Joint IUCN-WWF Plants Conservation Programme

Biodiversity

The Key Role of Plants

WWF

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BIODIVERSITY: THE KEY ROLE OF PLANTS

What is Biodiversity?

"Biodiversity" means simply the variety of living things on this planet. As such, the conservation of biodiversity has always been a major concern of conservation organisations. However there has up to now been a tendency to concentrate on a small part of the total, for instance large mammals, species with an immediate psychological impact. Another focus has been tropical forests, which again have had great impact. As the conservation movement has matured, there has been a shift of interest from species to ecosystems, and now to species in ecosystems. Conservation of maximum biodiversity within ecosystems is now considered as paramount for the future.

The current conservation interest in biodiversity - the full variety of life - stems from increasing extinctions, and a desire to ensure that no species falls through the net. Many constituencies of interest are involved with biodiversity, but all approaches are founded on the same common ground: a perception of the variety of life as a raw material, a resource and a priceless possession in its own right.

How can we measure or characterise this variety? Its simplest expression is as the total number of species that exist. However, the use of species to characterise biodiversity is arbitrary. Not only is the "species" a subjective category, but we are interested in diversity below the species level (genetic diversity) as well as above (taxonomic diversity). Alternatively we may be interested in diversity of organism form or size, or diversity with reference to some special-purpose classification, e.g. variety of flower colour, rather than the traditional taxonomic one.

Different constituencies of interest will look at diversity on different levels; the evolutionary biologist may be interested in the panorama presented by orders and families, while the plant breeder will put diversity under the microscope to look at variety below the species level. Nevertheless species richness is the most widely used measure of diversity.

There are several problems with interpreting species richness. Firstly, the taxonomist's tasks are far from done. There are many species still to be described, possibly some 10% of higher plants and the majority of insects. World species richness is usually estimated at 5-10 million, or even 30 million, of which about 2 million have been described. Secondly, whether a particular set of individuals is classified as a species or a subspecies is often subjective; biologists still argue over whether "a species" is a real or an arbitrary concept.

Another problem lies in estimating the species richness of an ecosystem or area from a sample. If the species are equally abundant (high evenness), all the species will be found in a relatively small sample. If, on the other hand, some species are very rare, while others are very common (low evenness), then a much larger sample will be needed to contain all the species. For this reason diversity is often measured by an index calculated from dividing species richness by unevenness.

Lastly one other aspect of diversity that should be mentioned is mosaic diversity. An area may have high diversity because many species are packed into one ecosystem, or alternatively because there are a mosaic of different habitats.

Having said all this, world species richness, however one assesses it, is vast; so vast in fact as to be almost beyond human comprehension. The fact is, and it is one of the most extraordinary facts of our technological century, that *we just do not know*, to any greater accuracy than one order of magnitude, how many species co-habit this planet with us. We *just do not know* the size of the biological resource on which Man's future ultimately depends. *We just do not know* the magnitude of the biological heritage which it is our responsibility to safeguard.

TABLE 1

Numbers of species in the major plant groups

Kingdom	*Division*	*Common name/examples*	*Approx. no of species*
Monera		Bacteria	2500 archaebacteria prob. 200 cyanobacteria
Fungi		Fungi	100,000
Protista	Rhodophyta	Red algae	4000
	Phaeophyta	Brown algae	1500
	Chlorophyta	Green algae	7000
	Chrysophyta	Chrysophytes, diatoms	6650
	Pyrrhophyta	Dinoflagellates	1100
	others	Water moulds, slime moulds	1800
Plantae	Bryophyta	Liverworts, mosses, hornworts	16000 6000 liverworts 100 hornworts 9500 mosses
	Psilopsida	Psilopsids	several
	Lycophyta	Clubmosses	1000
	Sphenophyta	Horsetails	30
	Pteridophyta	Ferns	12,000
	Coniferophyta	Conifers	550
	Cycadophyta	Cycads	100
	Ginkgophyta	Ginkgo	1
	Gnetophyta	Gnetophytes, Gnetum	70
	Anthophyta	Flowering Plants	235,000 - 250,000

Source: Mostly following Raven, P.H. *et al.*, *Biology of Plants*, 4th Ed. (1986).

The Special Significance of Plants in Biodiversity

1. The Visible Expression of Variety

"The .... traveller should be a botanist, for in all views plants form the chief embellishment" (Darwin).

The response of man to nature is largely mediated by plants - the most visible expression of life in the landscape. The exuberance of a tropical landscape with flowers of different colours, plants of different forms (trees, lianes, herbs, epiphytes) is a memorable sight. What makes it memorable is the diversity: animal life of course contributes, but green plants by their size and abundance (the largest organisms on this planet are plants) celebrate diversity more than any other group.

The shock of coming face to face with diversity has stimulated artists and scientists alike. The great 17th century naturalist, John Ray, described how his inspiration to study organisms came to him: "first the rich array of spring-time meadows, then the shape, colour and structure of particular plants fascinated and absorbed me: interest in botany became a passion". John Ray's response to species-rich meadows is merely an extension of the response to diversity that has been omnipresent in human history and is expressed in the "millefleur" grounds of medieval tapestries and the flowery mead of the medieval imagination. Boccaccio (Decameron) describing a castle garden says of it: "What seemed more delightful than anything else, was a plot of ground like a meadow; the grass of a deep green spangled with a thousand different flowers".

2. The Biomass Matrix

Average biomass figures for the United States have been estimated at 6 kg per sq. m. Of this 89% consists of higher plant matter. A further 7.7% consist of lower plants (algae, fungi, bacteria). A mere 3.6% consist of animals (mainly earthworms). Livestock and other mammals, including humankind, make up 0.152% of this. These suggested figures for the United States are not unexpected. The universally higher biomass for plants is the basis for the concept of trophic levels, whereby "all flesh is grass". Plants not only provide the primary source of fixed solar energy: their mass provides and determines habitats, *lebensraum*, perches, substrates. Plants are even necessary to most processes of soil formation (pedogenesis).

From this it follows quite simply that a decline in plant diversity may have a catastrophic effect upon ecosystems. This idea can be approached through the ecological idea of complexity. Complexity is proportional to the number of biotic interactions between species (obviously enhanced by diversity). The removal of a plant species (likely to be the centre of numerous biotic interactions) will lessen greatly the complexity of an ecosystem.

Complexity, or the number of between species interactions, is what gives ecosystems their interest and fascination for biologists. Complexity is not to be confused with diversity: it is something quite different, but diversity is an essential pre-requisite for complexity. Obviously when diversity is high, complexity tends to be high too. Complex ecosystems may also under some circumstances be more stable than simple ones.

3. Plants as a Cause of Animal Diversity

One of the consequences of ecological thinking on competition is that for a given physical environment, the best-fitted species will come to dominate. With a few best-fitted dominant species, diversity should be extremely low. It is easy though to see how animal diversity can arise nevertheless. There are around 250,000 species of higher plants alone, each providing a multitude of different foods and substrates (bark, roots, petals, seeds, etc.) for the animals which depend on them: animals which can exist each in a separate plant-based niche.

Plant diversity is then considered by many scientists a prerequisite for the evolution and maintenance of animal diversity.

TABLE 2

Total plant species and diversity estimates for selected countries

Country	*Species richness*	*Area*[1]	*Diversity*[2]
Europe			
United Kingdom	1800	244,754	334
Italy	4800	251,447	888
Albania	3200	28,748	717
Czechoslovakia	2700	127,870	528
Norway	1700	323,895	308
Tropical Africa			
Gabon	8000	267,667	1473
Cameroon	9000	475,500	1585
Zaire	11,000	2,345,410	1726
Tanzania	10,000	939,762	1674
Uganda	5000	236,578	930

1. Sq. kms
2. Estimated number of species per 10 sq. km, assuming a linear relationship between species and the logarithm of area, calculated by dividing species number by log area.

Source: *Plants in Danger: What do we Know?* (1986)

4. Plants Correlate with Animal Diversity

Plant diversity is far from uniform from region to region. Two important generalities are possible:

1. High plant diversity occurs in regions of suboptimal soil conditions, e.g. South-Western Australian heaths (kwongam), South African heaths (fynbos), tropical forest on laterite soils;

2. Plant diversity is highest in the tropics and declines with increasing latitude.

The first generality is usually explained by suboptimality preventing the establishment of dominance. The second generality is usually regarded as a function of environmental stability. The glaciations and climatic changes of the Quaternary period have caused much extinction, while the high diversity tropical forest environments near the equator may have been less affected. Centres of high plant diversity such as New Caledonia, Madagascar and Mt Kinabalu, which have what may be considered "relict" floras, are also centres of animal diversity.

From a purely pragmatic point of view, identifying and preserving centres of high plant diversity is the best way of preserving high animal diversity.

Plant Diversity and People

1. The Plant Breeder

Although only about 100 plant species have become major commodities traded between nations, the number of crops is being expanded as plant diversity is better explored and understood. A recent example of a new crop is Jojoba (*Simmondsia chinensis*), whose high quality oil is the only substitute for sperm whale oil and has found many uses. There are also a number of crop plants which have never broken out of small-scale agriculture, but which could have global significance - the so-called "under-exploited species". As biodiversity is reduced, so is the potential for the development of new crops.

Besides new crops, there is a constant need to improve old ones. In most crops that are grown as monocultures over large areas there is a "varietal relay race". New varieties replace old ones as pathogens adapt to disease–resistant types. As the breeder tries to take care of the ever-pressing needs of the farmer wild species are often turned to. The first person to realise the importance of wild relatives of crop plants was the great Russian botanist Nikolai Vavilov. A posthumously published work (1949) drew attention to "Centres of Diversity", areas of the world particularly rich in crop plants and their wild relatives. The so-called Vavilovian Centres of Diversity are a good place to begin the conservation of the diversity needed by the plant breeder.

Use of wild species in plant breeding can produce spectacular results. A wild relative of the tomato growing in the Peruvian Andes collected in 1962 has conferred a higher sugar content on cultivated tomatoes, a trait useful to the processing industry to the tune of US$ 5 million per annum. A single population of the Indian wild rice *Oryza nivara* was used by breeders to produce IR36, the disease-resistant rice variety which did more than any other to bring about the Green Revolution. This portion of wild genetic diversity could so easily have become lost before it was discovered. Similar examples are legion.

Even weeds contribute their biodiversity. Weedy relatives of maize (teosinte) have exchanged genes with maize in central America since its domestication: this is said to account for the variety and productivity of the maizes of Mesoamerica.

This variety of primitive cultivars is another component of plant diversity that is important to the breeder. Unfortunately, it is endangered by the very product it helps to create. As new varieties arrived from developed countries and breeding stations, the small farmers, who are the traditional guardians of crop plant diversity, abandoned their old varieties. Even as early as the 1920's American-bred cereals were extinguishing valuable land-races in remote Saharan oases such as Mariout in Egypt, as better roads increased the penetration of new agriculture. It is even said that Henry VIII destroyed huge amounts of early crop diversity, when in 1534 he dissolved the monasteries in England and their associated gardens.

2. Pharmacists and Chemists

Plant diversity produces biochemical diversity. So far some 20,000 naturally occurring compounds have been scientifically identified and characterised. This number is thought to be only a tiny fraction of the number of chemicals produced by plants. Examples include the anti-cancer alkaloid vincristine, the cyclo-propanoid pyrethrin insecticides, the napthoquinone root pigment shikonin (used as a cosmetic) and monoterpenoid perfumes such as geraniol (rose oil). The plant-derived pharmaceuticals industry is worth around US$ 10 billion annually in the U.S. alone.

These figures are impressive but considering how little is known about the biochemical diversity of plants the potential is unimaginably vast. Studying the use of plants as drugs and medicines by indigenous people in centres of plant diversity is probably the most efficient way for industry to get at the drugs of the future, and this is reflected by new journals such as the "Journal of Ethnopharmacology".

Many other industries reap the benefits of plant diversity besides the pharmaceutical industry. Oils, waxes, dyes, textiles, rubbers, gums, resins, tannins, fatty acids, as well as a host of other useful chemicals all come from plants and mostly from tropical plants growing in regions of high diversity. If we reap these benefits already, even after a cursory examination of the plant resources, then the conservation and full inventory of our centres of plant diversity seems more than worthwhile.

3. Indigenous Peoples

To native people, centres of high plant diversity (such as the tropical rain forest) are not perceived as "green hells" but as bountiful habitat in which countless needs are provided by wild plants in the forest. Their use of the forest is sustainable and non-destructive. In this way, indigenous peoples are the interpreters and guardians of the forest.

The complex system of natural resource management evolved by the ancient Maya culture was directed at the maintenance of biodiversity. Maya orchards were planted not with just one species but around 50 tree species, in as many genera. The suggestion often made that Maya culture collapsed because they failed to manage their resources adequately is an over-simplification. Likewise the Kayapo Indians of Brazil maintain their crop plant diversity in hillside gardens maintained exclusively by women elders. A diverse resource of plants in the families Zingiberaceae, Marantaceae and Araceae is thus maintained in case of disaster in the main croplands.

As centres of plant diversity often occur together with fast disappearing pre-industrial societies, conservation of one means the conservation of the other. If the resources of biodiversity can be likened to a book, then indigenous peoples are the indexes.

4. **Foresters**

The plant diversity of tropical forests gives rise to the finest timbers in the world and the greatest diversity of timber: afrormosia (*Afrormosia*), agba (*Gossweilerodendron*), antiaris (*Antiaris*), avodire (*Turraeanthus*), bubinga (*Guibortia*), ebony (*Diospyros*), iroko (*Chlorophora*), mahogany (*Swietenia*), padouk (*Pterocarpus*), paldao (*Dracontomelum*), primavera (*Tabebuia*), purpleheart (*Peltogyne*), rosewood (*Dalbergia*), sapele (*Entandophragma*), satinwood (*Chloroxylon*), teak (*Tectona*) and zebrawood (*Microberlinia*), to name but a few.

Almost all of this timber is logged from wild grown trees. With present methods this wonderful diversity of timber is not proving to be a sustainable resource: the disturbance of logging often destroys the forest and the forests are rarely replanted. Furthermore, tropical forests rarely regenerate their structure from cut stumps, unlike temperate hardwoods, which coppice. Even where the logging is done carefully and selectively, so that the plant structure remains, plant diversity, especially of epiphytes, usually declines.

This process puts the quality of our timbers of the future in jeopardy. Genetic resources are eroded by selective felling: for example it is difficult now to find good specimens of Cuban mahogany. Important timber trees are even being lost before they are described. A near miss was *Persea theobromifolia* now reduced to a population of a dozen mature trees at Rio Palenque, Ecuador, although for years it was a favoured timber tree. Yet it was only "discovered" by science in 1977!

The conservation of plant diversity and the conservation of our timber resources for the future are one and the same.

5. **Gardens and Horticulture**

"God Almighty first planted a garden, and, indeed, it is the purest of human pleasures; it is the greatest refreshment to the spirits of man, without which building and palaces are but gross handyworks: and a man shall ever see, that when ages grow to civility and elegancy, men come to build stately, sooner than to garden finely; as if gardening were the greater perfection" (Bacon).

Gardening, which in its western form takes its cue from the medieval desire to create a vision of Eden (or the *Hortus Paradisi* of the Persians), may be defined as the forced creation of an ultra-high-diversity ecosystem. In an ecological sense the garden has artificially high diversity combined with low complexity. The gardener reduces complexity by growing the plants apart, so reducing biotic interactions: this prevents any one species dominating (e.g. a noxious weed) and reducing diversity.

As islands of artificial diversity, gardens have an important role in the conservation of diversity. However, *in situ* conservation is always better if it is possible, as in a garden natural processes of evolution are stayed and populations are, of necessity, small and vulnerable. There are other ways though, in which Botanic Gardens are taking the lead in the conservation of plant biodiversity. Botanic Gardens are the showcase of biodiversity and as such perform a vital educational function. Also Botanic Gardens, particularly in the tropics, are increasingly providing back-up to conservation projects in natural ecosystems as well as taking on the tasks of inventory and research.

It is to regions of high plant diversity that we may turn to find new plants to brighten drab city life, and Botanic Gardens can provide a link between biodiversity and the horticultural trade. A case in point is the introduction during the last 20 years of the houseplant *Spathiphyllum* to dwellings and offices of the temperate developed world. Not surprisingly this plant was found in Colombia - a region of exceptionally high plant diversity.

Saving Biodiversity: the Conservationist's Tasks

The conservationist has a desperate need to understand plant diversity: to know how to locate it, to be able to inventory it and to know how to manage it as a complete ecosystem. Its inventory is the vast and profound task of the taxonomist, whose science is at the very centre of our understanding of biodiversity. Its management calls on the new and vitally important science of conservation biology.

Not only is plant diversity an important issue in its own right, it is also the vital lead into the conservation of animal diversity. Indeed, the most efficient way of conserving biodiversity (both animal and plant) is to locate and conserve areas of high plant diversity.

The best policy is always to conserve biodiversity *in situ*, i.e. in the places where is occurs naturally. *In situ* conservation allows large numbers of individuals to be conserved, something that is more difficult to do *ex situ*. However, *ex situ* methods should also be used, especially for plants, as a complement to *in situ* techniques; in some cases *ex situ* conservation is the only possible option.

Much important work has been carried out recently in conserving crop plant genetic diversity in gene banks (collections of seeds or tissue stored under special conditions and from which new plants can be grown). Genetic resources, however, need to be conserved in natural ecosystems too. This is not only cheaper in the long term, but allows natural selection to continue with the possible evolution of new taxa, and co-evolution with pests and diseases. Another advantage is that it ensures the participation of a wider community of people in genetic diversity conservation.

As Cyrille de Klemm has pointed out in a major paper ("Conservation of species: The need for a new approach", *Environmental Policy and Law* 9: 117-128, 1982), one problem in conserving biodiversity is that its users - plant breeders, pharmacists, foresters - rarely pay a fair price for the wild stock that reflects the costs of conserving that resource for them, either in the past or in the future. While individual plants have value and can be owned, a species is a concept, and as such cannot be owned and has no "value" in the eyes of the law, in the same way that a piece of property might (even though the continued survival of a species may have enormous value to Mankind). Species thus cannot be bought or sold.

This gives rise to problems when attempting to conserve biodiversity through law. If a tree is chopped down unlawfully, courts in most countries do not hesitate to award compensation to the aggrieved party. If a species is extirpated by negligence or greed there is no owner: no-one to whom compensation can be paid. Theoretically though, the compensation could be high: 50 million dollars *per annum* is a typical figure for the sales of a plant-based drug.

This phenomenon of the careless destruction of unowned resources is another manifestation of what has been called "the tragedy of the commons"!

Many plant species (probably several hundred) exist as one individual only. Whoever owns that individual plant in a sense may be said to own the species. The value of that plant however is only taken to be the value of that single individual, as firewood or fodder, etc. Obviously this is not ideal: there is scope for the countries of the world to agree a Convention to balance the obligations of states to conserve their biodiversity with the obligations of users of biodiversity to contribute to that cost of conservation. In order to do so, the Convention could vest ownership of species in the trusteeship of the world community. The trusteeship would thus have responsibility for, and ownership of, world biodiversity: it would be able to sue for the protection of its right and collect royalties.

This would circumvent one of the rankling problems of using plant biodiversity. At present plant breeders in developed countries can (and frequently do) collect quite freely species or other genetic material in developing countries; using "plant breeders rights" (whereby varieties can be patented) they can generate a large revenue without paying any of it back to the country where the resource originated.

These are the conservation goals of the future, in the face of a situation of such gravity that cost-ineffective single-species conservation is increasingly difficult to justify.

TABLE 3

Higher Plant Species Richness in Selected Areas

Region	*Species*	*Threatened species*
Australia	25,000	1716
Europe	11,300	1927
New Zealand	2000	186
South Africa	23,000	2122
U.S.S.R.	21,000	653
U.S.A.	20,000	2050

Source: *Plants in Danger: What do we Know?* (1986)

How the IUCN-WWF Plants Programme is Acting to Safeguard Biodiversity

1. **Spreading the Message**

WWF and its 23 National Organisations ran an awareness campaign on plants in 1984-1985: plant diversity was a key issue, especially in the resulting presentations, including the book *The Green Inheritance* by Anthony Huxley. Individual field projects all contain an awareness component and additional projects have been set up on awareness alone, e.g. a project in India to demonstrate the socioeconomic and developmental benefits of conservation of plant diversity in existing climax forests. As the awareness of biodiversity increases, plant species richness is increasingly seen as an important asset.

2. **Building the Capacity to Conserve**

Biodiversity is an excellent focus for encouraging plant conservation action by governments, concerned organisations and citizens. To provide the broad and strategic thinking needed, IUCN and WWF have established a joint Plant Advisory Group to provide ideas and guidance. The Group also sets the knowledge and experience of professional botanists, particularly regarding plant diversity, at the disposal of the conservation movement.

The Threatened Plants Unit of IUCN monitors the decline in plant diversity through its database on all known threatened species and through its programme to assist other organisations to develop their own plant databases.

The programme is also working on legal approaches to the conservation of biodiversity and is contributing to the development of the proposed convention on it.

A handbook on the principles and practice of plant conservation is being prepared by David Given for adaptation and dissemination of ideas and techniques throughout the world. Diversity will be a major theme.

3. **Conserving Plant Genetic Resources**

The genetic diversity of our crop plant resource is under threat. Wild relatives are disappearing through habitat change and primitive land-races are disappearing through changes of agricultural practice.

The Plants Programme is collaborating with other organisations to stem this loss, with emphasis on *in situ* conservation of wild crops and their relatives. For example, a joint project with IBPGR is conserving wild Mangoes (*Mangifera*) in the important centre of plant diversity of Borneo. Previously 10 species were known in the area, but after survey this figure was raised to about 20 species, 2 of which may be new to science.

4. **Conserving wild plants of economic value**

Economic botany is charged with providing plants to feed, clothe and house humanity as well as curing the sick. Increasingly the emphasis is changing from the hundred or so plants that enter into international trade, to the relationship between plants and people in centres of plant diversity.

The Plants Programme is engaged in several projects to safeguard the diversity of traditional economic plants, varying from overall assessment of the global priorities to detailed ethnobotanical studies in tribal societies. Special emphasis has been placed on the conservation of medicinal plants, working with WHO's programme on Traditional Medicine, and on the conservation of palms, a group of great economic potential.

5. **Strengthening the capacity of Botanic Gardens to achieve conservation**

There are about 1500 botanic gardens around the world. They could form the world's showcase for plant diversity, as well as a link between conservation of diversity in the field and conservation planners. Under the Plants Programme, IUCN has prepared a Botanic Gardens Conservation Strategy and has set up a Botanic Gardens Conservation Secretariat (BGCS), which is co-ordinating the conservation efforts of botanic gardens and promoting the flow of information, ideas and expertise between gardens, e.g. by twinning and liaison programmes.

6. **Promoting Plant Conservation in Selected Countries**

Besides setting the conceptual and strategic framework for the conservation of biodiversity, the Plants Programme also comprises on-the-ground field projects, aimed at safeguarding diversity in a selected range of 20-30 countries. Tropical forests are obviously a priority and the Programme is contributing to the establishment and consolidation of a wide range of protected areas, especially large tropical ones, e.g. La Amistad in Costa Rica, Manu in Peru, Sapo in Liberia and Sinharaja in Sri Lanka.

The Programme also contains many field projects specifically on plant diversity, e.g. rescuing the endangered flora of Mauritius by a judicious mixture of *in situ* reserves and *ex situ* cultivation, identifying the conservation needs for the *campo rupestre* in Brazil, and contributing to a plant conservation strategy for the Canary Islands.

As a guide to priorities, not just for the Plant Programme but to the whole conservation and aid community, IUCN and WWF are preparing a major book on plant diversity, entitled *Centres of Plant Diversity: a Guide and Strategy for Conservation*. An initial outline has already been produced. The book will outline the geographical distribution of plant diversity. Regional summaries will provide the background and detailed data-sheets on specific sites will provide the information for action.

A more detailed review of the whole programme may be found in the parallel booklet *The Joint IUCN-WWF Plants Conservation Programme: Achievements 1984-1987 and Activities Planned 1988-1990* (1988).

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