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Trends in Agricultural Biodiversity

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"Biodiversity is a non-detachable part of the concept of sustainability. ... biodiversity is essential for agricultural production, as agriculture should be for biodiversity conservation."
Brazilian Government proposal to SBSTTA of the CBD, Second Meeting
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Although the context of this paper is a "World Biodiversity Update," any attempt at such would be presumptuous if not impossible. What I will attempt, however, is to highlight some of the major developments in biodiversity action and policy that have emerged during the past year or two. In fact, several of these are directly related to agricultural biodiversity, and indeed to the issue of new crops. Then I shall explore the main trends in the appreciation, conservation and sustainable use of what is termed agricultural biodiversity.

The coming into effect of the Convention on Biological Diversity has led to a wide range of activities and initiatives as governments attempt to get to grips with the problems of implementing what is no more than an outline convention. The deliberations of the Conference of the Parties (COP) of the Convention and its Subsidiary Body for Scientific Technical and Technological Advice (SBSTTA) have been criticized by some as spending too much time on issues such as biotechnology, biosafety, and intellectual property rights (Raven 1998) while issues such as the preservation of species have been ignored. Others regard the Convention as providing incentives for countries to conserve and sustainably use their own biodiversity and ensure that the benefits derived from it by third parties are equitably shared (Seyani 1998). Certainly, a great deal of controversy has been generated by matters such as access to genetic resources, farmers' rights, and technology transfer, reflecting different attitudes and perceptions between developing and developed countries. These are serious issues that demand attention and while those of us who are alarmed at the growing rate of biodiversity loss and habitat destruction are naturally impatient and would like to see more urgent steps being taken to stem the losses, progress in reconciling the different positions is being made and at the same time many countries are taking positive steps to put in place mechanisms for the conservation and sustainable use of their biodiversity.

Another key development was the endorsement by governments of the Global Plan of Action (GPA) for the "Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture" at the International Technical Conference on Plant Genetic Resources held in Leipzig, 17–23 June 1996 (FAO 1996).

The GPA sets out a global strategy for the conservation and sustainable use of plant genetic resources for food and agriculture with an emphasis on productivity, sustainability and equity (Cooper et al. 1998) and complements the CBD. In fact, a significant development that followed from these two was the convergence of interest between bodies such as FAO and IPGRI and conservation and development organizations and agencies such UNESCO-MAB, IUCN, WWF, and ITDG. On the one hand, the CBD recognized agricultural biodiversity as a focal area in view of its social and economic relevance and the prospects offered by sustainable agriculture for reducing the negative impacts of biological diversity, enhancing the value of biological diversity and linking conservation efforts with social and economic benefits (Decision III/11 Conservation and Sustainable Use of Agricultural Biological Diversity of the Conference of the Parties to the Convention on Biological Diversity). On the other hand, it is recognized that the Global Plan of Action covers a number of multidisciplinary areas such as in situ conservation of wild plants and crop relatives in natural ecosystems that extend the traditional activities of sustainable agriculture and plant genetic resource conservation and that successful implementation will require the development of new partnerships with a range of intergovernmental and non-governmental organizations as well as with indigenous and local communities.

Another area of developing concern is the role of indigenous communities in the conservation and sustainable use of biodiversity. Although the all-pervading influence of human action in modifying biodiversity is widely recognized, and the Global Biodiversity Assessment (Heywood 1985) included a whole section on this topic, the complexity of the social, cultural, ethical, religious, and other human interactions with biodiversity and agroecological systems. As the STAP Expert Group on Sustainable Use of Biodiversity (UNEP 1998) notes, "*Development of sustainable use projects requires a paradigm shift from a focus on protection and the development of protected areas to considering also such skills as dealing with the interaction of socio-economic and ecological systems.*"

TRENDS IN BIODIVERSITY

It is exceedingly difficult to assess overall trends in biodiversity since there is little agreement as to which parameters, such as rate of deforestation, species loss, extent and number of protected areas etc., to measure as a baseline. An appropriate core set of indicators is still being developed for the CBD and for use in national reports on biodiversity. Various sets of indicators of biodiversity conservation have been proposed (Reid et al. 1993; Hammond et al. 1995; UNEP 1993; WCMC 1992, 1994) and the reviews, analyses, and tables given in World Resources. A guide to the global environment series produced by WRI are also relevant. It has been agreed by the COP that a Global Biodiversity Outlook, partly based on national reports on measures taken for the implementation of the provisions of the Convention, will be produced but the first issue has not yet been prepared.

A recent overview of the state of the environment is given in the "Global Environment Outlook" published by UNEP (1997). This notes that while significant progress has been made on several fronts in confronting environmental challenges in both developing and industrial regions, from a global perspective the environment has continued to degrade during the past decade (to 1997), and significant environmental problems remain embedded in the socio-economic fabric of nations in all regions. Progress towards a global sustainable future is just too slow. A sense of urgency is lacking.

Perhaps the most alarming recent series of events has been the profound impact of the 1997/8 El Niño current on world climate, leading to disastrous forest fires, storm surges, and floods, in many parts of the world that have resulted in incalculable losses of biodiversity as well as famine, epidemics, death and injury. This is all the more disheartening since at a blow, much careful conservation action and planning has been undone. The ENSO (El Niño Southern Oscillation) phenomenon links climatic anomalies in different parts of the world and their simultaneous appearance in many localities has led Richard Grove (Grove 1998) to de-

Table 1. Summary of emerging global environmental trends (UNEP 1997).

Unsustainable use of renewable resources

The use of renewable resources—land, forest, fresh water, coastal areas, fisheries, and urban air—is beyond their natural regeneration capacity and is therefore unsustainable.

Increasing greenhouse gas emissions

Greenhouse gases are still being emitted at levels higher than the stabilization target agreed upon internationally under the UN Framework Convention on Climate Change.

Reduction in natural areas and biodiversity

Natural areas and the biodiversity they contain are diminishing due to the expansion of agricultural land and human settlements.

Increasing use of chemicals

The increasing, pervasive use and spread of chemicals to fuel economic development is causing major health risks, environmental contamination, and disposal problems.

Escalating use of energy

Global developments in the energy sector are unsustainable.

Unplanned urbanization

Rapid, unplanned urbanization, particularly in coastal areas, is putting major stress on adjacent ecosystems.

Disruption of global biogeochemical cycles

The complex and little understood interactions among global biogeochemical cycles are leading to widespread acidification, climatic variability, changes in the hydrological cycles, and the loss of biodiversity, biomass, and bioproductivity.

scribe them as being teleconnected. Such extreme climatic events and episodes of climatic instability have had the unexpected effect of convincing many of the public and not a few scientists that climate change is a real phenomenon whose effects will seriously impact upon them.

THE COMPONENTS OF AGROBIODIVERSITY

Agricultural biodiversity, also known as agrobiodiversity, is no easier to define than biodiversity itself. It can be generally regarded as biodiversity in an agricultural context and can be described as the variety and variability amongst living organisms (of animals, plants, and microorganisms) that are important to food and agriculture in the broad sense and associated with cultivating crops and rearing animals and the ecological complexes of which they form a part. It is not just a subset of biodiversity but an extension of it in that it embraces units (such as cultivars, pure lines, and strains) and habitats (agroecosystems such as farmers' fields) that are not normally considered or even accepted as properly part of biological diversity. Some authors would in fact exclude artificial diversity such as introduced species in an area (including by implication agricultural crops) from the concept of biodiversity "because it cannot fulfil the full range of societal values that native biodiversity does" (Angermeier 1994).

Agrobiodiversity includes all those species and the crop varieties, animal breeds and races, and microorganism strains derived from them, that are used directly or indirectly for food and agriculture, both as human nutrition and as feed (including grazing) for domesticated and semi-domesticated animals, and the range of environments in which agriculture is practiced. It also includes habitats and species outside of farming systems that benefit agriculture and enhance ecosystem functions.

As with biodiversity proper, it can be considered at three main levels—those of ecological diversity, organismal diversity, and genetic diversity (Heywood 1995), each forming a hierarchy of elements (Table 2).

Agrobiodiversity is by definition the result of the deliberate interaction between humans and natural ecosystems and the species that they contain, often leading to major modifications or transformations: agroecosystems are the product, therefore, of not just the physical elements of the environment and biological resources but vary according to the cultural and management systems to which they are subjected. Agrobiodiversity thus includes a series of social, cultural, ethical, and spiritual variables that are determined by local farmers (in the broad sense) at the local community level. These factors must be taken into account as part of the process of selection and introduction of new or underdeveloped crops, although they are often overlooked.

The components of agrobiodiversity may be summarized as in Table 2. Thus it covers not only the whole gamut of genetic resources (from advanced cultivars to primitive land races, domesticates, semidomesticates, wild relatives) but the diversity of ecosystems and agroecosystems within landscapes that are exploited in some way for agriculture and forestry, and the complex set of human interactions.

The recognition of agrobiodiversity—i.e. diversity in crops, agroecosystems, and approaches—as a concept and as an issue, is a major conceptual breakthrough, reinforced by the CBD and the Global Plan of Action. It signifies, I believe, the emergence of a new paradigm for agriculture that embraces not just the most technologically advanced and efficient farming and production systems, dependant on highly bred or engineered crops and animal breeds, with an emphasis on uniformity and standardization, and based on a very restricted set of species, but recognizes that the great diversity of traditional farming systems and practices in many cultures in different parts of the world and the thousands of species that are locally cultivated or semidomesticated in home gardens or other polycultures, or harvested from the wild in nearby habitats make a major and essential contribution to food security for hundreds of millions of people across the globe.

It has been estimated that more than three million hectares survive under traditional agriculture as raised fields, terraces, swidden fallows, polycultures, home gardens, and other agroforestry systems (Altieri 1998) and while these seldom have the potential to produce marketable surpluses, they do make a major contribution to food security (Heywood 1999) and traditional cropping systems are said to provide as much as 20% of the world's food supply.

It is important, however, not just to pay lip service to the legitimate needs and aspirations of local, small scale farmers and agroforesters whose dependence on diversity has been threatened by the wide-scale conver-

Table 2. The composition and levels of agrobiodiversity.

Agroecological diversity	**Organismal diversity**	**Genetic diversity**
biomes	kingdoms	gene pools
agroecological zones	phyla	populations
agroecosystems	families	individuals
polycultures	genera	genotypes
monocultures	species	genes
mixed systems	subspecies	nucleotides
rangelands	varieties	
pastures	cultivar groups	
fallows	cultivars	
agroforestry systems	land races	
agrosylvicultural	breeds	
sylvopastoral	strains	
agrosylvopastoral	pure lines	
home gardens		
forest ecosystems		
managed forests		
plantation forests		
seed forests		
fisheries		
fresh water systems		
marine systems		
habitats		
field		
plot		
crop		
Socio-cultural diversity: human interactions with the above at all levels		

sion of the agricultural sector from traditional to modern systems. What we need is to assess, inventory, monitor, and try and understand this diversity of species and approaches in traditional farming systems and in various forms of wild harvesting and extractivism and also capture the traditional knowledge on agriculture, cultural practices, uses and so on which is rapidly disappearing as the older generations die out.

TRENDS IN AGROBIODIVERSITY

Several trends in agrobiodiversity may be discerned (Table 3), most of them outlined or implicit in the FAO Global Plan of Action and CBD/COP decisions. Although a great deal of attention has been focused on the possible impacts of biotechnology and genetically modified (GM) crops on agriculture and society, a topic that I shall simply refer to, it is notable that other trends are concerned with the conservation and sustainable use of biodiversity and agrobiodiversity, especially with the identification and conservation of the genetic variation in plants that are of actual or potential use to agriculture.

Sustainable Agriculture

The challenge facing agriculture over the coming decades in an expanding global economy is to achieve stable production on a sustainable basis, by introducing technologies and management practices that would ensure a healthy environment, stable production, economic efficiency, and equitable sharing of social benefits. With the global population likely to rise by 2.5 billion in the next three decades, FAO estimates that food production must rise by some 75% during that period. As Carter (1998) has observed recently *"Over-population, degradation of the environment, and exhaustion of crop land present significant challenges in the*

Table 3. Trends in agrobiodiversity.

Moves towards sustainable agriculture	
	Attempts to develop sustainable agricultural production in such a way that its negative impacts on natural biodiversity are minimized.
Bioregional perspective	
	Adoption of a broader perspective of agriculture as an element within a broader panorama of bioregional and landscape development.
Inventory needs	
	Recognition of the need to survey and inventory those plant and animal resources that may be used in agricultural development.
Genetic resource conservation	
	Efforts to conserve genetic resources both in situ and ex situ will be intensified
Importance of on-farm management	
	Recognition of the importance of on-farm management of crop genetic diversity in the form of land races and the need to manage and enhance these.
Importance of biodiversity in natural ecosystems	
	Recognition of the fact that natural and semi-natural ecosystems contain wild plant species, races, and populations that are of importance for food and agriculture, such as wild relatives of crops, are important sources of material for agroforestry, habitat restoration, and reforestation, and species that are wild harvested and contribute to farm household incomes.
Need to broaden the genetic basis of crops	
	Recognition of the very narrow diversity maintained in some crops and the need therefore to widen the genetic base of crops.
Need to cultivate a diversity of crops	
	Recognition of the desirability of cultivating a greater diversity of crops and the introduction of new crops as a way of promoting agricultural sustainability.
Contribution of diversity to farm households	
	Recognition of the role that a diversity of wild and semi-domesticated species may play in food and livelihood security of farm households and their potential for further development and wider use.
Importance of traditional knowledge	
	Recognition of the importance of traditional knowledge about agricultural practices and individual species and the need to record and conserve this knowledge.
The impact of biotechnology and GM crops	
	Recognition of the need to assess the effects of biotechnology on agriculture, the need to review mechanisms by which GM crops could be monitored, and impacts on Intellectual property rights.

new millennium. But unlike population booms of the past, this time crop acreage will not rise accordingly with population growth," he said. "For the human species, these simple facts define the major mission of the next century—bringing our relationship with the earth into balance. For those of us working in agriculture, our mission is no less critical—increase productivity simply to buy time."

However, while agricultural productivity has increased in the second half of this century at a greater rate than world population increase, such increases in productivity in the past have been at the expense of wide environmental damage, seldom recognized at the time. Sustainable agriculture, while it cannot be rigidly defined, is widely interpreted as consisting of practices that are ecologically sound, socially responsible, and economically viable (Thrupp 1996). Daily et al. (1998), for example, have drawn attention to the need to take into account the environmental and social costs of agricultural production as well as the direct farming costs. Achievement of high levels of GNP may be at the cost of a depletion of the natural resource base such as mining of the soil, lowering of water table, and impairment of other ecosystem services.

Bioregional Management

Instead of viewing agricultural ecosystems as self-contained units, there is an increasing tendency to adopt a broad landscape or bioregional approach in which all aspects of the landscape are taken into consideration—natural, semi-natural, heavily modified including agricultural, industrial, and urban, protected and unprotected.

As Miller (1996) in a valuable review of the bioregional approach comments, *"Since the landscape is fragmented and much wildland has been converted to other use, the boundaries and coverage of some protected areas may not conform to the size and shape of the ecosystems that are to be maintained and managed. ... Moreover, in landscapes where protected areas have not been established, key genetic, taxonomic, and ecological elements of diversity that once may have been found in wildlands, or extensive farm or forest operations, are now relegated to isolated patches in intensively managed farms, pastures, timber-harvesting sites, and suburban, urban, and industrial areas."* Natural vegetation fragments are now becoming an almost universal component of our landscapes—*"Storm-battered islands in a sea of human settlement"* (Lash 1996)—and their management and that of agroecosystems has to be planned and implemented in the context of large biotically viable regions.

It is at the landscape scale, as Halffter (1998) points out, where the consequences of human action such as deterioration, ecosystem modification and fragmentation as well as pollution are most dramatic. It is also from the landscape perspective that we can analyze the diversity of species not just as a function of the heterogeneity of the biological and physical environment but also as a function of human activity.

Survey and Inventory

The conservation and sustainable use of traditional agrobiodiversity is of course undertaken locally but before action to support or enhance it can be organized, we need to assess and survey what different farming systems exist and which species are currently being cultivated or used by them. As is the case with biodiversity conservation, inventory is an essential to provide a base line for monitoring and subsequent action. An increasing amount of information is being gathered on the diverse types of management systems of agrobiodiversity (e.g. Alcorn 1990; Gadgil and Berkes 1991; Redford and Padoch 1992; Hladik et al. 1993; Altieri 1995, 1998; Gómez–Pompa 1996) but we need a more systematic gathering of this information, perhaps through national biodiversity strategies/action plans.

Well over 6000 species of plants are known to have been cultivated at some time or another and many thousand that are grown locally are scarcely or only partially domesticated, while as many if not more are gathered from the wild. Not surprisingly, most of the partially domesticated or wild-collected species are found in the tropics. For example, the Plant Resources Project of South-East Asia (PROSEA) records nearly 6000 species in its Basic List of species (some of them exotic) used by humankind in that area (Jansen et al. 1993) and assuming similar levels in other tropical regions, we can extrapolate to a figure of 18–25 thousand species for the tropics as a whole. In addition several thousand plant species are used in human activities in Mediterranean and temperate regions of the world.

These figures exclude most of the 25 thousand species that are estimated to have been used or are still in use as herbal medicines in various parts of the world, especially China, tropical Asia, the Indian subcontinent, Africa, and Central and South America, and the many thousands of species that are grown as ornamentals in parks and in public and private gardens and in the horticultural trade.

Gradually efforts are being made to improve this inventory but again action is needed at a national level in the first instance and it is remarkable how little attention has been given in national conservation or biodiversity strategies or action plans to the importance of identifying and listing which species are used by humans.

Conservation of Genetic Resources and Questions of Access

As noted in the Recommendations made by a DIVERSITAS Working Group of Experts on various Articles of the CBD (DIVERSITAS 1998), the wide interpretation of the concept of genetic resources implied in the Convention will require a policy adjustment for both ex-situ and in-situ management. The national and international efforts of the last 30 or so years to sample and maintain genetic diversity of crop and pasture species for future use in plant breeding and crop production, mainly in seed banks or in a smaller number of cases in field gene banks or clonal collections, will continue although with changes in focus.

One of the key questions that has to be addressed when considering the use of wild species as potential new crops is access to their genetic material. The term "access" today normally has the connotation of national sovereignty over natural resources as covered by Article 15 of the CBD. However, in the case of new, underexploited crops and semi/pre-domesticated species, access in the sense of actual availability, irrespective of "ownership" tends to be overlooked. Most gene banks have tended to give little priority to acquiring accessions of "minor" species or crop relatives. In fact, attention has often been drawn to the narrow spectrum of species—mainly the staple crops—that make up the bulk of the main national and international germplasm collections (Heywood 1993). While 15–20 thousand species are represented in gene banks, the numbers and size of the accessions of the vast majority of these is small in comparison with the accessions of land races and cultivars of the main crop and pasture species. The formal genetic resources sector has not been able to devote substantial resources to these other species although in recent years there has been a substantial broadening of approach and this is likely to continue and develop further.

While this work on genetic resource conservation will still concentrate on ex situ approaches, increasing attention will be paid to the in situ conservation of genetic diversity of wild relatives of crops and other wild species that are of importance to agriculture, forestry, and other human needs.

At the grass roots level, genetic conservation is aimed at needs that are normally not covered by large international germplasm centers or even by national systems. Much of the work that has been done is at local level by NGOs with strong farmer participation and by grass roots movements, such as community seed banking (Berg 1996). Most of the wild plant species that are used in local farm households have not been the subject of attention by the formal genetic resources sector although in recent years more attention is being paid to so-called minor or underutilized crops and to the wild relatives of major crops. It is likely that in the future there will be strong demands for these centers, and for FAO and IPGRI, to focus attention on these grass roots needs and for assistance to be given to farm households and local communities to help them obtain, maintain, and conserve genetic material of their locally used crops and semidomesticates. Conventional approaches to germplasm conservation have tended to concentrate on "conserving much and using little" but the interests of the small farmer are more likely to be served by making germplasm available than by storing it in genebanks for potential future use. For these small traditional farmers in the developing world that are cultivating plants under conditions that may be considered marginal, satisfying their needs through the traditional means of breeding for client farmers may not be appropriate or possible and an alternative that has been suggested is breeding with partner farmers—this would involve deploying advanced breeding materials, recombination with local materials and exposing it to evaluation and selection by local farmers (Berg 1996).

Broadening the Genetic Basis of Crops

At the genetic level of agrobiodiversity, the danger of depending on uniform genetic material and the need to broaden the genetic basis of many of our crops has frequently been pointed out. The dangers of depending on uniform genetic material as the basis of production in major crops are now well known. For example, the need for greater genetic diversity in many tropical crops is frequently observed. In yams, for example, the white Guinea yam (*Dioscorea rotundata*) that is West African in origin, a great amount of diversity is being lost throughout Africa and the future of the crop is at risk. Germplasm of wild relatives is proving an important source of new traits that will help restore diversity to the crop. As Hodgkin (1996) notes, the conservation of genetic diversity found within crops is important both for the continuing demand for new improved cultivars and for ensuring that there is sufficient variation in current agricultural systems to prevent disease, epidemics, and other disasters.

The Role of Diversity in Crop Production Systems

The GPA suggest that *"In the future agricultural systems will need to incorporate a broader range of crops including inter alia crops which produce raw material or are sources of energy."* In recent years there has been a greater willingness on the part of some farmers in some parts of the world to increase the range of crops grown. This is a particularly important issue in arid and semi-arid marginal lands and links in with the introduction of new crops and the wider exploitation of underutilized species.

There is growing recognition of the role that diversity plays in traditional farming systems. It is estimated that about 60% of the world's agriculture consists of traditional subsistence farming systems in which there is both a high diversity of crops and species grown and in the ways in which they are grown, such as polycropping and intercropping, that leads to the maintenance of greater or lesser amounts of variation within the crops. As just noted, greater attention is now being paid to the desirability of maintaining genetic variation within crops as a strategy for avoiding losses or failure in the face of disease or other factors and often farmers will retain traditional varieties alongside modern highly bred cultivars (Brush 1995).

New Crops

While development of genetically modified soybean and other major species may play a key role in achieving enhanced productivity that is essential for human survival, we must also look to new crops for part of the solution. New species are being added continuously to our list of economically important cultivated plants but as is abundantly well known the scope for extensive introduction of new crops is strictly limited because of a whole series of technical and socio-economic problems. The contribution of the Center for New Crops and Plant Products and the work of the New Crops Symposia and other similar meetings are indicative of the progress that is being made in this area.

Underutilized Crops

Important initiatives have been started in various parts of the world to explore the potential use of hundreds of local crops that are currently underexploited. An outstanding example is the series "Especies Vegetales Promisorias" (Promising Plant Species) of the countries of the Andrés Bello Convention (Bolivia, Colombia, Chile, Ecuador, Spain, Panama, Peru, and Venezuela). Promising species, in this context, are defined as those that are essentially native, have not been extensively domesticated, are underutilized or little known but with economic potential in the short, medium, and long term and about which basic scientific knowledge is available to validate their status as promising species. Over 1000 species have been identified by this project and over ten volumes published (SECAB 1989), containing a mass of valuable information on taxonomy, geography, ecology, properties, uses, phytochemistry, economic importance, agronomy, and industrialization. A review of neglected crops (*cultivos marginados*) of the New World has been published by FAO (Hernández Bermejo and León 1992).

Several groups have focused on the development of new or underutilized crops, such as the International Centre for Underutilized Crops (ICUC) whose goal is food security, nutrition, and economic welfare of human beings through assessing, developing, and utilizing the biological diversity of underutilized crops and species for sustainable and economic production of food and industrial raw materials. It has published a number of books on genetic resources of underutilized crops (e.g. Anthony et al. 1995, de Groot and Haq 1995; Smartt and Haq 1997).

Various networks have been created such as the Network on Underutilized Fruits for Asia (UTFANET), a regional network of southern and eastern African underutilized crops (SEANUC), and those established under IPGRI's Underutilized Mediterranean Species (UMS) project, e.g. the Rocket (*Eruca*, *Diplotaxis*) Genetic Resources Network (Padulosi 1995). IPGRI also runs a program for Promoting the Conservation and Use of Underutilized Crops that has published a series of treatments that include information on cultivation, agronomy, production, prospects, and related topics. The MEDUSA network (Heywood and Skoula 1997) for the identification, conservation, and sustainable use of wild plants of the Mediterranean region is concerned with native species of actual or potential importance to agriculture, especially in the semi-arid marginal lands of the area.

Particular attention is being focused on energy and industrial crops. For example, a recent FAO report on potential energy crops for Europe and the Mediterranean (El Bassam 1996) gives a catalog of species, some of them wild, many already cultivated, together with information on their characteristics, cultivation methods and utilization for energy production. The report considers that it is vital to increase the number of plant species that might be introduced into cultivation for this purpose. In addition, many so-called minor species that have been traditionally used as herbs, condiments, and medicinals are now being looked at for possible industrial applications. A report, prepared for the European Commission (Smith et al. 1997), highlights the wide array of species and products that could be developed for industry and energy in Europe.

The Role of Biodiversity in Natural Ecosystems

An important trend is the recognition of the need to consider natural and semi-natural ecosystems in the context of agrobiodiversity. These ecosystems contain wild plant species, races, and populations that are of importance for food and agriculture, such as wild relatives of crops and species, are important sources of material for agroforestry, habitat restoration, and reforestation, and species that are wild harvested and contribute to farm household incomes. They also form part of the landscapes within which agricultural systems are found and provide a whole series of environmental services and functions, such as soil stabilization, water and air quality, on which healthy sustainable agroecosystems depend. It is also now increasingly recognized that alterations in natural ecosystems through accelerated deforestation, logging, or conversion to other uses, may also affect the viability of neighboring agriculture. As a recent report on the effects of climate change and land use on Amazonian forests notes (Laurance 1998), there are alarming synergisms between human land-uses and natural climatic variability. Thus logged or fragmented forests are increasingly susceptible to fire and climatic vicissitudes and fragmentation of forests can lead to a juxtaposition of forest fragments with fire-prone pastures and farmlands. The risks to farming systems under such circumstances are obvious.

Wild and Wild-harvested Species

While large-scale agriculture will continue to focus on monocultures of the major crops, increasing attention will be paid to the role of wild and wild-harvested species in farm systems. Another major source of agrobiodiversity is the tens of thousands of species that are grown in a pre- or semi-domesticated state on home gardens or similar polycultures. As noted above, many thousands more are wild harvested to supplement farm household incomes.

The biodiversity of most of the wild species used in traditional farming systems is usually poorly studied. Even their identification and classification is often unsatisfactory, leading to considerable confusion when the plants or their products are traded. Even less is known about their detailed distribution, the extent, size and diversity of their populations, their breeding behavior, pollination mechanisms and so on. Since most of the species we are concerned with have never been cultivated or are at most semi-domesticated on a local scale, our knowledge of their most basic biology and agronomy is virtually non-existent and we must depend on knowledge developed over long periods by local farming societies. Such indigenous knowledge, as Altieri (1995, 1998), points out often includes very detailed understanding of the physical environment, including weather and soil types. It is essential that this local knowledge, that is itself an important resource, should be recorded and made available for future generations.

On-farm Management

Much of the diversity in agroecosystems is found in the hundreds of thousands of land races that have developed over the centuries in farmers fields, through a process of unconscious selection and saving of seed or vegetative propagules for future planting seasons. These land races are agroecotypes that are adapted to the local ecological, agronomic, social, and cultural traditions. They are increasingly at risk through replacement by modern cultivars as farmers attempt to increase yields.

The term on-farm conservation is applied to the dynamic conservation of genetic diversity in such land races and weedy crop relatives in traditional, usually low-input farming systems and is an area of increasing interest and concern. As stated in the Global Plan of Action (Priority Activity 2), there is a need for better understanding and improvement of the effectiveness of on-farm conservation so that action can be taken to increase its contribution to food production and security. Amongst the research needed is work on the promotion of little known crops, their seed production, marketing, and distribution. On-farm conservation is a form of in situ conservation but is significantly different from in situ conservation of wild species in natural or semi-natural ecosystems and should not be confused with it as has happened frequently in the past.

Agricultural Biotechnology

An inevitable and highly controversial trend in the handling of agrobiodiversity is the growing and developing use of the techniques of agricultural biotechnology. Apart from the well-publicized risks that may be attendant on the cultivation and consumption of genetically modified crops, appropriate technologies are likely to play an increasing role in assessing genetic variability and in the breeding and enhancement of crops.

THE NEGLECT OF AGROBIODIVERSITY AND AGROECOLOGY BY CONSERVATION BIOLOGISTS

Although the World Conservation Strategy (IUCN, UNEP, WWF 1980) published in 1980 recognized the importance of agriculture and included a program for the conservation of zones rich in genetic resources, subsequently mainstream conservation gave them little priority, preferring to concentrate on charismatic or flagship species, or any kind of endangered species, and on protected area systems and tropical forests. Certainly, lip service was paid to the conservation of wild species used by humans in campaigns such as WWF's "Saving the Plants that Save Us," although agriculture was generally viewed as detrimental to the conservation of biodiversity; and occasionally attention was drawn to importance of wild species in tropical forests in terms of their value to extractivists, as a justification for their conservation rather than conversion to other uses. But with the exception of the pioneering work of Altieri (1995, 1998) and others on agroecology and the importance of traditional farming systems not only in terms of cultivated fields but the natural ecosystems that surround them, and Gary Nabhan on local seed savers, conservationists and conservation biologists alike have contrived to avoid these issues.

Only recently (Vandermeer and Perfecto 1997) in an editorial in *Conservation Biology* addressed the issue of the agroecosystem and the need for viewing it under the conservation biologists lens. The failure, they say, of conservation biologists to show much interest in agroecosystems, simply because they are already tainted, is matched by the lack of interest from agroecologists in the biodiversity found in traditional agroecosystems since it has no obvious connection to production. Since we are increasingly concerned with introducing forms of sustainable agriculture that will reduce the adverse effects of agriculture on biodiversity, it is vital that the conservation biology community changes its attitude and starts considering agroecosystems as legitimate areas for study and begin asking the same questions that they do about so-called "natural ecosystems."

The development agencies have not focused much attention on the effects of agricultural development projects on biodiversity and fewer than 2% of 377 agricultural projects financed since 1988 by the World Bank have dealt explicitly with biodiversity (Srivastava et al. 1996)

Vandermeer and Perfecto (1997) state the situation as follows:

> *The fact is that most of the terrestrial world is, in one sense or another, an agroecosystem. If we are to ignore this ecosystem simply because it does not fall within our romantic notion of "pristineness," we leave the vast majority of the Earth's surface to the husbandry of those who care little about biodiversity preservation. On the other hand, if we are to ignore the preservation of biodiversity per se simply because it does not fit obviously into classical production categories, we leave the preservation of the world's biodiversity to those who refuse to work outside of national parks and nature preserves.*

This reluctance to consider agroecosystems is another manifestation of the disdain shown by some for artificial, i.e. human generated biodiversity and who argue that this should not be our concern and that we should not advocate the preservation of diversity so much as protection of ecological integrity.

CONCLUSIONS

To summarize, many of the trends in agrobiodiversity center around the recognition of the benefits that accrue from diversity as such, whether it be in terms of genes in crops, the range of species cultivated, or the range of cultivated systems used. It could be argued that maintenance of biodiversity and achieving agricultural sustainability—the theme of this conference—is as likely to be found in developing strategies to maintain multiple species agroecosystems as in large-scale modern monocultures, despite the imperative facing us of raising staple food production to match the demands of the world's growing population. But there is no contradiction if we remember that 20% or more of human nutrition probably derives from traditional farming systems, not to mention non-food crops such as non-wood forest products and medicinal plants, supplemented by highly diverse systems of wild harvesting. We need to ensure that these traditional systems are not eroded or swept away by political and economic forces that lead to soil erosion, decreased biodiversity on farms, genetic erosion, and loss of traditional knowledge (Altieri 1998). On the contrary considerable efforts must be put into enhancing productivity and intensification of production in these systems so that they too can make a substantial contribution to the overall food demand in a way that does not put the peasant farmers at risk or lead to further environmental degradation.

"Biodiversity is a non-detachable part of the concept of sustainability. ... biodiversity is essential for agricultural production, as agriculture should be for biodiversity conservation." The agricultural and biodiversity conservation sectors must work in partnership and the fact that this is now beginning to happen is perhaps the most important trend of all in the development of agricultural biodiversity.

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