical weeding or killing; use of scaring devices; chemical repellents; biological control; killing by chemical application; physical exclusion.

The use of pesticides is now the most widespread method and it is also the one that causes the most concern to conservationists. The introduction and subsequent widespread use of some organochlorine insecticides was responsible for an unfortunate debate on the ethics of farming and management of the countryside.

For example, some of these pesticides were extremely persistent in the environment and organisms higher up in the food chains accumulated large quantities by eating poisoned organisms. Some bird of prey populations decreased to about 25% of earlier numbers. Increasing public concern led to progressive bans on some of the most persistent and powerful poisons.

Many insecticides are still in use today. However, most of them are much more specific to individual species or groups of pests, and most degrade into relatively harmless chemicals within a few days after coming into contact with air or soil.

Very importantly, the development of integrated pest management systems is greatly reducing pesticide use, and farmers are now using them in a much more responsible and restricted way.

Nevertheless, there are still a great many unknowns about these chemicals, and it must be recognized that there are no completely safe pesticides. They are designed to kill certain organisms and so are unlikely to be beneficial to others except perhaps indirectly. Conservation biology can contribute positively to the development of pest control systems.

Research Needs

1. Studies are needed on habitat requirements of organisms that migrate internationally, especially those that breed in temperate latitudes and winter in the tropics.

2. To help make better decisions concerning which areas can best accommodate agricultural expansion with the lowest threat to survival of species, new landscape classification systems need to be devised which are based on conservation potential as well as soil and water considerations.

3. Efforts designed to develop sustainable agricultural systems should be integrated with the study of biological conservation opportunities to maximize food production potential, conservation of biological resources, and aesthetic value of the landscape.

4. Studies are needed to determine the fate of animal populations in watershed areas and how they are affected by water management practices.

5. Assessment of alternative cultural practices as pest control devices. For example, many wildlife refuges plant crops for geese and swans to draw them off of farmers' cereals or irrigated pastures until after harvest time. This type of research can be combined with studies on the effects of changes in harvesting times on protection of crop species.

6. Determinations need to be made on how much edge and boundary habitat is needed to maintain native edge-inhabiting species, including migratory forms, the role of edges in integrated pest management, and the type and size of buffer zones that would be required to protect agricultural land and provide adequate habitats for indigenous species and the effectiveness of various types of corridors for the dispersal of organisms.

7. Studies need to be made to determine society's needs and interests in relation to the countryside.

8. Studies are needed of factors that favor success in control of weeds by introduced herbivorous insects, to predict whether effective pest control will increase plant species richness or simply result in the assumption of dominance by another weed.

FOREST LANDS

To a large extent, key questions about biological diversity in forest systems change with the spatial scale under consideration. At the local level, where the focus is individual stands or agroforestry plots, the major management question concerns the capability of a particular stand or plot to support a variety of plant and animal species. At the regional level, a broad and heterogeneous landscape containing abundant edge habitats and a variety of stand edges and vegetation types is expected to enhance overall species diversity.

> **All management decisions can potentially affect the size, shape, relative proportions, and spatial distribution of forest stands and thereby modify the capacity of a region to support a diverse mix of species.**

> **Modification of forests is generally positive for edge species and negative for species that depend on large stretches of unbroken habitat.**

Because of population demands on natural resources, almost all forest land is under some type of management. For some forests, such as wilderness areas, management activities are directed primarily toward recreational use and resource conservation. For most forest land, management for food and fiber production is relatively intensive.

These various management activities on forest lands are often grouped under the term forestry.

On one end of the forest intervention spectrum is plantation forestry wherein desired species of trees are intensively cultivated to maximize production of wood fiber. A typical plantation is an evenly spaced monoculture of single-aged trees with little understory.

> **The incorporation of biological conservation ideas into plantation management systems has not received sufficient attention and conservation opportunities may have been missed.**

At the other end of the forest intervention spectrum is wildland forestry, the management of natural forest systems with multiple use objectives. There has been considerable opportunity to incorporate biological diversity objectives into management of wildland forests.

One other management system with a significant forestry component is agroforestry. Agroforests are usually highly integrated systems including vegetable crops and livestock. They tend to have a history or tradition within a given culture. In addition to meeting the subsistence needs of local people, these systems utilize a mix of species and practices that are highly adapted to the local environment.

Plantation Forestry

Forestry, like other forms of agriculture, encompasses systems with various levels of human inputs and consequently, a wide range of exploitation. The management schemes applied follow a defined cycle including clearing the site, seeding or planting, suppression of undesirable vegetation, selective thinning, and final harvest.

Issues concerning biological diversity occur at both the local and regional level. The local stand will be the usual target of production management. The variety and distribution of various local stands determines the nature of a regional landscape and, therefore, are key elements in any strategy for increasing biological diversity.

Local Stand

Harvest: Silvicultural options range from complete removal of all trees in the unit (clearcut) creating an even-age stand, to cutting only a few individuals (select tree harvest) thus perpetuating an uneven-age stand.

> In species-rich forests the manner in which harvesting affects mixtures of species is one of the most important and least understood aspects of forest practices.

Many animal species depend on a particular or a few tree species for their survival. Therefore, changes in tree species composition as a result of harvesting, even if done on a broadly sustainable basis, may have negative impacts on animal species richness.

Studies in Peru have demonstrated that during the wet-dry season transition, when fruitfall is minimal and below the needs of the frugivore community, frugivores (animals and birds that eat fruit) are dependent on about 12 tree species out of the approximately 2,000 present in the system.

This suggests that the forest could be extensively harvested without much effect on the frugivore community if those particular "keystone" species of fruiting trees were maintained at close to their current levels.

To date, little knowledge has been gained regarding specific species dependencies and the potential impacts of alternative harvest schemes for temperate or tropical forests.

Site Preparation: After harvest, the site must be prepared for the next generation of trees. For clear-cut areas, all the debris and residue (slash) may be removed, and undesirable regrowth suppressed. In areas selectively harvested, the residues of harvesting may be left on the ground.

Removing residues can have both positive and negative effects on the next generation of trees and, thus, on overall biological diversity. Excessive growth of weedy species can eliminate regrowth of some desirable tree species. Burning of residues releases nutrients into the soil, can reduce fire danger, and prepares seeds and the seedbed for germination and sprouting. Removal of residue may eliminate habitat for some mammals and birds, and expose soil to erosion. Burning will add carbon to the atmosphere and enhance greenhouse effects. Weedy growth suppression using chemicals may have adverse effects in later years.

Site preparation and management after tree harvest may provide a great opportunity for innovative solutions to problems in conservation biology.

Tree Regeneration: A new tree crop is established either by natural regeneration (seed germination and sprouting) or artificially through aerial seeding or, most commonly, planting seedlings. Planted seedlings are often from genetically improved varieties.

Though current applications of artificial regeneration may result in significant and long-term impacts on the biological diversity of the forest, its use offers opportunities to favor natural species mixes. Integrated forestry and biological conservation objectives could include the use of non-commercial or rare species of trees at various densities and positions organized in ways beneficial to wildlife.

Most research in this field has examined how wildlife and non-commercial plant species are affected by replanting with commercial species as compared to natural regeneration. Aspects of seed selection, method of artificial regeneration, and management immediately after regeneration may provide greater opportunities for study.

Stand Management: Management of stands during growth of the trees can include thinning, undergrowth removal, pest control, and provision of recreational opportunities.

Early, pre-commercial thinning of trees is necessary when planting is dense and survival high. As the trees mature, commercial harvesting may be initiated early to reduce density and recover some small timber. The choice of species and the timing of thinning may have considerable consequences because thinning can be done to favor the natural mix of species for a site.

Controlled fires may be used to remove excess understory, prepare a seedbed under mature trees, and prevent devastating wild fires.

Stand management, especially practices that remove individual stems (thinning and fire) is a little explored aspect of forestry that has potential to affect diversity of organisms.

Landscape Scale

The proportion of land in forest, the distribution of these stands over the landscape, and the management of the stands, become the keys to conservation of many species within a region. Forest management issues must deal with regional issues where natural vegetation is forest, but agricultural lands and urban areas are interspersed with the forest.

Habitat in such areas can be referred to as fragmented.

For centuries, European forests were exploited using a system known as "coppice with standards." A few trees of value for construction timbers were allowed to grow to a large size. Other species were harvested at very short intervals; some trees were cut at ground level (coppicing) while others were cut about two meters above the ground (pollarding). The combination provided construction material, wood for cooking and heating, range for livestock, and a rich variety of wildlife. The system died out when coal became widespread as the main source of heat; there is renewed interest in the system as a conservation method.

Harvest: When to harvest and how much to harvest a given forest area are important questions affecting organisms requiring an extensive range for survival. Few landscape ecologists have considered this larger question of regional patterns of harvest.

Originally, harvest decisions were based on economic demand for logs together with a knowledge of maximum sustainable yield.

Increasingly, these decisions must be based on a consideration of the effects of fragmentation and insularization of forest patches on all forest organisms.

Regional patterns of age structure of stands, nature of residues and its management, distributions of pests, and mineral cycling through the forest are areas of importance to effective biological conservation.

Management: Under conditions of fragmented habitat, some animal species are unable to maintain viable populations. Often these species even find it difficult or impossible to cross short expanses of non-forest habitat.

> Habitat fragmentation can produce "island" subpopulations with limited or no dispersion (migration) among islands.

Artificially small population sizes are likely to change the pace of evolution and can easily lead to poor viability of some species, including extinction for very small isolated populations.

Management plans must strive to maintain some landscape which minimizes edge habitat and maximizes undeveloped, interior blocks of forest. National parks represent one attempt to achieve this conservation goal. However, a mosaic landscape may be more desirable.

The key factors are generally political, but research is urgently needed to determine the true impact of habitat fragmentation on specific species.

Wildland Forestry

The main concept of wildland forests is that their resources should not be exploited. However, some forests provide such a rich array of products that they have more value as "extraction reserves" than as areas for forestry or agricultural production. Extraction products including nuts, rubber, flowers, hunting, fishing, and hiking may exceed the value of the land.

Recreational uses can also exceed the people-carrying capacity of the forest. These activities can disrupt the terrain and increase pollution, but the negative effects must be managed in favor of the social value of recreational opportunity.

Economic benefits are difficult to determine because governmental subsidies are generally involved and may not include user fees. The social value of recreation has not been evaluated with regard to wilderness areas.

The World Bank has endorsed the concept of extraction reserves as an alternative to forest clearing.

Agroforestry Systems

Agroforestry systems are based on the cultivation of mixtures of trees, shrubs, and herbaceous crops, combined in various ways with domestic animals. Most such systems are characterized by having a number of species growing together in layered mixtures. However, trees may be in a small woodlot in a corner of the farm or even in a fence row, or tree and herb components may occur as intermixed patches.

> **Little attention has been paid to the role of traditional agricultural systems in preserving biological diversity despite the obvious fact that traditional agroforestry systems, while supporting fewer species of organisms than nearby primary forest, are much richer in both target and incidental species than are monocultures.**

Forest components may be a source of pest species as well as species beneficial to the agroforestry system. There also is the opportunity to support diversity of pest control species.

Research Needs

1. Forest management techniques need to be developed which are designed to maintain good mixes of tree species, determine how the overall mosaic of forest patches affects the survival of those species in individual fragments, and the importance of edge effects between harvested and unharvested areas, or between harvested units of different ages.

2. Data are needed in order to provide a better base for understanding the effects of alternative harvest methods and the timing of harvest operations in different forest patches on the survival of animal species.

3. Studies are needed to determine if keystone fruiting plants are important for the maintenance of frugivore communities, to measure the survival and fruiting patterns in keystone trees in areas where extensive logging has been carried out, and to determine the germination requirements of keystone tree species so that they do not need to be artificially planted after tracts are harvested.

4. Studies need to be made on the effect of the density of trees left on a harvest unit and the pattern of harvested units relative to pest and pathogen populations and the effect on mineral cycling from removing whole trees (log, branches, and foliage) versus removing only logs.

5. Comparisons need to be made of current mixed agroforestry systems with respect to the kinds and numbers of target and non-target species living in them and how regional mixtures of different types of agroforestry systems affect the total number of non-target species living in the area.

6. Studies need to be made of the human impact on the evolution of vegetation and fauna, including the possibilities of adaptation of these organisms to human impact and changing environments.

RANGELANDS

Nearly 50% of the earth's land area is categorized as rangeland. This large land area is generally unsuitable for intensive cultivation of row crops or forages because of limited available water, shallow or variable soils, or steeply sloping terrain. Rangelands include some non-commercial forests and woodlands, but they are composed mainly of grass, shrub, and savanna vegetation types.

> While they may appear to represent the pristine state of the environment, the introduction of animals to rangeland has had profound effects on the species composition of the vegetation and the population density and species composition of native organisms.

Many of the world's rangelands have been or are being overgrazed. Grazing pressure is such that palatable species are reduced, productivity of forage is below potential, and soil cover is below what can sustain natural ecosystem structure and function.

The most frequent cause of overgrazing is maintaining domestic livestock in excess of the carrying capacity of the land. Excessive protection of feral animals and removal of predators without corresponding adjustment of harvesting (e.g. hunting) has also contributed.

Overgrazing also results from random or cyclical variation in rainfall. During a series of good years, populations of grazing livestock or wildlife build up to the point that they exceed the carrying capacity during normal or poor years.

> Overgrazing is increasing in some areas occupied by pastoral peoples.

With nearly stable population sizes over the centuries, pastoral peoples tended to maintain sustainable numbers of animals. During the human population explosion of this century, these peoples began to experience the need, for various reasons, to increase their herds. The result has been an explosion of animal populations which has placed severe pressure on the land in many of the drier areas of the world.

Animal Management

The biggest factor affecting biological diversity in rangelands is introduced animals. But because of economics, the current knowledge base is weighted heavily toward understanding livestock performance.

> **There is a growing belief among scientists that rangeland conservation and rangeland production can be compatible. This points to the need for detailed environmental research on natural and perturbed rangelands.**

Another important driving force in rangeland management is governmental policy, which impacts such factors as marketing, grazing intensity, and land taxes. Federal land managers in the United States are required to promote multiple-use of public land and agencies have developed rating systems to value uses.

Multiple Grazers

There is evidence for several grassland/savanna systems that the total production of native herbivores exceeds that obtainable from domestic livestock even when mixtures, such as cattle, sheep, and goats, are employed.

> There is interest in the potential for managing native animal species for meat production.

Examples of grazing systems employing native species exist around the world. Their study could yield valuable information on converting natural vegetation to harvestable animal products without the use of currently domesticated species.

Feral Animal Management

Feral animal populations can have major impacts on both the biological diversity of rangeland and the productivity of livestock enterprises.

> **Uncontrolled feral populations of horses, burros, pigs, and goats have been responsible for destruction of habitats and reduced productive capacity of both public and private rangeland.**

Livestock Predators

Predation accounts for significant annual documented losses of sheep and goat flocks in many areas. It is one of the principal factors contributing to a reduction in sheep numbers in the United States from 56 million in 1944 to about 10 million in 1988. Thus, an entire food producing industry is threatened.

The most serious predator species is the coyote; domestic dogs probably rank second. Bears and mountain lions also cause significant losses in some regions.

> **Predator control programs, particularly the traditional publicly financed ones, are of variable effectiveness and are increasingly controversial because of their potential impact on biological diversity.**

It is highly desirable to maintain predatory animal populations whenever feasible. However, the price paid will be reduced food and fiber production from rangelands and a reduction in the diversity of domesticated species kept on those lands.

Management by Vegetation Manipulation

For the purposes of this discussion, private and public rangelands can be classified as: land unsuitable for range manipulation; land under minimal range management; land under intensive management; land under highly intensive management.

Rangeland may be classified as "unsuitable" because it is inherently low in productivity, highly erodible, without surface or well water potential, or has no development potential. Alternatively, the area may be of unique biological value because of rare plant or animal species and consequently it may be socio-politically unsuitable for utilization.

> The question of when land possesses special values that outweigh their potential importance for forage production or other commodity export uses has not been seriously studied.

Perhaps the most controversial rangeland management practice is vegetation conversion from shrubland or woodland to grassland.

Under minimal to intensive levels of management, prescribed burning to remove woody vegetation has become an accepted practice complementing efforts to reduce the dangers of wild fires. Burning also reduces the need for herbicide application.

Woody plants play a primary role in soil stabilization, nutrient recycling and micro- and meso-scale climate modification as well as providing browse for livestock and other herbivores and habitat for small mammals.

Restoration

Historically, most "restoration" projects have focused on increasing production of some commodity such as forage or water, or have sought to redress damage to the ecosystem caused by past over-exploitation.

These projects often involve wholesale replacement of native vegetation with monocultures of an introduced species, or even removal of vegetation in order to export more water out of a watershed. Such techniques obviously are inimical to preservation of biodiversity.

Management

Many public lands are now managed according to multiple use objectives which generally include some mix of commodity production, maintenance of biodiversity, and retention of aesthetic value.

The goal of modern range management, where multiple-use concepts are adhered to, is to adopt systems that enhance both wildlife and livestock production.

Since wildlife depends directly on habitat, often plant biodiversity goals will be met if wildlife needs are met. To achieve this end, modifications will be required both in policies and individual attitudes.

Prediction of impacts of rangeland management requires an understanding of the natural history of the biota and careful analysis of vegetation, soil, terrain, and climate. Model study areas should be established and government policy examined with respect to biological, environmental, and economic impacts.

Conservation of biological diversity and production of food and fiber can co-exist.

Modern range management goals must be effectively integrated to economically produce livestock, enhance game animals for recreation, and insure biological conservation.

Genetic Diversity

The first step in assessing diversity is usually to establish a census of all species found in the area of interest. Such a census should be made in more than one season and in more than one year. If the area is large, the list may be subdivided by features of the area, usually habitat, and lead to an assessment of the distribution of taxa.

Census data are essential to the consideration of questions concerning carrying capacity, competition, conservation, control of population sizes, species eradication or control, and species rarity or endangerment.

There is strong evidence that the ability of range plants to tolerate grazing is linked to their evolutionary history of grazing by native herbivores. Species diversity also seems to be enhanced by properly managed grazing.

> Numerous grazing systems have been designed apparently without regard for the evolutionary history of plant species.

Detailed analysis of the extent and structure of genetic variability within plant and animal species is required when questions of improvement or restoration of plant and animal range components arise.

To prevent local extinctions and maintain a relatively natural species composition (diversity), information is needed on the grazing behavior of indigenous fauna and whether livestock grazing mimics this behavior. These ideas also would be invaluable in establishing management systems for parks and reserves.

Research Needs

1. Studies are needed on the effects of grazing intensity and timing on vegetation dynamics and populations of non-commercial mammals, and on the significance of the sizes of grazing units and the potential interference with seasonal movements of native mammals.

2. Model study areas should be designated and multidisciplinary research needs organized to arrive at a better understanding of the natural history of biota.

3. Governmental policies need to be analyzed with respect to biological, environmental, and economic impacts.

4. Research is needed on how to effectively integrate the three main goals of rangeland management (economic gain through livestock production; management of game animals for recreational uses; conservation of biological diversity).

5. In light of the global climate changes expected to occur over the next 30 - 70 years, it is important to develop the capability to predict how changes in temperature, rainfall patterns, and increases in atmospheric CO_2 concentrations will affect competitive interactions on rangelands, both with and without grazing.

6. The following questions regarding interactions and their effect on biological diversity need to be researched: How will climate changes affect plant/animal interactions? Will climate changes affect the length of time green plant material may be available? Will CO_2-enhanced growth lead to more severe nutrient limitations, which, in turn, could result in decreased forage quality and, hence, decreased animal performance?

7. To prevent local extinctions and maintain a relatively natural species composition and diversity, information is needed about natural grazing patterns by indigenous fauna, and whether grazing by livestock will lead to increased natural diversity in rangeland systems populated with native plants.

8. In areas where certain native species have been eliminated by overgrazing or "unnatural" grazing patterns, research is needed to determine whether the native plants can be successfully reintroduced and maintained by grazing systems which more nearly simulate those of native herbivores.

WETLANDS AND AQUATIC HABITATS

Wetlands are essential nesting, feeding, resting, and wintering habitats for a large number of bird species, and essential components of many fishery systems.

> **Because aquatic habitats are often small isolated areas within a larger dry landscape, the natural subdivision of populations of aquatic organisms has led to increased genetic diversity and even speciation.**

Wetland areas are profoundly affected by agricultural practices, worldwide. For example, the United States Office of Technology Assessment estimates that almost 80% of the wetlands in the United States were converted to agriculture between 1955 and 1975.

> It is estimated that almost 35% of rare and endangered animal species are in some way dependent on wetlands.

> *For example, in California it is estimated that 60% of the 113 native fish taxa are either extinct, officially listed as in danger of extinction, or in need of special management to keep them from becoming endangered in the near future.*

> *For two river systems in the midwestern United States, it is estimated that 44% and 57% respectively, of the fishes are in similar trouble as those in California.*

Riparian areas provide corridors for migration and species interaction as well as habitat for aquatic and associated organisms. Although agriculture has modified many such areas, the construction of farm ponds and drainage ditches can create habitat to support biological diversity.

Drainage of Wetlands

About 250,000 acres of wetlands per year are drained to claim additional urban land, reduce populations of mosquitoes and other pests, or for use by agriculture. The drainage conversions in the last 20 years has been a major cause of declines in populations of plants and animals dependent on wetlands.

> **The enhancement of vernal pools and farm ponds should become an integral part of policies to improve the rural landscape. Tax laws generally favor conversion of wetlands to other uses.**

Private and public organizations have attempted to conserve habitat for migrating waterfowl through taking land out of agricultural production. Modifications of agricultural practice, associated with appropriate economic incentives, provide a greater potential for waterfowl habitat.

Water Diversion

Increasingly, the world's supply of flowing water is being diverted for human use. The effects of these diversions are many and often complex. In the most extreme, diversions dry up water-courses completely, eliminating aquatic and riparian communities.

> **Flow regimes are usually altered by reducing flows at times of the year when run-off is extreme and diverting stream flows during dry seasons. This results not only in reduced habitat but also in major changes in the quality of habitat.**

Diminished flows in coldwater streams that favor trout and salmon may result in temperature changes that favor nongame species, including introduced species like common carp.

The diversion of limited water from the lower sections of some streams during drought years may leave insufficient water for the passage of anadromous fish, such as salmon, thus reducing reproduction potential even though upstream habitat is suitable. Pumping water from underground aquifers can reduce water flows to natural springs endangering organisms endemic to caves and other isolated aquatic habitats.

Under current policy, maintenance of stream flows must be justified largely on a non-economic basis in many parts of the world.

However, recreational use of streams and other wetlands could be managed jointly by public and private entities with an economic return to the land owner.

Channelization

This action is essentially the process whereby meandering streams are converted into straight-flowing ditches.

The main purposes of channelization are to move water through farmland and urban areas as quickly as possible, to reduce meandering so that stream boundaries are stabilized, and for flood control. The negative effects include modifications of habitats with direct effects on biological diversity.

> There are few documented studies detailing the effects of stream channelization.

It is likely that some past channelization projects could be reversed for the long-term benefit of both agriculture and biological conservation. In other instances, proper management and the development of appropriate structures could provide complex habitat to support greater biological diversity than is currently realized.

Bank Stabilization

Physically altering stream banks to achieve long-term stability is often equivalent to channelization. From an agricultural perspective, it attempts to keep a river in one channel so that the rich soils of the flood plain can be farmed without the problems of periodic flooding. It is also considered essential as a flood control method in urban areas.

Alternatives to bank alterations include creation of meanderbelts and flood bypasses through which water can be diverted during excessive flow. Within flood bypasses, areas with a high risk of annual flooding are allowed to revert to riparian forest while areas with a low risk of flooding can be used for agricultural production.

Meanderbelts on lowland rivers provide outstanding serial and mature mosaics of habitat which can be effective corridors and buffer zones within agricultural land areas.

> Little attention has been paid to what constitutes an adequate buffer zone for various ecosystems.

Livestock Grazing

In the United States, a high percentage of streams flowing through public and private grazing lands have been altered by grazing, resulting in collapse of stream banks and pollution of water through animal wastes.

It is possible to argue that on public lands, there are many situations where the economic value of stream fisheries substantially outweighs the value of livestock. However, this may not justify eliminating livestock grazing from an area without proper analysis of potential social impacts.

Opportunities exist for integrated programs of recreational fisheries and livestock production.

Development of these opportunities will require careful attention to public policy issues as well as biological and economic assessments.

Aquaculture

Aquaculture is a branch of agriculture devoted to the culture of aquatic plants and animals. It is practiced in freshwater, estuarine, and marine environments, with the cultivated organisms confined in a variety of enclosures.

Relatively little attention has been given to the conservation implications of aquaculture, in part because its development in North America and Europe has been relatively recent and as yet relatively small areas are devoted to it.

The clear economic benefits of aquaculture are stimulating a rapid expansion of the industry, increasing the potential of adverse environmental effects identifiable only by speculation, and greater opportunities for fisheries management.

Research Needs

1. Studies are needed on the efficiency of irrigation systems (lined ditches, drip-irrigation, etc.) in different soil conditions.

2. Quantification of flow regimes are needed to understand effects on patterns of fish migration and the needs of aquatic and riparian species.

3. Documentation needs to be made of changes in biological diversity of streams when channelization is introduced, of differences in diversity between channelized and unchannelized streams, and long-term monitoring need to be done of changes in biological diversity of created meanderbelts.

4. Research needs to be undertaken to determine the effects of livestock grazing on biological diversity of riparian habitats and the development of livestock management systems that maintain biological diversity and to control streambank damage.

5. Studies are needed to determine the implications of the domestication of local species for aquaculture, opportunities for fish culture to contribute to fisheries, and the potential use of aquaculture wastes for irrigation of agricultural crops.

6. If foreign fish species are being cultivated, a question arises concerning what effects escapees will have on populations of native species, as well as potential interactions of domestic and wild stocks of the same species.

Section 3: Policy

U.S. INSTITUTIONAL POLICY

A multifaceted approach will be required in order to change the direction and momentum of the current goals, institutions, and programs of U.S. agriculture towards the conservation of genetic and biological diversity. This shift in focus will need to be done in ways that take into account an implied and complementary national goal of developing a more resilient and sustainable society.

We can farm and conserve biological diversity better if we are fully aware of the interrelationships between agriculture and conservation biology. To achieve this better understanding, policy research must concentrate on issues of implementation.

Policy Research

Background research in the social sciences, as well as interdisciplinary research by social and biological scientists, will be needed to facilitate the incorporation of biological conservation practices into agricultural practices.

Research objectives must yield knowledge that, when implemented as policy, will:

Expand agricultural options for adapting to and managing foreseeable environmental changes (such as global climate warming) and for adapting to foreseeable changes in the use of high cost inputs.

Improve the resilience of agricultural systems to a broader range of unforeseeable environmental, economic, and political "surprises."

Enhance the long-term productivity of agriculture.

Broaden the genetic resource base for sustainable agriculture.

Reduce environmental impacts of agriculture on other areas.

Improve the aesthetic appeal of agricultural landscapes.

Improve human welfare, especially in developing countries.

The maintenance of biological diversity per se can be thought of as an immediate objective. But biodiversity can also be thought of as a means of achieving the above objectives.

Ecological Goals

Current policies and programs have not been conceived in terms of ecological goals. At best, specific conservation, anti-pollution, or clean-up programs have been added onto existing programs and policies on an ad hoc basis as particular problems have been identified.

> Post hoc measures to problem solving are analogous to a purely curative approach in medicine: they address symptoms and seek to ameliorate them, often without addressing underlying causes of the problem.

Current policies and programs need to be reexamined to determine the degree to which they reduce or enhance genetic and biological diversity.

New policies and programs need to be developed which will systematically enhance the diversity of rural and agricultural America.

Better ways need to be developed to include full consideration of ecological goals along with the traditional social and economic goals in the policy-making process.

There is natural resistance on the part of vested interests, as well as politicians and research administrators, to doing any sort of social research or technological assessments on the consequences of current policies and programs. It is only natural to resist disturbance to the status quo.

Current paradigms make it easy for legislators, administrators, and researchers to assume that their work benefits agriculture or conservation biology. These paradigms invite complacency and allow vested interests to discourage research which might threatened societal balances by the questions it raises.

Ways in which current policies could be modified to enhance conservation biology without negatively impacting agriculture include:

> **Changing current set-aside policies (designed to reduce overproduction by taking land out of production) to enhance biological diversity both at the farm level and at the rural landscape level by allowing farmers to leave an unharvested field fringe to increase bird and wildlife habitat, and by encouraging crop rotation patterns that include pastures (and thereby more livestock).**
>
> **Expanding cooperative agency efforts on integration of agricultural practice and the conservation of biological diversity in agricultural and forestry programs.**
>
> **Changing range management focus away from its traditional emphasis on livestock toward conservation management approaches which include fish, wildlife, watersheds, and soils, along with livestock.**
>
> **Aligning grazing fee formulas with the values of forage to discourage overgrazing and provide more support for conservation planning, research, and administration.**

In re-examining existing policies or developing new programs, those relating to water and energy should receive special priority.

Strategies to develop sustainable, lower-input and less polluting agricultural systems should specifically include research and analysis of how greater diversity (genetic, population, and habitat) both depend upon and contribute to cleaner water and air, and contribute to human welfare.

Societal Goals

The increasing awareness and concern of the public regarding food safety, nutrition, and healthful diets is leading to increasing pressure for less pesticide residues and to a willingness on the part of the public to pay a somewhat higher price for safer, higher quality food.

A significant degree of support for rural programs among the general public could be developed by emphasizing the beauty and value of a diverse rural landscape.

The market for organically produced foods is growing, offering the possibility of increasing the number of small-scale farms where operations typically involve greater crop and animal diversity than those of conventional producers.

> Because of a three to five year production drop during conversion from conventional to low-input farming, support programs may be needed to assist farmers through this period.

Economic Goals

The continuing pressure to reduce Federal spending and the national debt will drive policy considerations in the coming years. These pressures provide an opportunity for realignment of the economic position of agriculture.

With certain exceptions (such as dairy supports), crop support programs tend to benefit larger farmers over smaller farmers. Since crops like cotton and rice can be grown only in warmer regions, allotments of support payments for them favor specific geographical regions which historically have been favored by large irrigation subsidies.

Tax provisions in the form of tax investment credits for new machinery and rapid depreciation tend to encourage and favor large, capital intensive producers. Large market distortions are caused by oligopolistic structures in grain trading, the broiler industry, the farm implement industry, and banking.

> **Here it is only strong political pressure, rather than budget deficits, which can lead to the tax reforms and vigorous anti-trust measures required to realign the playing field.**

Two additional, broad strategies are worth considering:

> **The first is the separation of support for the family farm from support for the production of commodities.**

One approach is the use of a negative income tax system which would provide a minimum guarantee for farm families with a declining scale of support as income rose.

The advantage in terms of genetic and biological diversity would be less pressure to specialize in order to maximize production of those particular crops which appeared to offer the best short-term prospects. This would tend to level the economics of various crops and allow farmers to respond to market changes more on the basis of the market than the availability of subsidy programs.

> **The second strategy to consider is the creation of new programs which financially recognize the contributions healthy farm practices make to maintaining genetic and biological diversity as well as to soil, water, and air quality.**

While there would still be a need for constraining regulation to prevent serious degradation, a positive support system for "environmental" or "habitat" maintenance would offer farmers an incentive to explore and adopt systems which would reduce a number of significant costs to society at large.

> If we take seriously the ecological goal of developing more adaptive and resilient systems which conserve diversity, we need to re-examine most other aspects of food, agricultural, and rural production policy.

Given the institutional and political difficulties involved in any re-examination of goals, it is important to remember that other powerful forces such as budgetary pressures, international uncertainties, increasing groundwater pollution, and possible climate change, are also urgent pressures on current food and agricultural policies.

Research Needs

1. Assessment of the costs of conservation of biological diversity under current and alternative agricultural practices and policies in the United States.

2. Evaluation of society's perception of the value or importance of alternative rural/agricultural landscapes.

3. Assessment of linkages between biological diversity, agriculture, climate change, and the changing rural landscape, with regard to social policy and institutions.

4. Evaluations of how much and by what means farmers, consumers, and taxpayers are willing to pay for the costs of biological conservation and the development of resilient and sustainable agricultural production.

5. Assessment of how evolution of the Land Grant University system, both organizationally and financially, has affected social and biological diversity of the rural landscape.

6. Evaluation of how the two-tier system of a few large producers and many small and part-time farmers has affected biological habitat and species diversity of the rural landscape.

7. Development of educational programs and data bases to inform the general public concerning true costs of food and fiber production and the value of a strong and diverse rural system.

DEVELOPING COUNTRY POLICY

The wealthy industrial nations (the U.S.A., Japan, and the European Community) exert a major influence on agricultural and biological conservation policy in developing countries through their agricultural, trade, foreign debt, and assistance policies.

Protectionism in the richer countries sharply reduces the ability of developing countries to generate adequate income from the use of their natural resources. Add to this the unpredictable nature of trade regulations and their potential impact on investments, and it becomes clear that developing countries navigate a treacherous course.

For example, Botswana exports more than half its beef output. Two-thirds of it goes to the European Economic Community (EEC), which has a high demand for lean, grass-fed beef. As a result, EEC development aid programs heavily subsidize the beef-export business in Botswana, where cattle are rapidly replacing wildlife.

> A major problem with export crops is that they no longer support the local human ecosystem. Instead, they feed the demands of distant, unpredictable markets by traveling as raw materials, so that the value is added overseas rather than in the country of origin.

Nothing about exportable crops makes them inherently more damaging to the local ecosystem than subsistence crops. If appropriate means are implemented for ensuring that traditional staple crops are also produced, and if export earnings are allocated equitably among the rural people, export crops can be important factors in the overall development of a country.

Development Agency Policies

Each development assistance agency must assess its internal policies and practices in dealing with agricultural issues as they relate to the environment.

Important policy issues concerning agricultural development projects include:

The necessity of a consistent and meaningful process for identification of environmental concerns during project and program formulation, implementation, and evaluation.

Agency follow up on cases where environmental mitigation or compensation may be required as part of the development project.

Agency support of development projects which give full consideration to the larger ecosystem within which the project is found.

Agricultural projects based on principles of sustainability, rather than those which foster dependency on outside sources of essential inputs.

Appropriate market prices for the agricultural commodities being produced.

Projects that support the production of commodities which provide the recipient with a comparative advantage.

> Each nation should outline its approach to various problems in international agricultural policy in a "Foreign Policy on Agriculture and the Environment" publication.

Each nation's foreign policy on agriculture and the environment should state national objectives for both trade and aid in relation to agriculture. It should identify various concerns and seek ways to ensure that the addressing of these concerns is congruent with other national objectives. It should review impacts on the environment both at home and abroad and from exports and imports. And it should review participation in international treaties and programs effecting agriculture and the environment.

Agricultural and Trade Policies

Developed countries enhance the earnings of their farmers through a combination of crop subsidies and trade barriers which limit the opportunities for Third World farmers to compete in First World markets. These limitations both lower the prices received by Third World farmers and reduce the opportunities for Third World countries to earn the foreign exchange they need to repay their debts to the First World.

> **In a sense, the developing countries subsidize importers of their products, incurring important short and long-term costs to themselves and their environments, and compromise their development prospects.**

Obviously, First World countries cannot tailor their agricultural and trade policies to the needs of specific countries.

However, if research indicates that the negative impacts are certain for some groups of products or groups of countries, and if the difficulties of earning foreign exchange are shown to lead to environmentally harmful activities, then appropriate adjustments in agricultural and trade policies should be considered.

Agricultural Assistance Policies

It is becoming increasingly clear that many development programs cannot be sustained over the long-term and often result in significant environmental disruptions.

Since donor's aid programs are managed separately from their commercial trade, private overseas investment, and other multilateral programs, there is often no coordination between the type of flow, its timing and its sectoral impacts.

> *For example, the impact of food aid programs is often in conflict with ongoing food production activities funded by development assistance. Or a trade regime promoted by a donor may encourage natural resources depletion while exacerbating balance of payments and debt problems of the recipient country.*

The performance of lending and assistance agencies is critical to the adoption of sustainable approaches since they play such a key role in the design and selection of development projects and the training of people in developing countries.

> Agricultural development projects must consider the larger ecosystem, including conservation of biological resources.

International agricultural research is currently undertaken through a system of thirteen international research centers whose priorities are established largely by scientists from the developed nations through the Consultative Group on International Agricultural Research.

These centers have recently reevaluated their programs to respond to calls to contribute to sustainable agriculture; in many cases, this will involve giving greater emphasis to agricultural systems instead of cropping systems.

Third World Debt

The interest on Third World debts became so large during the 1980s that it now dominates Third World economic planning. Given the crippling burden of paying interest on external debt, developing countries have found it difficult to worry about conserving biodiversity or implementing new approaches to agriculture.

While this situation is disastrous in some respects, it does offer possibilities for innovation.

For example, conservation groups have purchased Bolivian, Ecuadorian, and Costa Rican debt in exchange for the establishment of reserve areas. Research may identify further opportunities for exchanging debt for biological conservation.

Research Needs

1. Subsidies to cattle ranching in tropical rain forest should be eliminated where they directly affect or facilitate deforestation.

2. The useful life and effectiveness of irrigation projects should be improved by coupling them with forest management on the watershed of reservoirs, thereby providing an opportunity for favorable habitat management.

3. Further policy research is needed on how the principles of conservation biology can contribute to sustainable agriculture and be linked to the reduction, or at least the management, of the debt burden.

4. Greater aid project research is required for the development of integrated agricultural systems through funding of both First World and Third World research institutions.

5. Assessment of import/export policies should be undertaken with the objective of developing innovative policy to curb debt and enhance ecosystem sustainability on a global scale.

COORDINATING DISCIPLINARY AND ORGANIZATIONAL KNOWLEDGE

Our agricultural policy discussions tend to be rooted in the Newtonian paradigm. Typically, we look for single causes and effects. This kind of linear thinking leads to assumptions that agricultural production systems can be modified smoothly from one equilibria to another.

We continually forget that agricultural systems and their elements are in flux.

This mechanical way of modeling agricultural systems is of such a limiting nature that changes in relationships can only be considered on an ad hoc basis.

Conceiving agricultural systems in this Newtonian manner tends to keep our attention focused on the economic effects of alternative agricultural policies on different regions of the globe, and on poorer and richer farmers.

> We do not yet have ways of conceiving and modeling which facilitates our understanding of how agricultural and trade policies affect biological systems.

And yet, elaborate computer models have been constructed which link the agricultural economy to the physical processes of soil loss in the U.S. grain belt. Models have been constructed to examine how climate change will affect the optimum location and productivity of key crops.

Similar models could be constructed to help pursue linkages to the diversity of agricultural environments and to the attractiveness of using biological approaches in the management of agricultural systems. However, such an approach would require unselfish cooperation among social scientists, agriculturists, and ecologists.

Communication Across Disciplinary Knowledge

Many of our models of agricultural systems are rooted in particular disciplines. But biological models ignore the fact that farmers include the economic environment in their management decisions. And economic models of agricultural supply and demand are completely abstracted from biological systems.

> Each scientific mode has a unique perspective on a discipline.
>
> Each perspective, by itself, is incomplete.

In relation to science, each pattern of thinking entails assumptions about the nature of the world which simply must be accepted for one to enter into the world of that discipline.

Disciplines cannot be combined simply by making their boundaries adjacent.

Rather, disciplines are discrete because each has evolved patterns of thought which are determined by different, typically incompatible assumptions. Thus, scientists are usually locked in the "culture" of their chosen disciplines.

Communication Across Organizational Knowledge

Organizations evolve their own ways of perceiving the world through the data they admit or obtain. They also develop their own ways of explaining things based on the mandate around which they are organized and the disciplinary methodologies they emphasize for the processing of data into information.

When it is desirable for agencies to work together more efficiently, or "better", they typically broaden their mutual objectives and mandate the points at which their procedures must interrelate.

> **But even with mandated coordination, articulation will not succeed if the means of perceiving and methods of explaining remain incongruent.**
>
> "Better" ways of interacting in regard to renewable resource systems will entail:
>
> > Opening up of procedures;
> >
> > Expansion of information;
> >
> > Plurality of ways of knowing by all actors concerned.

Each actor in the proposed interaction will have to become tolerant not only of the organizational culture of other actors, but will also have to be adept at coordinating with it.

Governmental Organization and Diversity

Foremost among the concerns for agriculture and conservation biology is the question of whether large organizations can handle diversity.

Will large bureaucracies, like the U.S. Department of Agriculture and the U.S. Agency for International Development, be able to facilitate the technological diversity and cooperation that will be needed in order to protect biological diversity?

> **Will their modes of operating retard or even prevent the conception and implementation of these efforts?**

During the past decade the strengthening of local agencies, through decentralization, has increased public participation. The development agencies have begun to reorganize and change their behavior in response to increased public participation, resulting in the use of non-governmental organizations, and "putting-people-first". Such responses have been an attempt to overcome the tendency of large organizations to neglect local differences.

How can these organizations help promote diversity if they cannot respond to existing differences, and if they are thought to have contributed to the overall process of increasing homogenization?

Societies that are structured to be more responsive to local differences will also probably be better prepared to respond to change and to surprise.

The existence of a variety of programs across regions of the nation and the world would provide a larger menu to choose from in responding to change and surprise. However, the existence of options is not the same as flexibility or the ability to change.

Avoiding Irreversible Decisions

A redundant social structure with checks and balances between agencies and actors is typically more resilient than one in which each agency or actor has absolute say within a given domain of decision-making.

Consolidation of authority results in single attitudes imposing the same decision across all agro-ecosystems.

Checks and balances between and within agricultural departments, wildlife management agencies, county planning departments, and farmers' and community organizations - the very structure we decry as inefficient when we presume there could be perfectly informed planners with the right way of analyzing problems - can be very effective in reality.

Research Needs

1. Studies are needed to determine how multilateral and bilateral agencies might best participate in the coming agricultural changes, how to monitor them, and how developing countries can develop more adaptive planning approaches.

2. Studies are needed to determine how monitoring systems should be enhanced.

3. Studies are needed to determine how research centers could build on the foundations of conservation biology to improve sustainability, shifting research efforts by seeking opportunities to work with national research centers, taxonomic institutions, ethnobiologists, and ecologists.

4. Determination needs to be made of how diverse approaches to research can be integrated at the level of designing agricultural policy.

5. Studies need to be made to determine how the "opening up" of procedures might occur.

6) The historical relation between social organization and the loss of social and ecological diversity in agricultural systems needs to be identified.

7) Ways need to be identified to restructure agencies so that local diversity can be enhanced.

8) The minimal global coordination needs to be identified which would reduce the use of hydrocarbons associated with global climate change without reducing the effectiveness of more decentralized agencies for responding to local conditions.

9) Studies need to be made of the differences between temporal and areal adaptability.

APPENDIX 1

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