Biological Diversity

Its Conservation and Use for Sustainable Agricultural, Forestry and Fisheries Development

An FAO Working Paper
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IDWG Sub-Group on Biological Diversity

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FOREWORD

The imminent loss of global biotic resources through species extinction and ecosystem impoverishment threatens the livelihood of millions of people in the developing world. The social, economic and political pressures created by such a confluence of local and global threats can divide societies into factions, each blaming the other for the problem, and each garnering for itself as much of the finite resources as possible. A deadly form of "prisoner's dilemma" is then played with no alternative but to extract resources from a static nature, to pit utilization against preservation and present against future generations. But alternatives do exist that can remove perceived constraints to conservation and use, and allow the nations of the world to enter more mutually beneficial programmes. The current interest in biological diversity offers an opportunity to develop such alternatives.

Biological diversity is more than a reference to all organisms, it implies the existence of multiple dynamics, values and management systems. It is not a fixed resource, but one that can be increased and managed for ecological, economic and social objectives. It is possible to escape the constraints of this "prisoner's dilemma" since many more options can exist by using, instead of destroying, the dynamic processes of nature. New initiatives are required and mutual cooperation between organizations and countries already active in developing global biological diversity programmes.

This report explores some of the concepts and issues of biological diversity, and suggests cooperative action that may be taken to strengthen the conservation and equitable use of the resources. The unique position of FAO, as an international agency with a wide mandate to conserve and use biotic resources, is recognized.

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EXECUTIVE SUMMARY

Biological diversity is fundamental to human life. It is a basic feature of the general biota, for ecosystems support, water and atmospheric regulation, and commodity production. When genetic variations are lost, specific and potential properties and adaptations are also lost, species are diminished and ecosystem functions impaired.

The global crisis now penetrating public awareness is that genetic variations within important crop populations are being lost, and whole populations, species, and ecosystems becoming extinct at an unprecedented rate and scale.

While losses are inevitable, diversity has been and can be managed by a wide range of human activity, from breeding to ex-situ and in-situ conservation and establishing reserves. Gene level actions can often be affected or managed by different breeding techniques and field management methods can be used to diversify ecosystems. Management by breeding within species can be conducted for different objectives, ecosystem reserves can be managed for different components, and many techniques can be used for a variety of biotic and socio-economic objectives.

A global programme is needed to ensure that the productivity of the biosphere is maintained for all of its values to all of its users, that a broad diversity of its elements is available for the future, and that there is a continuing evolution of the biota and of our interactions with it.

FAO's mandate is to ensure the full utility of biological resources and not to preserve a particular fixed state of diversity. It is therefore necessary to specify what the elements of biological diversity are, how they are influenced (for good or ill) by human activities, and what objectives may exist for their use and conservation.

Biological diversity is a property of a group and encompasses variation among genes, individuals, species and ecosystems, but cannot be measured or evaluated the same way at all levels. Genetic variations are not measured in the same way as variations among ecosystems because they have different properties and their values and uses are different. Biological diversity is also an ensemble of elements that are evolving and dynamic, and not fixed.

The distribution and dynamics of biological systems is such that ecosystem conservation cannot be reduced to conserving genes, nor can gene conservation be reduced to conserving ecosystems. It is necessary to include all levels of biological organization in the objectives of a conservation programme and no one level is sufficient for any other.

For highly valued species and those with potentially high value in the near future, breeding for species survival or commoditiy production is a feasible way to manage biological diversity. The expense of these efforts limits them to plants, fish, and animals with a high direct utility value, and diversity among advanced lines is needed for breeding these commodity species. For many crop species, testing and enhancement are not extensively available and the diversity of less well-known materials from random or wild collections or explorations can be directly used.

For longer-term values, breeding objectives are less certain and more diverse traits, performance characteristics, and genes are needed. For present and future needs, enhancement, evaluation, and exploration of a wide breadth of diversity is essential. Pre-breeding can also enhance adaptability for different environmental or economic demands and can differentiate populations to generate more useful diversity within crop species.

For the vast majority of species, intensive genetic management is not practised. Nevertheless, even mild selection in systems of natural regeneration, if persistently applied, can increase as well as decrease intra- and inter-population variation. Even without direct breeding, substantial control of population level can be exercised by ecologists or land managers.

For long-term values and multiple objectives, survival and differentiation requires managing for more variation and with larger populations (Soulé, 1987). "Ecological management" is not necessarily less intense but is usually more extensive and can increase as well as decrease diversity. The least intensive methods, such as excluding human intervention in reserves, can as easily decrease diversity as increase it. Hence, while it is clear that a network of reserves is a useful management tactic, various levels of intensity and types of management methods can be used to increase and decrease the utility of diversity for short- and long-term values. Loss of diversity can sometimes be reversed and management therefore involves integrated programmes with different time perspectives, including techniques for managing different levels of diversity among multiple areas.

There will inevitably be conflicts between users at multiple levels. For example, the diversity in tropical forests that is locally useful may not be useful for recreation, wildlife, or watershed values, and plant diversity on marginal agricultural lands, important for future breeding, may not be significant for immediate crop production.

Agriculture has historically evolved the most elaborate system for exploring, collecting, characterizing, testing, evaluating, enhancing and breeding advanced varieties. It selectively screens out diversity as more stringent requirements are imposed. However, means exist for increasing, as well as for losing, genetic diversity in every stage of varietal development from reserve management to line breeding. For forest trees, much the same array of techniques can be employed though differences will exist mainly at the stage of final varietal development. Animal systems have not historically developed as elaborate a system for the breeding utilization of the wider levels of biological diversity, while fisheries are still largely dependent on relatively unmanaged levels of diversity. Thus, mixtures of agronomics, forestry, animal production, ecology, and wildlife management require higher levels of management in each discipline as well as integration across disciplines.

The broad view of biological diversity provides us with more options to manage total diversity, but also requires a broader integration of management techniques. In-situ conservation of plant genetic resources requires targeting by geneticists and management by ecologists. Reserve management may require targeting by taxonomists and restoration by breeders. A strong focus on biological diversity will have major impacts on how the biological sciences are applied.

In addition to the economic, sociological, and political issues, there are critical legal issues involved. Not only do existing national laws require re-examination, but international legal instruments can be thwarted or abetted by the legal implications of stated national policies and programmes. Assistance is therefore needed in interpreting and drafting legally-binding documents and legal research is needed to help develop model instruments for national and international bodies.

The present mix of national laws and international agreements on genes, crops, trees and shrubs, vegetable and animal products, and ecosystems requires some codification and any new agreements should be drawn in a way that assists in policy development.

Since the parts of the system for managing biological diversity usually lie in many countries, international cooperation and supra-national organizations are needed within sectors to share techniques, costs, and benefits for effective management. With wider access to materials and the possible implications of other global changes, even more cooperation and joint efforts will be needed in the future.

Inter-sectoral effects often cross national boundaries, as when inland forest clearing affect water and fish resources elsewhere. Hence, international coordination and programmes will be needed. Therefore, means for addressing cross-national issues that affect resource use must also address biological diversity issues that may cross sectoral divisions.

The condition and management of the biotic resources upon which productivity is based is necessarily within the scope of FAO's agriculture, forestry, and fisheries programmes. An FAO policy therefore appropriately arises from the use of biological diversity, including present and future utility, consumption values and commodity and non-commodity values.

FAO's mandate provides a broad basis for conserving and using biological diversity in all its forms. It is the only agency with an organizational structure encompassing a wide array of programmes that seek to maximize the total utility of biological diversity and maintain a global perspective on species and action priorities. The Global System on Plant Genetics Resources, with its International Undertaking, Commission and Fund, can also be a conceptual framework for other genetic resources.

For agricultural plant production, it would be useful to formalize an international programme for the whole system of utilizing intra- and inter-specific diversity so that targets and priorities for collection, characterization, testing, enhancement, and breeding can be coordinated. For forest trees, more rapid breeding and testing of source populations of species, and much wider testing of potentially useful species would serve to bring more of the biota into production.

For animals, the use of wider sources of genetic variability for different environments, and for local adaptabilities and cultivation systems could be assisted by a global programme on species and hybridization trials.

The use of semi-wild species for either domestication or ranching purposes could also be genetically linked to production systems using traditional species, and wider use could be made of the potentially useful animal diversity. The need for managing biological diversity of non-consumption species is as great as for domesticated animals. The roles that domesticated as well as wild species play in economic development and the efforts required to manage their diversity require clarification.

In addition to providing a global perspective, FAO is charged with assisting national efforts in all of these areas and hence must help to develop programmes within nations to coordinate the development of their biotic resources and the flow of materials into use. There is a critical need for systems of field management, and political coordination that crosses traditional sectoral boundaries. Efforts to assist cross-sectoral management of biological diversity are needed as much among as within nations; FAO must develop programmes and means to adjudicate between nations.

There is a lack of infrastructure to manage and use biotic resources within developing countries and even in many industrialized countries. As intergovernmental mechanisms to deal with supra-national biological diversity issues are weak, both intra-national and international programmes are difficult to develop and maintain for the kind of broad and long-term programmes needed for the conservation of biological diversity.

Action programmes developed within sectors, and for inter-sectoral problems will require substantial research support in the biological sciences, as well as in economic, legal, and political mechanisms. In the sciences, research on rapid breeding and evaluation is needed as well as on basic population dynamics and conservation biology. The economics of resource use and intra-national and international means for developing basic biological resources for the common good also need research and development.

In order to practise what is already known and to apply the new knowledge needed, a vast expansion of training and education programmes on biological diversity is needed both within sectors and in the emerging fields of conservation biology and integrated use. This includes support for short-term programmes in conservation, and long-term programmes in basic population biology, genetics and breeding, and in ecology and systematics, to name but a few of the traditional disciplines. Broader education of the public and public leaders is also needed to develop public support priorities for programmes on biological diversity that directly apply to the dire problems that threaten the globe.

It is unique to FAO that its policies and programmes on biological diversity are defined in agreement with its member nations. Given its broad mandate related to conservation and use, FAO must assert global leadership in biological diversity for the international community.

ISSUES HIGHLIGHTS

ISSUE ONE - The biotic heritage of humanity is being abused to an extent that the basis of human progress itself is jeopardized. Massive extinctions and ecosystem collapse are predicted, and the evolutionary dynamic that produces the diversity of life on which we depend is threatened. Yet much more than species preservation is required if the biota are to continue evolving and be of benefit to humanity. The conservation and use of biological diversity requires that it be managed, protected, and developed.

Since biological diversity is part of an ensemble of elements that vary and are evolving, it cannot be preserved as a fixed property nor can it serve as a fixed target unless the processes that evolved diversity are abrogated. To ensure the full utility of biotic resources, it is necessary to specify how the various elements of biological diversity are influenced for good or ill by human activities, and what objectives exist for their use and conservation. Then, by direct and indirect management, it is possible to ensure the productivity of the biosphere for all its users, so that a broad diversity of its elements is available for the future.

ISSUE TWO - Biological diversity encompasses variation at the molecular, individual, population, species, and ecosystem levels of biotic organization, and each level has different properties, uses, and management systems. A variety of management tactics can be used to affect the structure and levels of biological diversity including intensive breeding as well as establishing strict nature reserves. However, since all levels of biotic organization are inter-related, management effects must be coordinated.

While some losses are inevitable, diversity can be managed through a wide range of activities. For example, gene level variation can be increased by breeding populations for different objectives and ecosystems can be diversified by selecting different reserves or by diversifying managed areas. To ensure the continuing evolution of biological diversity, the structure of variation among and within units must be managed. Management may include intensive breeding ex situ for high value products and non-intervention in strict nature reserves. When local extinction is likely or product values are high, ex-situ methods will be affordable. When ecosystem services are required and when non-use and long-term or uncertain values exist, in-situ methods will be used. The protection of strict nature reserves to ensure future options for their own existence, for research and for use, is one of the management tactics available. Management directed at one level of biological diversity affects all levels of the biota. Since gene level management affects the structure of species and the stability of ecosystems, and ecosystem structure affects genetic variation, it is necessary to include all levels of biotic organization in the objectives and management of conservation, and one level of management is not necessarily sufficient for any other level.

ISSUE THREE - The development of species for utilization includes intensive selection, enhancement and other pre-breeding activities, evaluation, and testing, in addition to collection and characterization as critial phases in the development and use of biological diversity. For many species, intensive genetic management is not practised but ecological management can be used to increase biological diversity. Broad programmes of conservation and use of biological diversity are required for the efficient utilization of species and should be systematized.

Species that are highly valued, either for commodity production or for their existence values (such as some endangered species), justify the development of breeding programmes. In agriculture, systems exist for exploring, collecting, characterizing, testing, evaluating, enhancing and breeding advanced varieties. At every stage of varietal development, means exist for increasing as well as losing biological diversity. For more variable and less controlled ecological and economic conditions and for long-term objectives, greater diversity is needed among individuals, populations, species, and ecosystems. For many crop species, if testing and enhancement are difficult, the diversity among random or wild collections may be more directly useful, and for long-term and uncertain future needs, selection for divergence among populations can generate more useful diversity than currently exists.

For plant production, an international programme for the whole system of utilizing intra- and inter-specific diversity under the Global System on Plant Genetic Resources should set targets and priorities for collection, characterization, testing, enhancement, and breeding. For agricultural crops and for forest trees and shrubs, much the same array of techniques exist, with some differences in the final stages of varietal development.

For agricultural and forest production, programmes should be developed to advance the use of more rapid breeding and testing of source populations and species, and to more widely test potentially useful species to bring more of the biota into production. Animal development systems have not elaborated as extensive a system for utilizing the wider levels of biological diversity, and fisheries are still dependent on relatively unmanaged levels of diversity. For these, the use of wider sources of variability for different environments and for local adaptations could be aided by a global programme on species and hybridization trials.

Intensive genetic management is not practised for the vast majority of species, but even mild levels of selection in separate mating demes can affect the level and allocation of variation among and within populations. For long-term values and for divergent use objectives, managing for increased diversity among large populations is required. "Ecological management" may be required that, though not necessarily less intensive, is usually more extensive and is susceptible to decreasing diversity. Management, therefore, requires integrating short- and long-term programmes and techniques that affect multiple levels of diversity among multiple areas.

<u>ISSUE FOUR</u> - Biotic effects extend across species and sectoral boundaries, and management effects on one can be beneficial or detrimental to the diversity of other species, sectors, and levels of organization.

There will inevitably be both beneficial and harmful effects of management on biological diversity and its users within one sector on others. The diversity in tropical forests that is locally useful may not be useful for recreation, wildlife, or watershed values, and plant population and species diversity on marginal agricultural lands that may be important for future breeding may not be significant for immediate crop production. The management of one area would then impact the diversity of another, and a higher level of integration among agronomy, fisheries, forestry, animal production, ecology, and wildlife management systems is required. Inter-sectoral effects also often cross national boundaries, such as when inland forest clearing affects water and fish resources elsewhere. Therefore, international coordination and supra-national programmes for inter-sectoral management of biological diversity are needed.

ISSUE FIVE - FAO's mandate to ensure the full utility of the global biotic endowment requires it to assist in developing a globally coordinated programme to halt the erosion of biological diversity, to ensure its continuing evolution, and to ensure that biotic productivity is enhanced for the benefit of all people. International cooperation and supra-national organizations are needed within sectors to effectively share techniques, and to fairly allocate costs and benefits of the effective management of biological diversity.

The Global System on Plant Genetic Resources provides a framework for developing effective conservation and use programmes. Within that framework, FAO should assist nations and, through international cooperative agreements, establish crop advisory committees and identify gaps and priorities for developing productive uses of genetic diversity, especially in the testing and pre-breeding phases of crop development. Useful diversity at the various levels of biotic organization should be increased to ensure present and future utility. Intersectoral planning and management are also needed to ensure the coordinated development and use of the total array of biological diversity, and a United Nations perspective must be developed. To this end, FAO should assist nations and, through international cooperative agreements, develop means to adjudicate conflicts and foster cooperation between sectors. FAO must assert global leadership to develop a globally sufficient set of programmes for all nations. A vast expansion of training and education programmes on biological diversity and its supporting sciences, and broader education of the public and of public leaders is needed.

FAO must provide broad, integrative programmes for conserving, developing and using biological diversity in all its forms, and must provide a supra-national organization structure for programmes that seek to maximize the total utility of biological diversity and a global perspective on species and action priorities. It could convene a meeting of all agencies concerned with biological diversity to define goals and objectives, and initiate global coordination of their multiple efforts. In addition to providing a global perspective, FAO must assist national efforts within sectors and efforts to coordinate the flow of biotic materials.

There is also a critical need for systems of field management and political coordination across traditional sectors, and for such coordination among as well as within nations. Critical legal issues will be involved and will require mechanisms to adjudicate. Presently existing laws require reexamination, and assistance is needed in drafting and interpreting international laws and conventions. Legal research is needed to develop model instruments for national and international bodies. A vast expansion of training and education programmes on biological diversity and its supporting sciences is needed, and a broader education of the public and public leaders in developed and developing countries.

I. THE PROBLEM

Diversity of life forms is necessary for the continued existence of the global biota and for human survival. It is not a luxury. Some species directly provide food, fuel, and shelter; others provide indirect values by supporting water and atmospheric ecosystem services and many non-commodity values. Even considering only commodity values, a diversity of species and genetic variations are required to provide the goods and services used. In the constant struggle to increase yields, or to combat pests and adapt to changing environmental stresses in fields, forests, and waters, variation is necessary.

As stated by Prats-Llaurado (1989),

> "Today, it is generally recognized that the Earth's biological diversity is a major global resource. This resource is increasingly perceived as a common value, and its conservation as a common responsibility. The reduction, caused by man, of this human heritage has emerged as a matter of great public concern and as an important international issue."

If the diversity of species is reduced, their ecosystems are reduced, their direct utility is lost and both local and global opportunities to develop potential foods, medicines, and other options are foregone. Similarly, if significant populations of a species are lost or their genetic variations otherwise diminished, not only are specific properties lost from that species, but the potential to adapt to new conditions or to increase productivity is reduced. In addition, their effects on other species are lost and if key species are lost, whole ecosystems can collapse. By removing tree cover, for example, under-story vegetation and dependent animals may not survive, soil fertility can decline and erosion can further affect adjacent and down-stream ecosystems.

There is now global awareness that not only are genetic variations within important crop populations being lost, but whole populations, species and ecosystems are becoming extinct at an unprecedented rate and scale. At an estimated loss rate of 11.5 million ha per year of tropical forests (Lanly, 1982), and the degradation of dry land and other fragile ecosystems, a loss of 20-25% of all of the world's species over the next 20-30 years has been predicted (Simberloff, 1986). Temperate zone ecosystems are also being degraded and with a global intensification of resource consumption, we are in the midst of a vast reduction in biotic diversity.

Under present conditions, if the biosphere is to support the broad demands for goods and services that will increase at least as fast as populations increase, it will have to do so with fewer biotic resources. If the destruction is not contained within the next 10 to 20 years, the resource base of variability at the gene, population, species, and ecosystem levels will be so reduced that, not only will further collapse be likely, but present levels of production will be unattainable, and our ability to respond to any new challenges will be critically impaired.

Our traditional production and consumption patterns have led to these abuses of biotic resources. This is a problem in developing countries and has been part of the economic development of the industrialized world where ecosystem losses due to agricultural, industrial, and urban pressures continue. However, the current focus of attention is on the remaining areas of the richest species diversity in the tropics and sub-tropics, where there is most pressure on ecosystems and extinction rates are highest. While the type, source, and effect of the threats to biological diversity differ around the globe, there is now a common awareness that the effects of local biotic catastrophe are globally shared. When forests are removed, hillsides are denuded and waterways are silted affecting hydro-power, fresh water fisheries, marine ecosystems and may even affect global climatic patterns.

The origin of current problems is condensed by Prats-Llaurado (1989):

> "There was a time when the world's farmers used thousands of different seed varieties developed over centuries by their ancestors. At that time, the survival or extinction of almost every wild form of life on the planet was a consequence of the laws of nature alone. Today, the survival of such a rich diversity of genes, species and ecosystems is threatened by human interventions ranging from the widespread use of uniform commercial seeds to the conversion of forests to man-made landscapes. There is general consensus now that this negative trend must be reversed. But there is disagreement, even confrontation, as to the policies to be adopted and the activities to be carried out."

However, diversity can be positively influenced by human activity. Humans have not only created useful products from natural biota by managing genetic variation, they have sometimes created more useful diversity than previously existed. Gene level actions can often be affected or managed by different breeding techniques and field management methods can be used to diversify whole ecosystems. Management by breeding within species can be conducted for different objectives, ecosystem reserves can be managed for different components, and many techniques can be used for a variety of biotic and socioeconomic objectives.

By intensive management or by non-intervention, both increases as well as decreases in biological diversity can be achieved, and can affect the public in different ways. Unmanaged reserves may actually lose species richness and carry high opportunity costs, while breeding for industrial agriculture may also adversely affect societal welfare. The technical and financial resources available to affect management are not equal and, hence, what is valued in biological diversity, how it can be managed, and for whom, are critical issues. While all people benefit from the availability of natural resources, conflicts exist as to its use and management, and all people suffer from the lack of developing the resources.

In addition to the technical and biological problems, there is a lack of human and financial resources to manage and use biotic resources within developing countries and even in many industrialized countries. Intergovernmental mechanisms to deal with supra-national biological diversity issues are weak. Hence, both intra-national and international programmes are difficult to develop and maintain for the kind of broad, long-term programmes that are usually needed for the conservation of biological diversity. Strengthening existing programmes may not be sufficient and new biological, economic and managerial systems may be needed just to halt the accelerating loss of biological diversity. Therefore, a global programme is needed to develop and coordinate the broadest possible conservation and use of biological diversity to ensure that the productivity of the biosphere is maintained for all of its values to all of its users, that a broad diversity of its elements is available for the future, and that there is a continuing evolution of the biota and of our interactions with it. The mandate of FAO is to ensure the full utility of those resources and not necessarily to preserve a particular state of resource distribution. Therefore, it is necessary to specify what the elements of biological diversity are, how they are influenced (for good or ill) by human activities, and to choose objectives for their use and conservation.

II. BIOLOGICAL DIVERSITY

Biological diversity is usually broadly defined (Prats Llaurado, 1989). The US Congress (Office of Technology Assessment, 1987) defines it:

> "Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequency. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus the term encompasses different ecosystems, species, genes, and their relative abundance."

FAO defines it:

> "Biological diversity denotes the variety of life forms, the ecological roles they perform and the genetic diversity they contain (Wilcox, 1984). Genetic diversity occurs at gene level (the molecular level), the individual level, the population level, the species level, and the ecosystem level."

The inclusiveness of the definitions recognizes the interrelatedness of biotic elements within, as well as between, levels of taxonomic organization, and requires a diversity of programmes to ensure its conservation. The breadth of biotic elements and their different uses and values included in the definition also creates a multiplicity of inferred meanings for biological diversity.

To avoid ambiguity in defining agency goals and programme objectives for biological diversity, a definition is required that recognizes the biological dynamics involved, the factors that influence the creation, maintenance, and use of diversity, and how agencies like FAO can influence its management. It is also necessary to establish objective measures of diversity that are related to its values so that priorities can be set, the efficiency of actions can be evaluated, and agencies can be held accountable for their actions.

Properties of biological diversity

Obviously, diversity is a property of a group and not of individual elements. Diversity itself may be valuable, as when mixed genotypes in a field out-perform a monoculture, or for aesthetic reasons, or when multiple species are necessary for ecosystem functions. However, its value often emerges in processes that use variation such as in selective breeding among genotypes or populations where the value of diversity lies in creating variations from the particular biotypes that can be developed. The value of a released variety, for example, is attributable to the variations needed to derive that product, but diversity is not necessarily a property of the final product. While diversity encompasses variation among genes, individuals, species, and ecosystems, it cannot be measured or evaluated the same way at all levels.

The difference between genes is not measured the same way as differences among ecosystems because they have different properties, and the value of genes is different from ecosystems. Further, there are at least two different kinds of values that we place on diversity. One is on its utility for present or future expected values, and another is on the inclusiveness of biotypes either because they may ultimately be useful or because uniqueness or existence is valued in itself. For each kind of value, different measures of diversity exist (Magurran, 1988) and in some cases, it may be possible to combine different levels of biological organization into a single measure of diversity (Pielou, 1975).

In general, the meaning and measures of diversity vary according to the properties of the organisms and the values placed on them. For some purposes, the utility of diversity will be reflected in a measure of means and variances, and agencies may strive to fit the variation to anticipated needs. For other purposes, the sampling and development of extreme or unique biotypes may be sought and measures of inclusiveness are needed. When much is known about the organisms, then specific types can be targeted for maximizing the value of a collection, but when little is known, then the biotypes have to be sampled more randomly, and large numbers may be required.

Since biological diversity is a property of an ensemble of elements that themselves vary and are evolving, it cannot be a fixed property that can be preserved nor can it serve as a fixed target unless the processes that evolved the diversity are abrogated. At the level of the gene, there are an infinite number of allelic types that can exist, given the vast number of base-pair substitutions that can be made. Hence, to sample all the types that ever were or ever will be, is impossible. Therefore, we can only consider how a collection can ensure certain probabilities that alleles of some initial frequency will exist for some length of time (Namkoong, 1988).

Similarly, at the level of the species, there are multiple states of subdivision and selective differences among populations that may have existed in the past or may yet exist. At any one time, the dynamics of genotypic frequency change, population growth, and interspecies interactions, may be serving to either homogenize or diversify populations. What exists today, or 200 years ago, or 2 000 years ago is not, a priori, an ideal state.

Extinctions are obvious reductions in diversity, but local extinctions can be parts of a dynamic that ultimately increases diversity. In fact, in vegetational succession systems, local extinctions are an integral part of the progression of species abundances that often generates a maximum species richness during secondary succession stages. In such systems, there rarely exist a stable composition of species and, at least for the many pioneer and early secondary succession species, the prohibition of disturbances could mean system-wide extinction.

Thus, while we acknowledge our dependence on diversity and the fact that the evolution of genes, individuals, populations, species, and ecosystems are intricately and dynamically interwoven, there are no "naturally" defined fixed objectives for diversity. Obviously, saving everything is impossible, and saving only the immediately useful is self-defeating. We can, however, define some of the values that we attribute to diversity and can approach objectives for conserving biological diversity and its evolution that can help guide programmes.

Values of biological diversity

Many kinds of values exist in variations at all levels of biotic organization, but can be roughly divided into two major categories: use, and existence values (Norton, 1987). While not denying existence values, FAO's mandate emphasizes human benefits and hence, only use values are considered in this report, and these can be again roughly divided into immediate uses, long-term utility options, and non-commodity uses. Hereafter, we refer to this broader sense of use to imply that utility values for all types of use can be included. The immediate use values for biological diversity include the genetic variations needed to produce economically useful biotypes, particularly among the species already used and therefore of foreseeable economic utility. These are the values that most concern breeders. The utility option values are those that exist for some biotypes in their potential future use as substitute crops, or as producers of value on lands or in ways not presently used. These are significant for sustaining productivity for the distant future and for combating environmental and biotic stresses that are not easily predictable. The non-commodity use values exist for biotypes that do not directly produce consumption goods but that sustain the rest of the biota by either unique or general functions and for which variation is necessary.

The immediate utility of diversity is usually associated with intensively-managed systems, such as breeding where the development of advanced lines or varieties depends on genetic variation within or among breeding populations. Variation <u>per se</u> is also useful when monocultures are not desirable in fields of crops or when an ecosystem is buffered by the existence of genetic, demographic, or ecological diversity. Thus, diversity is both directly and indirectly useful and requires that the variations are in a form, time, and place available to managers. For breeding, this often requires not only collecting the extant variations (Kloppenburg, 1988), but also characterizing, testing, and pre-breeding so that the development of improved varieties from different source populations is economically feasible (Kannenberg, 1984). For these purposes wide, random collections of extreme biotypes are not as useful as targeted collections for predictable needs.

For longer-term utility, diversity among species can be valuable, especially where new species or remote relatives of well-known crop species may ultimately be useful as substitutes in case of disaster, or for new sites or products, or when their economic value is insufficiently developed. To actually bring such species into practical use may require more exploration and characterization than needed for biotypes that are already partially known, but they too require evaluation and some degree of pre-breeding. For many species of both immediate and long-term utility, rapid and efficient evaluation and pre-breeding are needed to make practical use of any diversity that may be collected (Goodman, 1985).

For non-commodity values, diversity also has direct and indirect uses. Directly, variation itself may be important for water production and control, amenity, tourism, and for other products that may not be assignable to a particular biotype. Indirectly, variations among insect and fungal decomposers, pollinators and mutualists, competitors and pathogens, for example, are needed at some level to avoid a collapse of ecosystems. However, it is not sure that maximizing species numbers always increases value, or that an optimum form of diversity can be defined. While the desired variation among biotypes is certainly much wider than for direct utility, the value of conserving all unique biotypes is difficult to define. Since evolution of genes, populations, and ecosystems are dynamic systems and the utility of biotypes varies with their uses, the conservation of biological diversity lacks biologically and economically simple objectives. Attempts to impose simplicity could only misdirect efforts towards unachievable goals.

The distribution and dynamics of biological systems is such that ecosystem conservation cannot be reduced to conserving genes, nor can gene conservation be reduced to conserving ecosystems either in principle or in practice. It is therefore necessary for all levels of biological organization to be included in the objectives and measures of a conservation programme, but no one level of conservation by itself is sufficient for any other level of the biota.

While difficulties exist in defining an exact goal, the need for conserving diversity and evolutionary processes for present and future production systems is clear and pressing. There are many common programme elements among agencies devoted to preservation, conservation and use of biological diversity. The full benefits from the world's biological resources are not being realized and future possibilities of their use are being foreclosed as they disappear. The problem is to discern which resources are most critical to conserve and how to ensure a continual productivity of the biota. A management objective can be to increase diversity, in addition to its uses for generating other values.

Managing biological diversity

Whether we avoid actions that we believe can adversely affect biological diversity, or intervene in population dynamics, we institute a de facto management system on the transient state of a dynamical system. We have choices regarding the objectives and methods of management, and the degree to which active versus passive interventions should be used.

In one sense, the conservation of biological diversity and its utilization cannot be simultaneously satisfied. If the world is viewed as a conflict between human extractions from a natural, stable, and complex present, then human use is counter-poised in a struggle against nature and future uses. The management objective for biological diversity would then be to preserve as much of the remaining natural world as possible in a zero-sum game between users and preservers.

However, the present massive levels of extinctions and habitat loss are extraordinary and disastrous for present and future generations. The preservation by non-intervention in remnants of ecosystems is not justifiable on the grounds of nature conservation; if humans are viewed as a part of ecosystems, then present and future uses and ecosystem functioning are not necessarily in conflict. Humans have increased, as well as decreased, diversity at all levels of biotic organization and the present threats to biotic resources might best be met by using methods to increase diversity when needed, or merely to maintain it.

With the possibilities of managing biological diversity by direct genetic control (such as through breeding), and by natural area management (such as through damage or harvest control), broad choices exist for simultaneous conservation and use. Natural preserves can play a significant role in maintaining and protecting portions of biological diversity for immediate as well as future uses, but preservation in such cases is a management tactic, not an objective. More active and direct management can affect the level and form of biological diversity in a predictable manner but only of a relatively few species of direct economic importance. Therefore, good management requires an assortment of tactics and techniques applied to different levels of biotic organization, for an array of objectives.

For different institutions and nations, the relative values of inclusiveness and utility will not be identical, nor is the effectiveness of in-situ and ex-situ tactics the same. Each evaluator can obtain different estimates of the total value of increasing diversity by sampling new areas or species, by managing reserves, or by intensive breeding. When evaluations are similar, concerted action is possible, but when dissimilar, independent action is more likely to succeed. For many nongovernmental, governmental, and supra-national organizations active in biological diversity, it is likely that substantial differences in their evaluations and priorities exist, as well as in their capabilities for exercising different management techniques. It is then necessary to form different coalitions for action programmes.

To fulfill its mandate to utilize biotic resources in the broad sense, FAO places heavier emphasis on utility values than do agencies devoted more to existence values. It is appropriate that FAO take a leadership position on ensuring the utility of biological diversity. This does not deny the validity of other values nor the importance of long-term uses of biotically inclusive programmes, but requires that their ultimate utility be defined. Agencies that emphasize existence values and give high priority to inclusiveness can have different value functions than FAO, promote different management systems, and give priority to different portions of the biota. If diversity itself is an objective, in addition to its value for improving the productivity of the biota, then closer cooperation between agencies can be expected.

III. METHODS FOR CONSERVATION AND USE OF BIOLOGICAL DIVERSITY

For highly-valued species and those with high potential, captive breeding for species survival or breeding for commodity production are forms of managing biological diversity for utility. The expense of these efforts limits them to plants, fish, and animals whose direct utility justifies the effort. In the elaborate breeding systems established for the major crop plants, minimum and optimum levels of variation among specific alleles and traits can be defined. The most frequently used material for advanced breeding of the major crop species are the advanced lines themselves. Since these are usually limited in their sample of alleles, the most readily useful diversity is among tested and enhanced lines or populations. Useful variations among population performance characteristics can be made available by sampling among different populations or by breeding for different performances, or both (Brown et al, 1989).

Testing and enhancement are not extensively available for many of the so-called "minor" crop species, and the diversity among less well-known materials from random or wild collections or explorations are directly used. Even without testing and pre-breeding, the direct use of diversity among wild species may be of high value. For example, for tropical forestry, previously untested species or source populations may be useful alternatives to presently used, but less productive, varieties or may be used on previously unmanaged land. For long-term values, breeding objectives are less certain, and more diverse traits, performance characteristics, and genes are useful.

For immediate objectives, the value of specific genes and traits can be described and the span of useful variation specified. Therefore, immediate production and survival objectives may only need variations sufficient to ensure a single generation's survival, while long-term productivity requires enhancement, evaluation, and exploration of an increasingly wider breadth of diversity. Thus, a single population of a few tens of individuals may suffice for short-term survival and even to avoid inbreeding depression for a few generations, but multiple source populations of large size will be necessary for longer-term productivity. For more diverse needs, multiple varieties may be needed even for immediate breeding purposes. If diversity among populations, species, or ecosystems is an objective of management, then farm, field, and fishery management will reinforce the need for genetic diversity at those levels.

Intensive genetic management is not practised for most species. Nevertheless, even mild selection applied in systems of natural regeneration, if persistently applied in separated mating demes, can affect both intra- and inter-population variation. By selecting different areas, a population sampling is imposed, and by habitat management, including controls on land use, type of protection against fire, pathogen intensity, differential survival and reproduction are affected. More directly, by thinning and harvesting regimes, the removal schedule can strongly affect population evolution and by planting or moving reproductive individuals, the recruitment schedule is managed. Thus, even without direct breeding, substantial control of population level is exercised by ecologists or land managers, if often inadvertently.

For long-term values and for wider, multiple objectives, longer-term survival and differentiation requires managing for more variation and with larger populations (Soulé, 1987). "Ecological management" is not necessarily less intense but is usually more extensive and can increase as well as decrease diversity; the least intensive methods, such as excluding human intervention, can as easily decrease diversity as increase it. Hence, various levels of intensity and types of management methods can be used to increase and decrease the utility of diversity for short- and long-term values.

The management of biological diversity, therefore, includes integrating techniques for different levels of diversity among multiple areas. To face immediate threats to whole ecosystems, species, and populations, a network of reserves would be a useful element in a management programme. However, many other values are derived from biotic diversity and management plans must include if and how they are to be served by reserve techniques.

While it is easy to overestimate the reliability of intervention techniques and to ignore the often unanticipated effects of active management, the utility of unmanaged systems is also debatable unless clearly tied to direct values or to long-term development programmes. A benefit of embedding specific programmes, like reserve networks, within a broader management programme is that the mutual support of development agencies and conservation organizations is then based on explicit value functions and a degree of mutual accountability can be developed.

There will inevitably be conflicts between users at multiple levels. For example, the diversity in tropical forests that is useful for Amazonian Indians may not be the same as the diversity sought by other Brazilians or ecologists. The genetic diversity useful for timber production may not be useful for recreation, wildlife, or watershed values, and plant diversity on marginal agricultural lands important for future breeding may not be significant to present crop production. Solutions may involve economic and political compromises on the degree of use or non-use, while some may require a separation of activities. When land uses can be segregated then boundaries can be set for different management purposes. When ex-situ gene conservation is possible, seed collection can substitute for field conservation. A broad view of the uses of diversity can provide a basis for allocating costs and benefits in different parts of a biological diversity system, whereas a limited view of competing land uses can lock contestants into a zero-sum game.

While it is possible to combine many different management techniques on genes, populations, and ecosystems to apply intensive gene management to some populations, and extensive ecosystem management to others, this mixture of agronomics, forestry, ecology, and wildlife management requires higher levels of management planning in each discipline and much higher levels of integration across disciplines. Thus, while a broader view of biological diversity creates more options to manage the total diversity, a broader integration of management techniques is also required. In-situ conservation of plant genetic resources requires targeting by geneticists and management by ecologists. Reserve management may require targeting by taxonomists and restoration by breeders. There can be major impacts that a focus on biological diversity induces on how the biological sciences are applied.

In addition to the economic, sociological, and political issues involved, there are critical legal issues involved. Not only do existing laws require re-examination, but proposed conventions can be thwarted or abetted by the legal implications of stated policies and programmes. Assistance is therefore needed in interpreting and drafting legally-binding documents and legal research is needed to help develop model instruments for national and international bodies. The present mix of national laws and international agreements on genes, crops, vegetable and animal products and ecosystems requires some codification, and new agreements should be drawn in such a way that policy development is aided.

Agricultural plants

In pre-industrial agriculture, the traditional development of useful crops included local explorations, observations and trials of plants that could be used and cultivated. Of an estimated 5,000 potentially edible or otherwise useful plant species, a few hundred are now used and a few tens of species account for most of the global food intake. These latter few are amenable to breeding techniques, and yield well on arable sites. Modern genetics has also enabled breeders to continually improve the economic efficiency of crop production through yield increases, resistances and special site adaptabilities. The higher levels of performance of improved varieties has required more refined testing and efforts to segregate ever more finely distinguished differences among genotypes. This has often resulted in longer and more expensive development cycles, and has reduced the economic accessibility of source populations that are not already near the performance levels of the advanced lines. Thus, the actual appearance of what is termed exotic germplasm in newly released varieties in the United States, for example, is only a few percent for the major food crops (Cox et al, 1988). While the few genes introduced by traditional inter-cross and back-cross methods are often of high value, the actual use of collected germplasm is low.

Alternative breeding systems are being developed (Goodman, 1985) but the major limiting factor in using the broader diversity available in collections is the lack of evaluation and pre-breeding. Similar problems may exist in using available germplasm for developing potentially useful but presently under-utilized species and varieties, since inadequate characterization and evaluation of source materials inhibits using genetic diversity. In addition, breeding new crops is more difficult and, even if seed collections are available, there are gaps in the process of varietal development. In the meantime, there is a rapid decline in old farmer varieties, land races, and populations of wild relatives. Integrating stores of previously used varieties, and collections of characterized or described wild relatives and potentially useful species from reserves or managed areas into a regular development programme for long-term utility are needed.

In many of the most important crop species the system is not intact so that food production at present levels cannot be ensured. The lack of a system for fully using the available genetic diversity is felt especially in developing countries where testing and pre-breeding are hampered by lack of personnel and funding.

Collection and exploration of various species have increased substantially over the past 20 years, partly due to the efforts of FAO/IBPGR and others and the utilization of collected germplasm of some species has been advanced by national governments, the IARCs, and other supra-national organizations. Nevertheless, there seems to be common agreement (Brown et al, 1989) that much more needs to be done to make the collected diversity more useful in both developed and developing countries. By opening more channels for utilizing wild relatives and primitive cultivars, and by testing and pre-breeding more potentially useful varieties, useful diversity can increase.

Forestry

Less than 500 forest tree species have been tested for any kind of utility, and less than 40 are being bred. Modern tree breeding, however, is only one to three generations old and the genetic and phenotypic distance between uncultivated populations and advanced generation varieties is not yet large. Trees often require decades to mature and to display their breeding value. Hence, breeding systems that rely on generations of back-crossing are not useful in tree breeding. Instead, the continual enhancement of divergent populations is needed to effectively utilize diversity for future variations in ecological or economic adaptability. Whereas agricultural crops can use the wider diversity in testing and enhancement populations, either as sources of genes for filtering into advanced varieties, or as alternative populations that can substitute for established varieties, in forest trees, the first option is largely unavailable (Namkoong and Kang, 1989).

Many species have yet to be tested and bred for utilization in traditional forestry programmes and for agroforestry, but widespread testing and initial breeding is limited to a few tens of species. Approximately 350 tree species, many of recognized commercial value, have been reported to be endangered in whole or significant part, and the threat of further taxon loss is substantial, especially in the dry and humid tropics. Much broader testing of many hundreds more species over a span of test environments is technically feasible, but not yet organized. More rapid breeding techniques could be of critical value.

Both intra-specific and inter-specific diversity of tree species needed to maintain ecosytem functions is also in danger of serious erosion. Environmental degradation in all parts of the world is impoverishing forest genetic resources and, even if global warming is at the low end of predictions, many species will not be able to migrate across natural or human barriers, nor be fast enough to shift habitat. For these systems, the management of natural regeneration will require some restructuring of genetic variation and more intensive forms of management, such as advanced planting of pre-adapted genotypes. Therefore, a closer integration of programmes for the more rapid utilization of populations for naturally regenerated and planted forests will be needed.

Historically, most of the transfer of forest tree materials among nations has been within latitudinal zones, but if climates change, there could be a substantial increase in tropical to temperate to boreal zones. This could place moisture stress on tropical forest ecosystems, and the ability of natural reserves to protect even their present taxa.

Animals

Intensive breeding in animal species is limited to a few species of birds and mammals and commodity production is limited to bees, domesticated poultry, buffalo, cattle, goats, horses, sheep, and swine. Except for limited use of cryostorage, there is no genotypic storage system comparable to plant seed collections and the continuity of populations is dependent on the continual regeneration of standing breeding stocks. As such, most animal breeds are subject to occasional incidents of extreme genetic stress and population bottlenecks, as well as incidental hybidization, especially of rare breeds by more popular ones. Large animals also have relatively long regeneration cycles and low reproduction capacities and, therefore, population recovery is comparatively slow. Hence, the danger of eroding biological diversity is persistent in domesticated animals, especially minor and rare breeds.

While no imminent losses of diversity are expected within at least the major commercial breeds of beef cattle, goats, sheep or swine, rare breeds of swine are endangered and some poultry breeds (U.S. Congress, 1987) may already be genetically impoverished. Furthermore, while large populations of the major breeds are being maintained, there seems to be little effort made to increase the diversity among populations of these breeds. Some long-term erosion of genetic variation can be expected, especially if artificial insemination, embryo transplanting, and ovulation promotion result in reduced population sizes. To assuage these effects, rare breed hobbyists and organizations strive to maintain populations, and cryogenic storage is used to retain semen samples of cattle (U.S. Congress, 1987). The possibility of single gene transfer into valuable lines may make wild or semi-wild species more directly useful for commercial breeding, thus increasing genetic diversity even if it does not increase population level diversity. Otherwise, pre-breeding activities to utilize diversity of rare breeds or wild relatives seems limited to hybridization for specific disease resistances. There is an absence of genetic information and evaluation.

The other path to developing the utility of diversity by enhancing other species or varieties for special niches or as long-term potentials for replacing widespread breeds is largely unexplored. There are no global strategy statements for such developments but some local efforts, such as with Guinea fowl in West Africa, the Bos x Yak hybrids in Burma, and the domestication of Bos, may bring new genetic resources into production uses. In contrast to domesticating previously free ranging species, efforts with wildlife ranching may provide means for intensive exploitation of species such as crocodile, ostrich, deer and vicuña.

The non-commodity values of animal species is also dependent on their immediate and long-term survival which, in turn, is affected by the structure of the genetic diversity. While interest is mostly focused on birds and large mammals, the other vertebrates, arthropods and other phyla make up the vast majority of species existing today. Bacterial and fungal resources are also essential for food products and industrial processes as well as for normal growth and decay processes.

For the species of direct value for their symbolism, aesthetic, touristic, or other non-consumption uses, a wide variety of *in-situ* and *ex-situ* (e.g. zoos) methods are used. For the more intensively managed species, embryo transfer and semen freezing are used, and captive breeding can take on heroic measures such as for Speake's Gazelle (U.S. Congress, 1987), Pen David's Deer, and the California Condor. Less intensive management is also affected by habitat management, and by establishing reserves and protected areas. These are largely devoted to maintaining sufficient adult population sizes to ensure at least a good probability of survival for a few generations (Soulé, 1987). Ex-situ management of herds in zoos or other parks is possible and instances exist of the reintroduction of species into areas where they had been extinct.

Natural regeneration in areas of low human density remains the primary means for maintaining the biotic variation of most wild animal species. The design of reserves is usually based on the needs of species that either command wide public attention or are biologically associated with a large community of plants or animals. However, it is not generally known how such reserves will affect biological diversity other than at the level of selected species.

The little research presently being conducted on population genetics or demography is limited to a few species. Substantial efforts are needed to ensure the long-term evolution of most animal species and the continued productivity of the ecosystem for direct consumption, as well as for indirect, non-commodity values, and the productivity of domesticated animals.

Fish

Most of the fish for human consumption come from wild populations with litle management required, other than harvest regulations. A few freshwater species of trout, bass, carp, catfish and Tilapia are managed in breeding ponds, and about five species of shrimp are cultivated. However, the vast majority of the marine resources consumed are fish about which little is known genetically and less about the efficacy of genetic management techniques. For example, introducing genetically distinct populations into wild fisheries can have many unforeseen consequences (Nelson and Soule, 1987); in fresh water fisheries, introductions in the recent past have substantially altered their composition and their ongoing evolution (Campton, 1987).

It is known that there are areas of high species richness such as along the Philippine coast, and that environmental changes, pollution, and over-harvesting can reduce intra- and inter-specific variation, especially for crustaceans. Harvesting by size classes changes not only the death rates of species of different sizes, it also changes the intraspecific distribution of size classes, and can affect the life-history strategies of subsequent generations of fish. Thus, when a fishery is harvested, even if the mean yield does not initially change, the array of species and genotypes may quickly change and the diversity among them may be easily reduced. If this continues, the recruitment process will eventually be impoverished and the whole fishery may collapse. However, relatively little is known of the degree that community diversity is being lost, or that genetic diversity is being eroded.

The loss of habitat, such as by destruction of coral banks by harvesting or pollution, or the silting of mangroves and offshore fisheries is a direct threat, but one that involves managing not the fisheries, but the land. Obviously, it would be of great value to not only learn more about the present state and dynamics of fish populations but also the effects of harvest and habitat management techniques so that reserves can be efficiently designed. Further research on how planted populations can be effectively managed to increase diversity would be important for long-term conservation and use.

Inter-sectoral relations

The utility and management of biological diversity varies widely within and among sectors, and depends as much on the objectives and techniques of management as on the biological status of the biota. Nevertheless, all sectors depend on biological diversity for immediate utility and long-term productivity, and all sectors can exercise more or less intensive management for commodity production as well as for non-commodity values.

For each sector, the development and use of biological diversity from wild species to advanced breeding can be systematized. Agriculture has evolved the most elaborate system for exploring, collecting, characterizing, testing, evaluating, enhancing, and breeding advanced varieties. For forest trees, much the same array of techniques can be employed though differences exist mainly at the stage of final varietal development. Animal systems have not developed as elaborate a system for the breeding utilization of the wider levels of biological diversity, while fisheries are still largely dependent on relatively unmanaged levels of diversity.

Since biological diversity can be managed at several levels of biotic organization and for different uses, management prescriptions will vary among sectors. However, in-situ and area management often involve inter-sectoral questions. Management affects the interactions of forest, range, and field ecosystems across shifting boundaries. Programmes that prohibit clearings or human intervention in reserves, conflict with other uses and with management for secondary forests and many wildlife species, and land management has substantial downstream and coastal marine effects. Hence, in terms of a total biological diversity, not only do we require a broad view of managing diversity for various uses within sectors, but inter-sectoral effects on the total utility of biological diversity must be considered. This is the main focus of Unesco's Biosphere Reserve concept.

It is also clear that inter-sectoral coordination requires political solutions within countries, with policy makers taking a broad biological perspective. With such complex biological, economic, and political issues, a challenge for new research and development is in the management of multiple resources. The development of national strategies for the conservation of biological diversity will require means for managing diversity of all sectors, to some extent in segregated areas, but also in multiple-use areas.

International cooperation is needed to share techniques, costs, and benefits for managing biological diversity. With wider access to materials and the possibilities of global climate change, cooperation and joint efforts will be needed more in the future than even now. Inter-sectoral effects also cross national boundaries, as when inland forest clearings affect water and fish resources elsewhere. Hence, integrated programmes to manage biological diversity are essential.

If each sector can systematize the development of various levels of biological diversity, it is also possible to systematize the management of diversity between sectors. However, the biotic interrelationships of multiple species are not well known, the effects of management of one set of species on another set are not known, nor is integrated management well developed. In addition, the means for agricultural, forestry, animal, and fishery departments to integrate their objectives or develop integrated programmes are poorly developed. Hence, basic studies and pilot activities are needed to integrate socio-economic values across sectors and political mechanisms are needed to stimulate action and adjudicate conflicts.

IV. ORGANIZATIONAL OVERVIEW

In the face of ecosystem alteration, loss of species habitats and threats to sustainable development, there is now a new willingness to coordinate conservation and development programmes. Given the modest support for global conservation systems, these coordination efforts should be welcomed and abetted as much as possible.

FAO is active in the in-situ and ex-situ maintenance and rational use of the biological diversity of terrestrial and marine ecosystems, wild and domesticated species of plants, animals and fish and genetic resources of both the vegetal and animal kingdoms.

In the field of **animal genetic resources**, FAO focuses primarily on the utility of genetic variation in buffalo, cattle, chickens, goats, horses, sheep, and swine. For these species, the focus of breeding is on disease resistance and, to a lesser extent, on productivity levels. FAO, with a Panel of Experts and with EAAP helps to maintain a Global Genetic Data Bank for domesticated breeds especially for endangered ones. FAO also cooperates in local breed conservation.

Since 1973, FAO, in collaboration with UNEP, has carried out activities for the improved management and conservation of national and regional animal genetic resources. Regional gene banks in Africa, Asia and Latin America, and a global animal genetic data bank have been established. In 1983, FAO and UNEP set up a Joint Expert Panel on the Conservation and Management of Animal Genetic Resources.

FAO's activities in **plant genetic resources** include strengthening national capabilities for the collection, conservation, evaluation, exchange and use of plant germplasm. A specialized newsletter has been published since 1957, a Panel of Experts was established in 1965 and a Plant Genetic Resources and Crop Ecology Unit in 1968. The first international technical meeting was held in 1961 and has been followed by others. FAO has, until recently, housed and supported the IBPGR.

Within a Global System on Plant Genetic Resources, a framework for the conservation and use of plant biological diversity has been established by FAO. It consists of a basic legal document (International Undertaking), an international forum (Commission), and a financial mechanism (Fund). The goal is to ensure that the benefits from plant genetic resources are equitably shared as a "heritage of mankind", and safely conserved, their availability unrestricted, and their utilization sustainable. This is a global coordination effort to ensure that plant genetic resources for agriculture and forestry are made available for breeding and research. It is intended to foster international cooperation in all phases of genetic resource development primarily for food crops, and through the Fund, to bring technical and financial resources to bear on crop development. The Commission serves as a forum for developing global policy and strategy.

Aside from IBPGR's programmes, mainly for seed collections of food crops, FAO promotes under-utilized species of food crops and those whose potential productivity has not previously been considered. For these species, the full range of resource development activities must be considered, from exploration, collection, and exchange to evaluation and trial establishment. For major crop species, FAO cooperates with the IARCs and with national programmes but does not usually take a leading research role. Efforts are focused on the more immediate food crop needs of developing countries.

FAO strengthened its forest genetic resources programme in 1968 with a Panel of Experts on Forest Gene Resources. In collaboration with IUFRO, FAO organized three World Consultations on Forest Tree Breeding (1963, 1969, 1977). In 1978 and 1984, programmes for testing multipurpose tree species were established. Broader interest in genetic conservation led to the publication of a databook on endangered species (1981) that has subsequently simulated interest in the loss of species and provenances, and to programmes in in-situ conservation. The Tropical Forestry Action Plan, including the conservation of tropical forest ecosystems as one of its main components, was set up in 1985.

FAO supports national programmes in exploration, evaluation and conservation of genetic materials for species of socio-economic importance. It is also active in the in-situ conservation of the genetic resources of tropical woody species.

While considerable experience has been accumulated in coordinating programmes between nations and with groups of donors, most programmes directly run by FAO are necessarily of a "pilot" programme size. There are no means for ensuring that such programmes are expanded to encompass other targeted species and areas. For other species that lie primarily in developing countries where forest management is not extensively practised, FAO programmes on inventory and monitoring are effective, but natural area management is often weak. FAO coordinates plans with groups such as the Ecosystem Conservation Group (IUCN, UNEP, Unesco, FAO).

Protected area management is included in wildlife and national parks programmes. FAO has helped to organize working parties in a number of countries and regions, most notably in Africa, where a standing working party on wildlife operates within the framework of the Africa Forestry and Wildlife Commission of FAO. An information processing system (FOWCIS) has been developed for linkage to data in the IUCN network. FAO also supports a network of National Park Services.

Within fisheries, where the productivity of biological diversity that is harvested is still largely from unmanaged ensembles of species, the utility of biological diversity is difficult to measure. However, it is known that heavy harvesting of large fish changes the size and species profile and that habitat destruction by siltation and pollution from point sources can have widespread effects. To maintain species, it is therefore felt that undisturbed ecosystems are needed, at least until much more is known about managing stocks and the effects of introductions. Research is thus far limited to the demographics of dominant species and the establishment of reserves representing diverse ecosystems. There are few other means available to ensure the continued existence of marine species except by pollution control and programmes to integrate land and marine policies to protect the extant biological diversity are needed.

FAO is active in the conservation and utilization of fish genetic resources, in particular by promoting the establishment of reserve areas to maintain genetic diversity at the stock level in lakes and rivers, by contributing to the reduction of the risks involved in species transfers and introductions, and by helping to preserve genetic diversity with regard to aquaculture.

Institutional and financial aspects

With a very broad definition of biological diversity necessitated by its biological complexity, and the wide variations in organizational objectives among agencies involved in its management, there are wide disparities in programme content. There is a universal need to more clearly define objectives and to adopt measures of diversity that can be used to set priorities and to evaluate action programmes.

One way to array functions in biological diversity programmes is to define their objectives in terms of intensive versus low-level intervention. In general, intensive intervention implies that specific organisms or even genes are known and acted upon, and that both genetic as well as environmental management is intensive. Low intervention or non-intervention ensures the existence of ecosystems. Thus, management techniques vary from advanced crop breeding or captive breeding of particular families, to pre-breeding and collection, to merely exploration and establishing reserves.

A second scale for arraying organizations is the degree to which present versus future values are significant. The two scales are correlated, in that intensive management is usually applied when immediate uses are evident or can be easily foreseen, and non-intensive management is used when broader variations of unspecified but potential future value exist. Figures 1 A and 1 B, show a two-dimensional graph with several types of management activity arrayed along an "intensity" scale, and a time scale apposed.

In agriculture, FAO focuses primarily on advanced breeding and on pre-breeding for more immediate production. With IBPGR focusing on collection activities a gap appears in the pre-breeding and testing phases. Forestry is directed more to the testing and collection phases and has de-emphasized activities in advanced breeding, while the wildlife management emphasis in forestry is focused on wildlands and economic utility. Animal production is focused on intensive breeding in a few species, and while it maintains rare breeds, there are few activities to use greater diversity, and its emphasis is on immediate production. Fisheries, on the other hand, are much less intensively managed. Thus, within sectors, there are different styles of use and different opportunities for improved use of biological diversity.

As an international organization, FAO policy is to support national governments' efforts and foster intergovernmental cooperation. It therefore functions at policy level in addition to providing the technical means to advance programmes of biological diversity. As such, FAO provides mechanisms for technical programmes to function. Most significantly, it can also provide the forum for adjudicating conflicts of interest. Between sectors, even within national governments, policies developed within sectors may conflict and evaluation of the biota and its management may differ. Assistance in formulating comprehensive evaluation of biological diversity is needed and stronger mechanisms for adjudicating conflicts among sectors. Obviously, when interests cross national boundaries, international mechanisms are needed not only to solve conflicts, but also to advance more global concepts of the values and management of biological diversity.

Among the other agencies, the World Bank and USAID emphasize immediate utility and the intensive management of biotic resources, while the Nature Conservancy emphasizes the preservation of natural ecosystems through the least intervention. WRI, IUCN, and both WWF programmes have moved to support long-term and more immediate use values, with WRI perhaps supporting, at a policy level, more intensive management methods for immediate utility, and WWF funding less-intensive methods. This brief description of programme emphases reveals the differences that exist among organizations in dealing with the array of values they perceive to be at risk, and their response to the threat.

It was estimated in 1987 that the total investment of primarily US-based organizations in international biological diversity per year, incorporating some 873 projects, amounted to $37.5 million. In contrast, an estimated US $20 to US $59 billion per year (at least a 200-fold increase) was needed to support developing country conservation programmes (WRI, 1989). Clearly, the programmes now operating would have to form the basis for any expanded programmes in the conservation and use of biological diversity, but none can simply scale-up present operations to fill all the needs of a global programme. A broader mutual appreciation of the diverse objectives and modes of management, mutual support and closer coordination are necessary.

Political problems require political bodies to solve them, and biological problems require scientists to manage them. At this time, there is no single agency that can encompass all of the levels of action needed. Still, lead agencies such as FAO can help to develop an integrated sense of what biological diversity means to its different users and how it can be conserved. If no single organization can direct, fund, and administer such a programme, new umbrella agreements or organizations might be useful, if constructed to facilitate management of biological diversity in the broad sense. There is already a tendency to over-use the term biological diversity and to deprive it of meaning. The danger is that of refragmentation, rather than developing a more global view of what biological diversity implies.

V. ELEMENTS FOR A STRATEGY ON BIOLOGICAL DIVERSITY

Policy

A primary goal of FAO, as stated in the preamble to its constitution, is to promote the common welfare. Applied to agriculture, forestry, and fisheries, the condition and management of the basic biotic resources upon which productivity is based is necessarily within the scope of FAO programmes. In order to increase productivity and its contribution to economic development, and to sustain it for present and future development, the conservation and use of the basic resources must be managed. The diversity of genes, populations, species, and ecosystems is a feature of the biota that is of value in itself and is subject to management for production purposes.

An FAO policy would, therefore, be appropriate for the management and use of biological diversity at all levels, including present and future utility for commodity and non-commodity values. The utility of biological diversity must include the direct and indirect values of wild ecosystems as well as the immediate contributions that intensive management can have, and the ecosystem support services that are of local and global value.

While recognizing the wide scope of management issues and biotic inclusiveness implied in such a policy, it is also important to recognize the limitations of direct management interventions, and therefore the necessity to target actions to achievable objectives. Management may thus include passive programmes such as monitoring reserves, as well as interventions such as captive breeding and reintroducing key species, or even breeding crop varieties for agricultural production. These will differ among sectors, and among nations, but as a key organization to assist both separate as well as collective actions by national governments, FAO must provide broad, integrative programmes for conserving and using biological diversity in all its forms. Within sectors, FAO is probably the only agency that can provide a supranational organizational structure for programmes that seek to maximize the total utility of biological diversity.

Programme

For plants, an international programme for the whole system of utilizing intra- and inter-specific diversity would be useful to formalize, target and coordinate collection, characterization, testing, enhancement, and breeding within the present Global System on Plant Genetic Resources with its Commission, Undertaking, and Fund. For agricultural plants, some national and private company programmes exist for establishing priority species, and agencies associated with the CGIAR have established action priorities and IBPGR has collection priorities. However, a UN perspective on globally significant species and action priorities has not yet been developed. Hence, global targets for managing biological diversity to effectively use the productive potential of biotic diversity are not defined and international accountability is lacking. Establishing global crop advisory committees of specialists on targeted species would be useful. Better coordination between seed banks and breeding agencies is needed and all nations would benefit from an internationally coordinated programme on all phases of development for a wider diversity of species.

For forest trees, also within the Global System on Plant Genetic Resources, more rapid breeding and testing of source populations of species, and a much wider testing of potentially useful species would serve to bring more of the biota into production while the losses of intraspecific variation, if not the extinction of species, requires the rapid establishment of collections in seed and field testing/storage systems. In addition, the diversity within and between species that is necessary to maintain forest ecosystems and that serves as a reservoir of species of potential value for production purposes is largely unprotected. Therefore, the entire system of use of biological diversity from reserves to a global testing network, to breeding for wood production requires efforts on a much larger scale than presently being organized.

For animals, industrial systems for the protection of intra-specific variation exist for some major species. However, the use of wider sources of genetic variability for different environments, and for local adaptabilities and cultivation systems could be assisted by a global programme on species and hybridization trials.

The use of semi-wild species for either domestication or ranching purposes could also be genetically linked to production systems using traditional species, and hence wider use made of the potentially useful animal diversity. The linkage of such production systems with wildlife values at this time is weak and the need for managing biological diversity of non-consumption species is as great as for domesticated animals. The roles that domesticated as well as wild species play in economic development and the efforts required to manage their diversity require clarification.

Coordination

In addition to providing a global perspective, FAO is charged with assisting national efforts and hence must help develop programmes within nations to coordinate the conservation of their biotic resources and the flow of materials into use. There is also a critical need for systems of field management, and political coordination that crosses traditional sectoral boundaries. Efforts to assist cross-sectoral management of biological diversity is clearly needed as much among as within nations. FAO must develop programmes and means to adjudicate between nations.

Losses in biological diversity in one sector may be offset by gains of comparable value in other sectors, or could provide means for compensatory increases in biological diversity. An international programme is needed that can, not only provide means for coordination activities, but provide an integrated view of how the total benefits of conserving and using biological diversity can be realized. FAO's coordinating mechanism for environment might be used to facilitate cross-sectoral programmes on integrated management, and to facilitate the establishment of systems to adjudicate conflicts between sectors.

Research

The action programmes developed within sectors, and for inter-sectoral problems will all require substantial research support in the biological sciences, as well as in economic, legal, and political mechanisms. In the sciences, research on rapid breeding and evaluation is needed as well as on basic population dynamics and conservation biology. The economics of resource use and intra-national as well as international means for developing basic biological resources for the common good also need research and development.

In order to put into practice what is already known, and to apply the new knowledge needed, a vast expansion of training and education programmes on biological diversity is needed both within sectors and in the emerging fields of conservation biology and integrated use. This would include support for short-term programmes in conservation, and encouragement for long-term programmes in basic population biology, genetics and breeding, and in ecology and systematics. Broader education of the public and of public leaders is also needed to develop public support priorities for programmes on biological diversity.

Conclusions

Given the magnitude of work that can be accomplished with current technologies, the important question remains of how directly should FAO become involved in project management, funding, and support. Since sectors differ in programme needs, and FAO departments differ in staff, resources and programme orientation, the answer must be mixed. However, it is essentially unique to FAO, that the global policy and elements of a comprehensive programme on biological diversity can be defined in agreement with member nations.

While FAO supports both utility and non-utility objectives, it is appropriate for the Organization to assert global leadership in programmes dealing with conservation and use of diversity. Other agencies may be better suited to lead programmes that emphasize non-utility objectives and establish standards for them, but FAO can uniquely set programme standards for utility objectives, and indeed, must do so for the international community.

Based on the principle that biological diversity is a global dynamic, it must be protected, managed, developed, and used to enhance human existence. Since it is interrelated, management across all levels should be integrated to affect the structure and amounts of diversity. Within sectors, an array of intensive to extensive, and in-situ and ex-situ techniques should be developed for improved use and development of diversity.

The present system for utilizing genetic variation has many gaps and weak infrastructure that prevent full use of biological diversity. FAO should assist nations to develop breeding systems that can provide the needed diversity within and among crop species and foster international cooperation to more efficiently develop variation for future uses.

Since biotic effects cross sectoral boundaries, inter-sectoral management programmes are needed. Hence, to ensure the full utilization of biological diversity and its continuing development and enhancement, FAO should support national programmes to manage biological diversity, develop inter-sectoral mechanisms and programmes to coordinate efforts, and provide a global forum for a comprehensive set of programmes serving all nations.

Figure 1A - OBJECTIVES

	Short-term ——— Utility ———	Long-term
MANAGEMENT SYSTEMS	Economic productivity ——— Inclusiveness ———	All biotypes (especially rare)
Advanced breeding	Commercial Variety Development	Rescue breeding
Pre-breeding		
Enhancement and early selection		
Testing and evaluation		
Collecting and describing old varieties	Seed collections Storage	Captive breeding
Wild relatives		
Sampling and surveying		
Ecogeographic survey and inventory		
Managment reserves	Ecotourism Watershed protection	
Strict nature reserves		Core preserves

Management systems are arrayed in descending order of intervention intensity. Objectives are arrayed with short-term objectives and economic productivity on the left, and long-term productivty and a broader inclusiveness on the right. Examples of programmes are given in the intersections between management systems and objectives.

Figure 1B - OBJECTIVES

MANAGEMENT SYSTEMS	Short-term —— Utility —— Long-term		
	Economic productivity	Inclusiveness	All biotypes (especially rare)
Advanced breeding	1, 5, FAO/AGA, FAO/FOR		
Pre-breeding	1, 5, 7, FAO/AGA, FAO/AGR, FAO/FOR		3(c) 8(c)
Enhancement and early selection	1, 7, FAO/AGR, FAO/FOR	10	
Testing and evaluation	1 FAO/FOR	10	
Collecting and describing old varieties	1, 2 FAO/AGA, FAO/AGR		
Wild relatives	2, FAO/AGR. 9, FAO/FOR	10 9, 3, FAO/FOR	
Sampling and surveying	2. 7(b) 9, FAO/FIR, FAO/FOR,	9, 3, FAO/FOR	
Ecogeographic survey and inventory	6, 9 FAO/FIR	10 8 3 8	4
Managment reserves	5(a), 3, 6, 9	10 3 8	4
Strict nature reserves	6	10 3 9 8	3, 4

Organizational progammes: 1) Developing country programmes; 2) IBPGR; 3) IUCN; 4) TNC; 5) World Bank; 6) Unesco; 7) USAID; 8) WWF (US); 9) WWF (Int.).

FAO/AGR = Research & Technology Division; FAO/AGA = Animal Production & Health Division;
FAO/FOR = Forestry Department; FAO/FIR = Fisheries Department.

(a) ecotourism; (b) New research and development; (c) Flagship species.

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ACRONYMS

CGIAR	Consultative Group on International Agricultural Research
EAAP	European Association of Animal Production
FAO	Food and Agriculture Organization of the United Nations
FOWCIS	Forestry and Wildlife Conservation Information System
IARC	International Agricultural Research Centre
IBPGR	International Board for Plant Genetic Resources
IUCN	International Union for Conservation of Nature and Natural Resources
IUFRO	International Union of Forestry Research Organizations
TFAP	Tropical Forestry Action Plan
TNC	The Nature Conservancy
UN	United Nations
UNEP	United Nations Environment Programme
Unesco	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
WCMC	World Conservation Monitoring Centre
WRI	World Resources Institute
WWF	World Wide Fund for Nature