Efficient Use of Biodiversity Resources

by

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C O N T E N T S

Chapter 1

1. INTRODUCTION

Thomas C. Schelling (1978), in his book "Micromotives and Macrobehavior" wrote:

> **It is hard to explore what happens when people behave with a purpose without becoming curious, even concerned, about how well or how badly the outcome serves the purpose. Social scientists are more like forest rangers than like naturalists. The naturalist can be interested in what causes a species to become extinct, without caring whether or not it does become extinct. (If it has been extinct for a million years his curiosity is surely without concern.) The ranger will be concerned with whether or not the buffalo do disappear, and how to keep them in a healthy balance with their environment.**

We begin the introduction to our study with this quotation because it reflects our belief that environmental issues involve a wide range of disciplines, among which we might list biology, economics, ecology, ... Each discipline looks at environmental problems from a different perspective, with its own methods and bias. For example, an economist's view of water pollution will not be the same as that of an engineer or biologist. Yet economics, biology and engineering all have valuable contributions to make in helping us look at environmental issues for a coherent and holistic point of view. Andreas Faludi (1987) in a book entitled "A Decision-centred view of environmental planning", wrote: "Method refers to established ways of inferring conclusions from assumptions and evidence. It conveys legitimacy on the outcomes of arguments, be it in research or in planning". Faludi continued: "Methods make no sense where there is no argument: and argument makes no sense where no methods are used.

So talk about methods in human pursuits rest on a view that debates are necessary, and the opinion of others are resources for the resolution of problems."

This passage makes it clear that efforts to deal with complex matters such as natural or environmental resources will often require some form of cooperation and coordination in order to achieve the outcome desired.

Now not all environmental planners act like rangers. In fact, they, particularly geologists and biologists, act more like naturalists and indeed they are, because they focus more on the causes of environmental problems than on how to find suitable remedies for these problems. This is not to say that the causes are not important. However, one should not neglect the effects, over time, of environmental problems on human life. In some cases, one can argue that it is easy to evaluate those effects; in other cases, the task is almost impossible. This brings us to a second assertion that more often than one can possibly imagine, the environmental effects of various activities of man are unknown. Uncertainty about environmental effects of man's activities brings great divergence of opinion even among experts. In the Icelandic fishing dispute there is considerable uncertainty about the size of the existing stock, not to mention the uncertainty over the bio-mass at which a species is endangered. In the context of preserving the natural environment, there is the possibility that the damage inflicted on the environment might be irreversible.

Man exists in a physical environment. When the world population was low, human activities had a negligible effect on the environment. Hence in the past researchers were only concerned with the question of how the environment constrains and influences the process of human development. In the last few decades, the world population has seemed to explode. In its efforts to clothe and feed itself, the human race has exerted an enormous pressure on the environment. The consequences are manifold and incalculable: water and air pollution, deforestation, desertification, global warming, ... The urgent question now is not how the environment influences man, but how to curb human activities from inflicting irreversible damages on the environment, damages that threaten life on earth.

The relationship between man and the environment has generated many passionate debates in recent years, and several viewpoints have emerged. One dominant viewpoint holds that nature's resources are there to be used, and this use should be characterized by efficiency and absence of waste. The second viewpoint represents aesthetic, religious, and ethical concerns, which call for a restraint on human actions affecting the environment. The third viewpoint, and on which this study emphasizes, is that the absence of caution in human undertakings can lead to an irreversible and sometimes disastrous impact on the ability of the natural systems to function. This issue is viewed by Fisher and Krutilla (1985) as being one in the spectrum of interactions between man and the rest of the living world. Their discussion focused on the importance of wilderness and endangered species as "economic resources". Further, they argued that wholesale loss of species or ecosystems have consequences that are impossible to reverse and difficult to ameliorate. They also argued that the optimal use of a natural environment is more likely to be continued preservation, where the passage of time can bring information about potential future benefits of preservation.

Our main objective in this study is to investigate the problem of uncertainty and irreversibility that might arise when we have to decide whether a natural environment should be developed. There is a high degree of uncertainty concerning the biodiversity that exists in the environment as well as the potential value of this biodiversity. The decision to develop the area brings immediate benefits. On the other hand, this decision also causes a total loss of its biodiversity, an irreversible decision with uncertain costs. Furthermore, if development is delayed to gather more information on the potential and magnitude of the biodiversity, then a more rational and efficient pattern of exploiting this natural environment might result. Which is the optimal decision: to develop or to wait? This is the question we wish to analyse in this study. Therefore, our investigation is manifold. The plan of the paper is as follows: In chapter 2, some useful biological concepts are presented. In chapter 3, we discuss about uncertainty and biodiversity. Chapter 4 presents a fascinating analysis on development versus conservation. Chapter 5 prescribes some remedies (what to do). Chapter 6 offers an application on the value of a forest. Finally, chapter 7 presents our concluding remarks.

Chapter 2

2. BIODIVERSITY AS NATURAL CAPITAL

2.1 Definition of the Term "Biodiversity"

The terms "Biological diversity" or "Biodiversity" are used interchangeably to describe the variability among living organisms from all sources, including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species, and of ecosystems.

Biological resources include genetic resources, organism or parts thereof, population, or any other biotic component of any ecosystem. Genetic diversity refers to the variation of genes within species, as expressed in the thousands of traditional rice varieties of Asia. Species diversity refers to the variety of species within a region, measured either as the total number of species present "species richness" or as a combination of species numbers and distinctiveness "taxonomic diversity".

Ecosystems are dynamic complexes of plant, animal and micro-organism communities and their non-living environment, interacting as an ecological unit. Among our natural resources, biodiversity is certainly our most valuable resource, but we are not too sure if it is our most appreciated one. Perhaps it is not even used effectively and efficiently. But as we can notice in the example of rice varieties in Asia, biodiversity has potential as we shall see in the diverse uses of it.

2.2 The Different Uses of Biodiversity

The Earth's genes, species and ecosystems, function as an ecological unit, which represents the basis for the survival of the human race. According to one estimate, almost 40 per cent of the Earth's net primary terrestrial photosynthetic productivity is now directly consumed, diverted or wasted as a result of human activities (Vitousek et al, 1986). Given the continued growth of the human population as well as the growth of economic activity, the rate of loss of biodiversity will unavoidably increase. These trends can be reversed if we have the will. There is furthermore, a positive aspect in addition to the reversal of the physical environment. An attempt to solve the biodiversity crisis offers great benefits never enjoyed before: to save a species is to study it closely, and to learn from this species well enough to exploit its potential in novel ways.

For the last two decades, because the old bunker approach to the conservation of biodiversity did not work to the desired degree in the developing countries, even though it has worked to some extent in the United States and Europe, a new approach has developed. This new approach brings new ways of thinking and a new way of looking at the practical value of biodiversity. Under the new philosophy, ecologists and other scientists work as an ecological or environmental unit to help humanity adapt to a changing environment. Except in pockets of ignorance and malice, there is no longer an ideological war between conservationists and developers. Both share the view that health and prosperity decline in a deteriorating environment. They also comprehend that useful products cannot be harvested from extinct species. If dwindling wildlands are mined for genetic materials rather than destroyed for a few more boardfeet of lumber and acres of farmlands, their economic yield will be vastly greater over time. Salvaged species can help to revitalize medicine, forestry, agriculture, and other industries located elsewhere. The wildlands are like a magic well: the more knowledge and benefits that are drawn from them, the more there will be to draw. Proponents of the *New Environmentalism* act on this reality. They also recognize that only new ways of drawing income from land already cleared, or from intact wildlands themselves, will save biodiversity from the mill of human poverty. The new challenge is to develop new methods, to draw more income from the wildlands without destroying them, and to give the invisible hand of free-market economics a green thumb.

2.2.1 Biodiversity Used as Medicine

From the ecosystems, we have star species such as pandas and redwoods as well as thousands of less conspicuous ones. We need to pay attention to all of them because the humble and less conspicuous species are often the real stars. An example of a species lifted from obscurity to fame by its biochemistry is the rosy periwinkle (catharanthus roseus) of Madagascar. This inconspicuous plant, has a pink five-petaled flower; it produces two alkaloids, vinblastine and vincristine, that cure most victims of two of the deadliest of cancers, Hodgkin's disease, mostly afflicting young adults, and acute lymphocytic leukemia, which used to be a virtual death sentence for children. The income from the manufacture and sale of these two chemical substances exceeds $180 million a year. And that brings us back to the dilemma of the stewardship of the world's biological riches by the economically poor. Five other species of periwinkles occur on Madagascar. One, catharanthus coriaceus, is approaching extinction as the last of its natural habitat, in the Betsileo region of the central highlands, is cleared for agriculture.

Few are aware of how much we already depend on wild organisms for medicine. Aspirine, for example, the most widely used pharmaceutical in the world, was derived from salicylic acid discovered in meadowsweet (Filipendula ulmaria) and later combined with acetic acid to create acetylsalicylic acid, the more effective painkiller. In the United States, a quarter of all prescriptions dispensed by pharmacies are substances extracted from plants. Another 13 percent come from microorganisms and 3 percent more from animals, for a total of over 40 percent that are organism-derived. Yet these materials are only a tiny fraction of the multitude available. Fewer than 3 percent of the flowering plants of the world, about 5,000 of 220,000 species, have been examined for alkaloids, and then in a limited and haphazard fashion. The anti-cancer potency of the rosy periwinkle was discovered by the merest chance, because the species happened to be widely planted and under investigation for its reputed effectiveness as an antidiurectic.

The discovery of such materials in wild species is but a fraction of the opportunities waiting. Once the active component is identified chemically, it can be synthesized in the laboratory, often at lower cost than by extraction from raw harvested tissues. In the next step, the natural chemical compound provides the prototype from which an entire class of new chemicals can be synthesized and tested. As an illustration, cocaine is used as a local anaesthetic, but it has also served as a blueprint for the laboratory synthesis of a large number of specialized anaesthetics that are more stable and less toxic than the natural product. Many drugs are derived from plants and fungi. Here is a short list:

DRUG	PLANTS SOURCE	SOURCE
Atropine	Belladonna (Atropa-belladonna)	Anticholinergic
Cocaine	Coca (Erythroxylon coca)	Local anesthetic
Codeine	Opium poppy (papaver somniferum)	Analgesic
Penicillin	Penicillium fungi (esp. Penicillium chrysogenum)	General antibiotic
Quinine	Yellow cinchona (cinchona ledgeriana)	Antimalarial
Taxol	Pacific Yew (Taxus brevifolia)	Anticancer (esp. ovarian cancer)

2.2.2 Plant Species Used as Food

The same bright prospect exists with wild plants that can serve as food. Very few of the species with important economic potential actually reach international markets. Perhaps 30,000 species of plants have edible parts. However, throughout history, only a total of 7000 kinds have been grown or collected as food. Among these, merely 20 species provide 90 percent of the world's food, with just three (wheat, maize and rice) supplying more than half. This thin cushion of diversity is biased toward cooler climates where it is sowed in monocultures sensitive to diseases and attacks from insects and nematode worms.

Fruits illustrate a pattern of underutilization. A dozen temperate-zone species (apples, peaches, pears, strawberries and so on) dominate the northern markets and are also used heavily in the tropics. In contrast, at least 3000 other species are available in the tropics, and of these, 200 are in actual use. Some like cherimoyas, papayas, and mangos have recently joined bananas as important export products, while carambolas, tamarindos and coquitos are making a promising entry. But most consumers in the north have yet to savor lulos (the "golden fruit of the Andes"), mamanes, rambutans, and the near-legendary durians and managosteens, esteemed by aficionados as the premier fruits of the world.

Here are other plant foods that could be developed:

SPECIES	LOCATION	USE
Amaranths (3 species of Amaranthus)	Tropical and Andean America	Grain and leafy vegetable; live-stock feed; rapid growth, drought-resistant
Buriti palm (Mauritia flexuosia)	Amazon lowlands	"Tree of life" to Amerindians; vitamin-rich fruit; pith as source for bread; palm heart from shoots
Lulo (Solanum quitoense)	Columbia, Ecuador	Fruit prized for soft drink.

2.2.3 Plant Species for Improving Agriculture

Even when stretched to the limit, modern agriculture represents only a sliver of what it could be. Waiting in the wings are thousands of unused plant species, many of which have been demonstrated to be superior to those that are popular. The winged bean (Psophocarpus tetragonolobus) of New Guinea has been called the one-species supermarket because the entire plant is palatable and particularly succulent for its spinach-like leaves. Its young pods can be used as green beans and its young seeds look like peas and tubers that when boiled, fried, baked, or roasted, are richer in protein than potatoes. Its mature seeds resemble soybeans which can be cooked as they are or ground into flour or liquified into a caffeine-free beverage that tastes like coffee. Furthermore, the plant grows at a phenomenal pace, reaching a lenght of 4 meters in a few weeks. Finally, the winged bean is a legume; it harbors nitrogen-fixing nodules in its roots and has little need for fertilizer. Apart from its potential as a crop, it can be used to raise soil fertility for other crops. With a small amount of genetic improvement through selective breedings, the winged bean could raise the standard of living for millions of people in the poorest tropical countries.

2.2.4 Information about the Agriculture of Native Peoples

From the mostly unwritten archives of native peoples has come a wealth of information about wild and semicultivated crops. It is amazing to realize - with a single exception, the macadamia nut of Australia - that every one of the fruits and nuts used in Western countries was grown first by indigenous peoples. The Incas were arguably the all-time champions in creating a reservoir of diverse crops. Without the benefit of wheels, money, iron, or written script, these Andean people evolved a sophisticated agriculture based on almost as many plant species as used by all the farmers of Europe and Asia combined. Their abounding crops, tilled on the cool upland slopes and plateaus, proved especially suited for temperate climates. From the Incas also have come lima beans, peppers, potatoes, and tomatoes. But many other species and strains, including a hundred varieties of potatoes, are still confined to the Andes. The Spanish conquerors learned to use a few of the potatoes, but missed many other representatives of a vast array of cultivated tuberous vegetables, including some that are more productive and savory than the favored crops. The names are likely to be unfamiliar: achira, shipa, arracacha, maca, mashua, mauka, oca, ulloco, and yacon. One - maca - limited to 10 hectares (25 acres) in the highest plateau region of Peru and Bolivia has great potential. On the verge of extinction are its swollen roots, resembling brown radishes and rich in sugar and starch. Having a sweet tangy flavour, they are considered as a delicacy by a handful of people still privileged to consume them.

Another premier native crop of the Americas is amaranth. It is only recently introduced and is now coming, mostly as a cereal supplement, into the markets of the Unites States. During pre-Columbian times, out of 60 wild species available to them, Indians from Mexico to South America, cultivated widely only three species with amaranth as the first of the three. Amaranth seeds yield a nutritious grain and the young leaves, when cooked, become a palatable spinach-like green. The plants grow so well in cool, dry climates that they were favored as much as corn in Mexico at the time of conquest. Except for a bizarre historical circumstance, Amaranth might have become one of the world's leading crops after the Spanish Conquest. Jean Marx (1977) described it this way:

> Five hundred years ago, amaranth grain was a staple of the Aztec diet and an integral part of their religious rites. The Aztec made idols out of the paste composed of ground, toasted amaranth seeds mixed with the blood of the human sacrifice victims. During the religious festivals, the idols were broken into pieces that were consumed by the faithful, a practice that the Spanish conquistadors considered a perverse parody of the

Catholic Eucharist. When the Spanish subjugated the Aztec in 1519, they banned the Aztec religion and with it the cultivation of amaranth.

2.2.5 Man's Ingenuity

The advance of agriculture has always been slowed by prejudice and inertia. In West Africa, for exemple, a plant named Katemfe (Thaumatococcus daniellii) that produces proteins has been found 1600 times sweeter than sucrose. A second West African plant, the serendipity berry (Dioscoreo-phyllum Cumminsii) yields a substance 3000 sweeter. There is a parable that says: Where among wild species do such progressions end? Human ingenuity has never been stretched to find the answer in this or any other domain of practical application. We believe that it is now time for us, humans, to realize that industrialization has perverse impacts on our own life. We then must, for our survival, find a novel way of doing things. Agriculture is among the best. A Japanese philosopher once wrote: "Un ignorant cherchait du feu une lenterne à la main mais s'il avait su ce qu'est le feu, il aurait pu cuire son riz beaucoup plus vite".

Are we ignorant? The answer is definitely a no, but it is evident, in the light of these observations, that we are not fully utilizing our ingenuity. Consider now a second instructive case. The Amazonian babassu palm (Orbignya phalerata), even though still harvested in the wild and semiwild states, gives the world's highest known yield of vegetable oil. A stand of 500 tonnes produces about 125 barrels a year from huge 100 kilogram masses of fruits. Different parts of the tree are used by local people to make feedcakes for livestock, pulpwood, thatching materials for roots and baskets, and finally charcoal. The babassu has not been bred to bring it to fuller commercial use, nor has it been planted extensively away from the fertile upland soils and alluvial bottomlands on which it originally grew as a wild plant.

2.2.6 Use of Salt-tolerant Plants

As yet, our ingenuity has not been developed in saline agriculture which consists of using salt-tolerant plants to cultivate land not previously arable. On an experimental farm in Mexico, farmers have begun to use seawater to irrigate salicornia, a native of salt flats. The small, succulent plants produce an oil resembling that of safflower. They yield two tonnes of oil seeds per hectare annually, leaving a residual straw that can be used to feed livestock. In Pakistan, Kallar grass is grown in soil saturated with saltwater, then harvested as animal fodder. In the forbidding Atacama Desert of northern Chile, where seven years may pass without rain, the tamarugo tree sends roots through a meter of salt to tap brackish water deep within the desert soil. This extraordinary plant can create open woodland and ground vegetation in otherwise sterile wastelands. Sheep reared in tamarugo forests grow about as rapidly as those reared in high-quality pastures elsewhere in the world.

2.2.7 Use of Animal Species

Animals, like agriculture and medicine, are not an exception to our hapharzard fashion of doing things. Many animal species have passed unnoticed by man. In many cases, the unattended species reveals to be superior. A good example of wildlife superiority can be provided by the Amazon river turtles of the genus Podocnemis. Apparently, only seven species are known. But, they are known by local people to provide a lot of protein. Their meat is of excellent quality and the base of a pleasing native cuisine. Overhunting has reduced the number of species and several are now endangered. We should not forget that they are very easy to cultivate. Each female lays a clutch of up to 150 eggs, and the young grow rapidly. One species, the giant Podocnemis expansa, reaches a length of nearly a meter and a weight of 50 kilograms. It can be confined in cement tanks and natural ponds along the broad low plains while being fed on aquatic vegetables and fruit, all at minimal cost. Under these conditions, the turtles produce each year about 25000 kilograms of meat per hectare (22000 pounds per acre) more than 400 times the yield of cattle raised in nearby pastures cut from surrounding forests. Since floodplains count for 2 percent of the land surface of the Amazon region, the commercial potential of the species is enormous. It carries far less cost to the environment than the cattle and other exotic animals now being thrust upon the land with disastrous results. Other similar advantages are offered by other species like iguana, a large lizard with light and tasty flesh, favored as a delicacy for centuries by farmers in the humid regions of Central and South America. But overhunting has led to the scarcity of iguanas. Despite the protection by law in several Latin American Countries, on the Panamanian black market, each animal can be sold for $25. Moreover, the accelerating destruction of their forest habitat does not help. If farmers were to leave more forests standing, there would be more iguanas for the stew pot. "But if you are a farmer with a family to feed, even a family with a taste for iguana meat", Chris Wille and Diane Jukofsky (1991) have observed, "you are likely more interested in chopping or burning down the trees on your land to make way for cattle or crops, something you can sell. After all, iguanas make a delectable dinner, but they won't keep the kids in clothes".

Although the result is a downward spiral both for the forests and the farmers, it can be reserved. As Dagmar Werner (1991) has shown in a series of impressive field experiments, the iguanas can be made to yield up to ten times the amount of meat as cattle on the same land if managed carefully, while leaving a large part of the forest intact. The trick is to cultivate a breeding stock, incubate the eggs, then protect the hatchlings during their earliest and most vulnerable growth before releasing them into the forest. The iguanas are left to feed on leaves in the tree canopies, perhaps helped along by kitchen scraps, until they are large enough to be harvested. It will also be necessary to cultivate a broader export market, while easing laws protecting the iguana in areas where cultivation is practiced. Below is a summary of a few wild animals that could be raised commercially for food products:

SPECIES	DISTRIBUTION	USES
Babirusa (Babyrusa, babyrusa)	Indonesia: Moluccas and Sulawesi	A deep-forest pig thrives on vegetation high in cellulose and hence less dependent on grain.
Green iguana (Iguana, iguana)	American tropics	Chicken of the trees, traditional native food for 7000 years; rapid growth; low rearing costs.
Alive ridley sea turtles (Lepidochelys olivacea)	Beaches of India and Pacific coast of Mexico and Central America	Turtles emerge from sea to lay eggs; egg harvesting productive when beaches protected.
Pigmy hog (Sus salvanus)	Northeasten India	One of the most endangered mammal species on earth; potential source of new genes for domestic pig.
Sand grouse (Pterocles many species)	Deserts of Africa and Asia	Pigeon-like birds adapted to harshest deserts; domestication a possibility.

The goal of all such innovations is to increase productivity and wealth with a minimal disturbance of natural ecosystems and loss of biological diversity. Chosen and managed wisely, the exotic becomes the familiar and favored, and remains environ-mentally benign. One of the potential elites is the babirousa, a pig like animal inhabiting the rain forests of Sulawesi, the Sula and Togian Island, and Buri in eastern Indonesia. The closest known relatives of the babirusa, all extinct, once roamed the forests of Europe. An adult is larger than most men, weighing up to 100 kilograms. Despite its resemblance to a Hindu demon, the species has been tamed by Indonesian forest peoples and serves as an important source of meat. Its most promising commercial feature, however, is its status as a possible ruminant pig. Its stomach is enlarged and chambered like that of sheep, a unique trait that apparently enables it to feed extensively on leaves and other vegetation heavy in cellulose. With luck, the babirusa might enter the ranks of domestic pigs, sustained by an inexpensive and universally available fodder.

Chapter 3

3. UNCERTAINTY AND BIODIVERSITY

The goals of economic growth and conservation might both be served by cultivating species within their natural ecosystems, in the manner of river turtles, iguanas, and babirusas, or by the transfer of hardy species to marginal lands possessing few endemic species. The greatest potential for expansion in production is by aquaculture, the rearing of fish, oysters and other mollusks, and other marine and freshwater organisms in artificial ponds or, in the case of mollusks, on the surface of support racks set up in estuaries. More than 90 percent of the fish consumed by human beings worldwide is obtained by the hunting of wild species in fully natural environments. This primitive industry prevails despite the fact that sophisticated aquaculture techniques are available, and fish, in particular, have been reared in ponds and other enclosed structures for 4000 years. If pressed aggressively, the production of animal protein by aquaculture could easily be increased many times over within one or two decades. According to Norman Myers: (1983), there are two reasons for this vast potential:

> First, water dwelling creatures enjoy a distinct advantage over their terrestrial relatives in that their body density is almost the same as that of the water they inhabit, so they do not have to direct energy into supporting their body weight; this means, in turn, that they can allocate more food energy to the business of growing than is the case for land animals. Second, fishes, as cold-blooded creatures, do not consume large amounts of energy to keep themselves warm. Carp, for instance, can convert one unit of assimilated food into flesh one and a half times as quickly as can pigs or chickens, and twice as rapidly as cattle or sheep. The

> tiny shrimplike crustaceans called Daphnia can, when raised in a nutrient-nourished environement, generate almost 20 metric tons of flesh per hectare in just under five weeks, which is ten times the production rate for soybeans - and at one-tenth the cost per unit of protein produced.

At the present time, aquaculture resembles the rearing of conventional crops and livestock in utilizing only a small fraction of the available diversity. It depends heavily on those species encountered hapharzard for the first time by the cultures that invented the practice. About 300 kinds of fish, finfish to be exact, as opposed to shellfish, are cultured for food somewhere in the world. But 85 percent of the yield comes from only several carp species, while tilapias contribute a large part of the remainder. There are 18000 more species known to science, and undoubtedly thousands of others still unknown. In the end, only a small minority will prove to be commercially valuable, but even if that figure is only 10 percent, it will vastly increase the utilized diversity.

The scientific and folkloric record is strewn with examples of plants as well as animals valued in folk medicine but still not addressed in biomedical research. The neem tree (Azadirechta indica), a relative of mahogany, is a native of tropical Asia and is virtually unknown in the developed world. The people of India, according to a recent report of the U.S. National Research Council (1992), treasure the species. For centuries, millions have cleaned their teeth with neem twigs, smeared skin disorders with neem-leaf juice, taken neem tea as a tonic, and placed neem leaves in their beds, books, grain bins, cupboards, and closets to keep away troublesome bugs. The tree has relieved so many different pains, fevers, infections, and other complaints that it has been called the "village pharmacy". To these millions in India, neem has miraculous powers, and now scientists around the world are beginning to think they may be right.

Apart from the loss of human life and ways of life, the most catastrophic result of tropical deforestation may be the mass extinction of hundreds of thousands, perhaps millions of plant and animal species. Most biologists agree that we are already amid an extinction crisis unmatched in at least 65 million years and that, if current trends continue, one-fourth of the world's species may be heading for extinction in the next 25 to 50 years. However, sensitive they are to assaults, tropical forests hold great biological riches. They cover just 7 percent of the world's land area but contain at least half of all plant and animal species. These species, most of which exist only in one or another forested region, face the same risk as their habitats. Scientists believe that countless numbers have already died out in the wake of tropical deforestration. Prospects for the future are even grimmer, as people convert and burn more forests.

How fast are the world's plants and animals disappearing? Even experts have to guess because nobody knows how many species call earth home. So far, about 1.4 million species have been named and described, some 250,000 flowering plants, 750,000 insects, and 41,000 vertebrates. Yet, except perhaps for vertebrates and flowering plants, the catalogue of life forms is far from complete. "Remarkable" states Harvard biologist E.O. Wilson (1988) in Biodiversity, "We do not know the true number of species on Earth, even to the nearest order of magnitude". The number falls somewhere between 5 and 30 million.

As we have already mentioned, less than 1 percent of tropical plant species have been screened for medical applications, but even that tiny sample has yielded enormous benefits. The possibilities are there and they raise the potential importance of every wide species for humanity. All 119 plant-derived drugs used worldwide today came from fewer than 90 of the 250,000 plant species that have been indentified. Each such plant is a unique chemical factory says Norman R. Farnsworth (1989) of the University of Illinois at Chicago, "Capable of synthesizing unlimited numbers of highly complex and unusual chemical substances whose structures could otherwise escape the imagination forever." In light of this, we can see that humans do not use fully and effectively plant species. This leads us to assume that a vast array of other beneficent but still unknown species exist. A rare beetle sitting on a orchid in a remote valley of the Andes might secrete a substance that cures pancreatic cancer. A grass down to twenty plants in Somalia could provide green cover and forage for the saline deserts of the world. No way has been discovered to assess this treasure house of the wild except to grant that it is immense and that it faces an uncertain future.

Chapter 4

4. OPTIMAL USE OF BIODIVERSITY

4.1 Irreversibility

In the last few decades, many concerns have been raised about the negative impact that economic growth exerts on the environment. The current debate now focuses on the right balance between growth and environment, with advocates of environmental conservation starting to gain ground. Petulla (1980) distinguished three perspectives on conservation:

The first perspective stresses the need to avoid wasting natural resources. This perspective was epitomized by the Theodore Roosevelt administration, especially by the views of Gifford Pinchot, the principal advisor of Roosevelt on conservation issues.

Pinchot was the first head of the U.S. Forest Service and a leading advocate for the scientific management of forests. His attitudes towards the natural environment are reflected in his three principles. For Pinchot, the first principle of conservation is development, the use of natural resources existing on this continent for the benefit of the people who live here now. Pinchot's emphasis on using resources now is, in part, a response to critics who argued that Roosevelt and Pinchot intended to withold resources from development. The second of Pinchot's principles is that conservation stands for the prevention of waste. Thus, although resources are to be used, this use is to be characterized by wise management and careful stewardship. The third of Pinchot's principles reflects the ideological overtones of the conservation movement of the turn of the century: The natural resources must be developed and preserved for the benefit of the many, and not merely for the profit of a few. This is consistent with the antimonopoly sentiment that was widespread in America during the Theodore Roosevelt administration.

The second perspective emphasizes the maintenance of harmony between people and nature. Decades before ecology became an established science, Marsh (1864) argued persuasively for the need to keep harmonies of nature from being turned into discords. His widely cited book, "Man and Nature, or Physical Geography as Modified by Human Action", is a synthesis of numerous scientific works and personal observations. Marsh examined the ability of natural systems to withstand disturbances and to restore themselves following major perturbations such as those caused by "geologic convulsions". He was distressed with the way human actions could interfere with the spontaneous arrangements of the organic or inorganic world and thereby cause instabilities and irreversible changes in nature. Based on his studies of the adverse environmental effects of human actions, Marsh warned that continued "human improvidence" could threaten the earth's ability to support human life.

As the science of ecology began to develop in the early twentieth century, Marsh's concern was articulated from a more rigorous scientific basis. Leopold's (1933) ecological studies led him to the following position:

> A harmonious relation to land is more intricate, and of more consequence to civilization, than the historians of its progress seem to realize. Civilization is not, as they often assume, the enslavement of a stable and constant earth. It is a state of mutual and inter-dependent cooperation between human animals, other animals, plants, and soils which may be disrupted at any moment by the failure of any of them. Land despoliation has evicted nations, and can on occasion do it again.

The ability of humans to inadvertently destroy natural systems increased dramatically in the 1940's. The post-world war II period witnessed the emergence of a variety of new substances, including radioactive materials and synthetic organic chemicals. Many of these new substances are persistent. They do not decay or decompose rapidly into simpler less harmful materials. Some scientists have responded to this dramatic increase in people's ability to disturb natural systems with demands for additional controls on human actions.

The third perspective, embodied in comtemporary scientists' calls for restraint, is often based on the same concerns that motivated Marsh and Leopold: The human ability to irreversibly destroy natural systems. The sense of urgency that often accompanies these calls for restraint is exemplified by Rachel Carson's (1962) "Silent Spring". The title of this widely read book refers to a hypothetical future springtime in which birds and other animals are silenced inadvertently. They are destroyed by manmade chemicals that are transmitted from one life form to another as part of the normal production and consumption activities in nature. Pesticides, such as DDT are the implicated chemicals in

Silent Spring. Carson (1962, pp 7-8) described the unintended effects of using such pesticides: These sprays, dusts, and aerosols are now applied almost universally to farms, gardens, forests and homes - nonselective chemicals that have the power to kill every insect, the good and the bad, to still the song of birds and the leaping of fish in the streams, to coat the leaves with a deadly film, and to linger on in soil - all this though the intended target may be only a few weeds or insects. Can any one believe it is possible to lay down such a barrage of poisons on the earth without making it unfit for all life?

The threat of irreversibility lies at the core of the current debate on economy and environment. It epitomises the tension between development and conservation and has generated many heated exchanges between those who are in favor of development and those who are against it. Although the debate is often conducted from the economic framework - how the natural environment should be optimally exploited - some proponents of conservation also invoke aesthetic and religious beliefs.

The methodology adopted by the third perspective for analyzing the tension between development and conservation can be illustrated by the following hypothetical problem. Consider for example, a given roadless tract of land subject to evaluation under the Wilderness Act; or possibly under the Wild and Scenic Rivers Act. The question to be asked is which of a number of allocation alternatives are to be preferred. For example, should the area be

(a) preserved in its undisturbed natural condition

(b) reserved for some non-wilderness type recreational activities that may be compatible also with some selective resource extraction or development, or

(c) devoted to the extraction of resources without providing for recreation?

4.2 Authenticity, an Attribute in the Pursuit of Preservation

For the majority of the art museum clientele, the difference between an original work of art by one of the masters and an exact forgery is undetectable. However, for a connoisseur, the mere suspicion of a forgery, so expertly done that even art critics will differ in their opinion as to its authenticity, will be significant and will result in a drastic reduction in the market value of the objet d'art, as many museum curators have been embarrassed to discover.

The nature of the unsatisfaction, of course, is not relevant to economics. To the purists, preservation of the constituents of the biosphere in precisely the way in which it has evolved, without disturbances from post-industrial man, is a matter of great significance in a profound personal sense. This clientele group represents a significant market that appears to be growing rapidly as the income, educational, and urban composition of the American society changes. Moreover, this is a market for which refinements in restorative technology will do little by way of recreating "undisturbed" natural environment. Accordingly, the argument based on irreversibility, whether technical or economic, is a powerful one where the clientele group place a high value on the attribute of authenticity in the amenity services yielded by natural environmental resources.

Recreation constitutes only one of the uses of undisturbed natural environment. Considering another of these uses, namely the provisions of a laboratory and materials for research in the life and earth sciences often with valuable applications in medicine and agriculture, we may arrive at a better understanding of irreversibility in the context of environmental resources use. Loss of the scientific and technological information needed to produce a specialized equipment, the services of which may be demanded in the future, is a matter of great consequence, and may be compared to the loss of the genetic information contained within the last viable mating pair of the species. Extinction of a species, or more generally destruction of a unique resource, represents an important reduction in the options available to society, and illustrates a central postulate of welfare economics: expansion of choice represents a welfare gain, reduction of options, a loss.

Even when the survival of a species is not at issue, a problem still exists because there is no known technology, human or otherwise, to recreate a Hells Canyon, once it is destroyed. Further, we can add that a natural environment, like a work of art, cannot be cut into small pieces, used, and then restored to its original condition, with value unimpaired. The problem is precisely our inability to achieve this transformation either technically or economically in important cases such as the Hells Canyon. There is also the equity issue. Many people believe that certain environmental assets are jointly owned by all generations. This raises the question, "does the present generation have the right to destroy such assets for its own benefits?" Taking into account the welfare of future generations would lead to more preservation.

Now, modern methods of genetic engineering have made it possible to transfer genes directly, excising them from the chromosomes of one species and placing them in the chromosomes of another without hybridization of the entire genomes. In other words, sex has been bypassed. Furthermore, the exchange can be accomplished among species of plants and animals so different as to make ordinary hybridization impossible. Thomas Eisner (1985) has described the possibilities in striking imagery:

> **A biological species, nowadays, must be regarded as more than a unique conglomerate of genes. As a consequence of recent advances in genetic engineering, it must be viewed also as a depository of genes that are potentially transferable. A species is not merely a hard-bound volume of the library of nature. It is also a loose-leaf book, whose individual pages, the genes, might be available for selective transfer and modification of other species.**

A species in the tomato genus treated as a loose-leaf notebook might share genes with species outside the genus, say plants in the larger nightshade family, or even beyond, with radically different flowering plants, donating or acquiring disease resistance, larger fruit mass, cold hardiness, the ability to grow all year, and so on through the full gamut of desired biological qualities. The possibilities are there, and they raise the potential importance for humanity of every wild species and race.

4.3 Option Value of a Species

Economists speak of the "option value" of a species whose worth is still unmeasured, and no measure in all of economics is more intriguing or more elusive. Its greatest difficulty is that it applies equally to commodity, amenity, and morality, the three standard domains of valuation. "As time passes", Bryan Norton (1987) has observed, we gain knowledge in all these areas, and new knowledge may lead to new commodity uses for a species or to a new level of aesthetic appreciation, or our moral values may change and some species will, in the future, prove to have moral value that we cannot now recognize. If placing a dollar figure on these option values seems a daunting task, the situation is actually far worse than it first seems. Calculations of option value can only begin after we have identified a species, guessed what uses that species might have, placed some dollar value on those uses and estimated the likelihood of discoveries occuring at any future date.

The attempt to valuate species has led to two competing guidelines of conservation. The first is cost-benefit (CB) analysis, which singles out each threatened species in turn, weighs visible and possible future benefits against the cost of keeping it alive, and decides whether to invest enough land and time to preserve it. The second guideline is the safe minimum standard (SMS), which treats each as an irreplaceable resource for humanity, to be preserved for posterity unless the costs are unbearably high. Surely, prudence and a decent concern for posterity demand the safe minimum standard. Cost-benefit studies consistently undervalue the net benefits conferrable by species since it is much easier to measure the cost of conservation than the ultimate gains, even in purely monetary units. The riches are there, fallow in the wildlands and waiting to be employed by our hands, our wit, our spirit. It would be folly to let any species die out by the sole criterion of economic return, however potent, simply because the name of that species happens to be written in red ink.

Chapter 5

5. BIODIVERSITY AND SUSTAINABLE DEVELOPMENT

It is a failing of our species that we ignore and even despise the creatures whose lives sustain our own. Wealth is of three forms: material, cultural, and biological. Unfortunately, biological wealth is taken much less seriously by humans. This is a major error, one that will be increasingly regretted as time passes. Diversity is a potential source of immense untapped material wealth in the form of food, medicine, and amenities.

The world biological wealth is passing through a bottleneck, destined to last another fifty years or more. The human population has moved past 5.4 billion, and is projected to reach 8.5 billion by year 2025, and may level off at 10 to 15 billion by mid-century. With such a phenomenal increase in human biomass, with material and energy demands of the developing countries accelerating at an even faster pace, far less room will be left for most of the species of plants and animals in a short period of time.

The human juggernaut creates a problem of epic dimensions: how to pass through the bottleneck and reach midcentury with the least possible loss of biodiversity and the least possible cost to humanity. In theory as least, the minimization of extinction rates and minimization of economic costs are not incompatible: the more that other forms of life are wisely used and saved, the more productive and secure our own species will be. Future generations will reap the benefits of wise decisions taken by our generation.

Knowledge and practical ethic bases are needed urgently on a time scale longer than usual. Environmental problems are innately ethical. They require vision reaching simultaneously into the short and long reaches of time. What is good for individuals and societies at this moment might easily turn sour ten years later, and what seems ideal over the next several decades could ruin future generations. To choose what is best for both the near and distant futures is a hard task, often seemingly contradictory, and requiring knowledge and ethical codes which for the most part are still unwritten. Even now, with the problem only beginning to come into focus, there is little doubt about what needs to be done. The solution will require cooperation among professions long separated by academic and practical tradition. Biology, anthropology, economics, agriculture, government, and law will have to find a common voice. The conjuncture has already given rise to a new discipline - biodiversity studies - which is both scientific (a branch of pure biology) and applied (a branch of biotechnology and the social sciences). While biomedical studies are concerned with the health of the individual person, biodiversity studies are concerned with the health of the living parts of the planet and their interactions with the human race. If we are to do something about that urgent problem, we must focus on biodiversity in order to try to save and use in perpetuity as much of the earth's diversity as possible. Here is a list of the tasks that should be carried out immediately:

1) Survey the World's Fauna and Flora

Biologists have only the faintest idea of how many species there are on earth or where most occur; the biology of more than 99 percent remains unknown. One thing we could do, is to have a global survey, aimed at the discovery and classification of all species; the recognition of the threatened habitats that contain the largest number of endangered endemic species (the hot spots) must be included.

We must also agree on an explicit mission with a timetable and cost estimates. The strategy most likely to work is mixed, aiming at a complete inventory of the world's species, spanning fifty years and taking place at several levels, or scales in time and space, from hot spots identification to global survey, audited and readjusted at ten-year intervals. As each decade comes to a close, progress to that point could be assessed and new directions identified. Emphasis from the outset would be placed on the hottest spots known or suspected. Three approaches can be considered: The first one is the RAP (Rapid Assessment Program) created by Conservation International, a Washington-based group devoted to the preservation of global diversity. The purpose is to investigate, within several years, poorly known ecosystems that might be local hot spots in order to make emergency recommendations for further study and action. The area targeted is limited in extent, such as a single valley or isolated mountain;

The second one is the BIOTROP, from the Neotropical Biological Diversity Program at the University of Kansas and a consortium of other North American universities formed in the late 1980s. Unlike RAP, which is pinpointing brushfires of extinction at selected localities, BIOTROP explores more systematically across broad areas believed to be major hot spots or at least to contain multiple hot spots. Examples of such regions include the eastern slopes of the Andes and the scattered forests of Guatemala and southern Mexico. The goal is to set up research stations across the areas that embrace different latitudes and elevations. The work starts with a few focal organisms and then expands to less familiar groups, such as ants, beetles and fungi. As enough specimens are collected, experts in the groups are required to study them. The most important and best equipped of the stations are likely then, to evolve into centers of longterm biological research, with leadership roles taken by scientists from the host countries. They can also be used to train scientists from different parts of the world.

From inventories at RAP and BIOTROP in different parts of the world, accompanied by monographic studies of one group after another, the description of the living world will gradually coalesce to create a fine-grained image of global diversity. The growth of knowledge will inevitably accelerate, even given a constant level of effort, by producing its own economies of scale. Costs per species logged into the inventory fall as new methods of collecting and distributing specimens are devised and procedures for accessing information are improved. Costs are not simply additive when none-elite groups of organisms are included, but instead decline on a per-species basis. Botanists, for example, can collect insects living on the plants they study, while identifying these hosts for the entomologists; and entomologists can do the reverse, gathering plant specimens in company with the insects they collect.

As biodiversity surveys proceed at several levels, the knowledge gathered becomes an evermore powerful magnet for other sciences. Field guides, and illustrated treatises open doors to the imagination and network of technical information and help to draw geologists, geneticists, biochemists and others into the enterprise of Biodiversity;

This brings us to the third and final approach of the prototype of Costa Rica's National Institute of Biodiversity (Institute Nacional de Biodiversidad), in short INBIO, established in San José in 1989. The aim of INBIO is to account for all the plants and animals, over half a million species in number, and to use the information to improve Costa Rica's environment and economy. Detailed distribution maps of plants and many kinds of animals have been drawn up in Great Britain, Sweden, Germany, and other European countries under governmental and private auspices.

Another essential element of biodiversity studies at all levels will be microgeography, the mapping of the structure of the ecosystem in sufficiently fine detail to estimate the population of individual species and the conditions under which they grow and reproduce. When applied to biodiversity and endangered species, the cartography is called gap analysis. Even when incomplete, gap analysis can reveal the effectiveness of existing parks and reserves, and can be used to help answering the larger questions of conservation practice. Do protected areas in fact embrace the largest possible number of endemic species? Are the surviving habitat fragments large enough to sustain the populaton indefinitely? And what is the most cost-effective plan for further land acquisition?

2) Creation of Biological Wealth

As species' inventories expand, they open the way to bioeconomic analysis, the broad assessment of the economic potential of entire ecosystems. Every community of organisms contains species with potential commodity value, timber and wildplant products to be harvested on a sustained basis, seeds and cuttings that can be transplanted to grow crops and ornamentals elsewhere, fungi and microorganisms to be cultured as sources of medicinals, organisms of all kinds offering new scientific knowledge that point to still more practical applications. And the wild habitats have recreational value, which will grow as a larger sector as the public travels and learns to enjoy natural history. The decision to make bioeconomic analysis a routine part of land-management policy will protect ecosystems by assigning them future value. When local faunas and floras are better known, the decision can be taken on how to use them optimally - whether to protect them, to extract products from them on a sustainable yield basis, or to destroy their habitat for full human occupation. Destruction is anathema to conservationists, but the fact remains that most people, lacking knowledge, regard it as perfectly acceptable. Some knowledge and reason must be made to intrude. The wise procedure is for law to delay, science to evaluate, and familiarity to preserve. There is an implicit principle of human behavior important to conservation: The better an ecosystem is known, the less likely it will be destroyed. As the Senegalese conservationist Baba Dioum (1991) has put it: "In the end, we will conserve only what we love, we will love only what we understand, we will understand only what we are taught".

A key enterprise in bioeconomic analysis is what Thomas Eisner (1990) has called "chemical prospecting", the search among wild species for new medicines and other useful chemical products. Each species has evolved to become a unique chemical factory, producing substances that allow it to survive in an unforgiving world. A newly discovered species of roundworm might produce an antibiotic of extraordinary power, an unnamed moth, a substance that blocks viruses in a manner never guessed by molecular biologists. Because chemical prospecting depends heavily on classification, it is best conducted in tandem with biodiversity surveys. In 1991, Merck and Company agreed to pay Costa Rica's National Institute of Biodiversity 1 million dollars for collecting and identifying the organisms, sending chemical samples from the most promising species to the Merck laboratories for medicinal assay. If natural substances are marketed, the company is committed to pay to the Costa Rican government a share of the royalties, which will then be earmarked for conservation programs. It follows that in a single success in Costa Rica - a commercial product from, say, any one species among the 12,000 plants and 300,000 insects estimated to live in the country, where only one in 10,000 species yields a promising substance (by procedures then in use) and millions of dollars are needed to bring a product fully on line - the eventual payoff seemed marginal. The companies turned to new technologies in microbiology and synthetic chemistry, hoping to design the magic bullets of the new medical age with chemicals taken from the shelf. To rely on human ingenuity rather than evolved natural chemistry in distant jungles seemed much more "scientific" and direct, and perhaps less expensive. Now the pendulum has begun to swing back, again from advances in technology because high-volume, robot-controlled biological assays allow larger companies to screen up to 50,000 samples a year using only bits of fresh tissue or extract flown in from any part of the world.

The path from wild organisms to commercial production can sometimes be shortened further by taking clues from the lore and traditional medicine of indigenous peoples. It is a remarkable fact that of 119 known pharmaceutical compounds used in the world, 88 were discovered through leads from traditional medicine. The Chinese, for example, employ materials from about 6,000 of the 30,000 plant species in their country for medicinal purposes. Extraction procedures and dosage have been tested by trial and error countless times.

Small farms around the world are giving way to the monocultures of agrotechnology. The goal is to make the practice more economical, while conserving the genetic reserves that will contribute to crops of the future. Species and strains of high economic efficiency, from perennial corn to amaranth and iguanas, can be channeled through research centers into local regions best suited to use them. A successful prototype of such enterprises is the Tropical Agricultural Research and Training Center (CATIE), created by the Organization of American States in 1942 at Turrialba, Costa Rica. CATIE maintains large samples of plant species, including disease - resistant strains of cacao and other tropical crops. Its staff members experiment with propagation methods for crops and timber, design wildland preservation programs, search for new crop species and varieties and train students in the new methods of agriculture and conservation. Institutions of the future can be profitably built to include not only these activities but also chemical prospecting and molecular techniques of gene transfer from wild to domestic species.

3. Sustainable Development

The rural poor of the Third World are locked into a downward spiral of poverty and destruction of diversity. To break free from this vicious circle, they need work that provides the basic food, housing, and health care taken for granted by the great majority of people in the industrialized countries. Lacking access to markets, hammered by exploding populations, they turn increasingly to the last of the wild biological resources. They hunt down animals at walking distance, cut forests that cannot be regrown, put their herds on any land from which they cannot be driven by force. They use domestic crops ill suited to their environment because they know no alternative. Their governments, lacking an adequate tax base and saddled with huge foreign debts, collaborate in the devastation of the environment. Using an accountant's trick, they record the sale of forests and other irreplaceable natural resources as national income without computing or by omitting computing the permanent environmental losses as expense. So the issue comes down to this: how can people in developing countries achieve a decent living from the land without destroying it?

The battle ground of sustainable development will be the tropical rain forests. If the forests can be saved in a manner that improves local economies, the biodiversity crisis will be dramatically eased. We will present an application concerning the value of a Peruvian forest in the last part of this study by showing that the extraction of nontimber products can yield similar levels of income as logging and farming, even with the limited outlets available in existing local markets. The practice has been regularized by the rubber tappers of Brazil without even the least of cost-benefit analysis. The tappers, or seringueiros as is their local name, draw their principal income today not only from rubber but also from Brazil nuts, palm hearts, tonka beans, and other wild products. Because they depend on biological diversity, the tappers are devoted to the preservation of the forests as stable and productive ecosystems. In 1987, the Brazilian government authorized the establishment of seringueiro extractive reserves on state land, with thirty-year renewable leases and a prohibition of the clear-cutting of timber. In 1980, rubber-tapper households occupied 2.7 percent of the area of the North Region of Brazilian Amazonian, including the states of Amazonas and Are, which is much smaller when compared to the areas occupied by farms and ranches of 24 percent. Only a small fraction of the flood of new immigrants now pouring into the region can make a living from extractive activities. The rest will seek income wherever they can find it, primarily by advancing the agricultural frontier. The key to the future of Amazonia and other forested tropical regions is whether employment made available to these immigrants saves or destroys the environment. The real challenge, writes John Browder (1990) is, "fundamentally not where to sequester forests, but how to turn people into better forest managers".

It is possible to harvest timber from Amazonian wilderness and other remaining great rain forests profitably with little loss of biodiversity. The method of choice, first suggested by Gary Hartshorn in 1979 and extended by other foresters, is strip logging. Strip logging imitates the natural fall of trees that creates linear gaps through the forest, with the artificial gaps being aligned along the contours. But the problem is how can governments and local peoples be persuaded to adopt such innovations as extractive reserves and strip logging? The shift to sustainable development will depend as much on education and social change as on science. Around the world, modest projects are being advanced with one common result: if procedures tailored to the special case are used, economic development and conservation can both be served. People can be persuaded; they understand their long-term interest and they can adapt. One good example is Peru's Palcazù Valley which was at risk of being used for cattle ranches and small farms. For this valley, an alternative plan was proposed by the U.S. Agency for International Development and approved by the Peruvian government. The plan is to extract timber by strip cutting, regulated to allow perpetual regeneration of the forest through thirty-to-forty year rotations. The plan permits limited permanent conversion of the most arable land to agriculture and livestock production. But it also calls for the establishment of the watershed reserve in the adjacent San Matias mountain range and the designation of the neighboring Yanachaga range as the Yanachaga-Chemillén National Park. With luck, the Palcazù will support a healthy human populaton and a slice of Peru's biodiversity into the next century.

Wildlands and biological diversity are legally the properties of nations, but they are ethically part of the global commons. The loss of species anywhere diminishes wealth everywhere. Today the poorest countries are rapidly destroying their natural resources and unintentionally wiping out much of their biodiversity in a scramble to meet foreign debts and raise the standard of living. The rich debt-holding nations aggravate the practice by encouraging a free market in poor countries while providing subsidies to farmers at home.

Developing countries competing on international free markets have a strong incentive to transfer capital into single cash crops, such as bananas, sugar cane, and cotton. To that end, governments often subsidize the clearing of wildlands and the overuse of pesticides and fertilizers. Small farmers are then forced to seek new land of marginal productivity, including natural habitats. Facing ruin, they have no choice but to press into nutrient-poor tropical forests, steep hillside watersheds, coastal wetlands, and other final refuges of terrestrial diversity.

This journey to the precipice is hastened by the agricultural support systems of the richest nations. At the present time, subsidies to developed-world farmers total $300 billion a year, six times the official foreign aid to Third World countries. For example, when European community countries created a huge artificial market for cassava, landowners in Thailand responded by clearing more tropical forests to grow cassava, and in the process displaced large numbers of subsistence farmers into deep forests and up the eroding hillsides. When the United States tightened import quotas of cane sugar to aid domestic growers, U.S. imports from the West Indies countries dropped 73 percent in ten years, forcing many of the rural poor out of jobs on the plantations and into marginal habitats for subsistence farming. Japan's extravagant subsidy to its own rice farmers has a depressing effect on the rice-growing populations of tropical Asia.

Once again, the impact on natural environments is aggravated.

The richest countries set the rules for international trade. They provide the bulk of loan and direct aid and control technology transfer to the poor nations. They themselves will suffer if the wildlands and biological diversity do not enter the calculus of trade agreements and foreign aid.

Every nation has an economic policy and a foreign policy. It is urgent now to speak more openly of a population policy. This policy must be based on a rational solution of the population problem: What is the optimal population of a society? The answer will follow from an assessment of the society's self-image, its natural resources, its geography, and the specialized long-term role it can play most effectively in the international community. It can be implemented by the encouragement of birth control and the regulation of immigration to arrive at a desirable target density and age distribution. The goal of an optimal population will require addressing, for the first time, the full range of processes that lock together the economy, the environment, the national interest, and the global commons.

4. The Remaining Species and Habitats

Can we save the remaining species? The answer to this question is not far from no. Following the extinction episodes of geological history, full recovery of biodiversity required between 10 and 100 million years, and homo sapiens, we believe, do not live that long. And even if it is so, this would require returning a large part of the land to its natural state. In any event, the new biota would be very different from the destroyed old one.

The American Type Culture Collection contains over 50,000 species suspended in the deep sleep of absolute biochemical inactivity, ready for warming and reaction as needed. The cultures are used in research, primarily in molecular biology and medicine.

Cryopreservation is at best a last-ditch operation that might rescue a few select species and strains certain to die otherwise. One method that works for many plants is the maintenance of seed banks: seeds are dried and kept in repositories in cool temperatures (about -20°C is typical) over long periods. This technique has been proved effective for preserving most strains of crop species. About a hundred nations maintain this technique in practice. In 1990, over 2 million sets of seeds were on deposit. Especially well represented were wheat, maize, oats, potatoes, rice, and millet. An effort has begun to include the wild relatives of existing crop species, such as the richly promising perennial maize of Mexico. But seed banks are not without problems; up to 20 percent of plant species contain recalcitrant seeds that cannot be stored by conventional means. Therefore, the task of collecting and maintaining thousands of endangered species would be stupendous. Other ex situ methods rely on captive populations that grow and reproduce; about 1,300 botanical gardens and arboretums worldwide harbor plant species that are endangered or extinct in the wild.

In general, animals are more difficult than plants and micro-organisms to maintain ex situ. All these considerations lead to the same conclusion: ex situ methods will save a few species otherwise beyond hope, but preservation of natural ecosystems is most likely the only way if we are to save the biodiversity that is left. If that is accepted, we are face to face with two realities. First, habitats are continuing to disappear at an accelerating rate, and with them a quarter of the world's biodiversity. Second, habitats cannot be saved unless the effort is of immediate economic advantage to the poor people who live in and around them.

The rescue of biological diversity can be achieved only by a skillful blend of science, capital - including human capital investments, and government: science to blaze the path by research and development; capital and human capital investments to create sustainable markets; and government to promote the marriage of economic growth and conservation.

The rescue can also be accomplished if natural habitats are not only preserved but enlarged, sliding the numbers, of survival species back up the logarithmic curve that connects quantity of biodiversity to amount of area. To put an end to the great extinction spasm, the next century must be, and we believe will be the era of ecological restoration.

Chapter 6

6. A CASE STUDY : THE ECONOMIC VALUE OF A FOREST

6.1 The Value of a Tree

We begin this chapter by asking the question: what is a forest's intrinsic value? This question can be adequately answered if we commence by searching for the value of a tree and then extend the results to the forest which is composed of wide varieties of trees. Many efforts have been attempted to evaluate the uses of a forest; and these evaluations were in most cases very difficult to calculate in monetary terms. In the United States, for example, in an attempt to find out what a tree is worth to the average urban American, the American Forestry Association(AFA) evaluates at fifty billion dollars the United States' seventy million acres of urban tree spaces alone. As for a single tree, in 1985 AFA's Gary Mold estimated that an average 50-year-old city tree would provide 73 dollars' worth of air conditioning, 75 dollars' worth of erosion and storm water control, 75 dollars' worth in wildlife shelter,and 50 dollars in air pollution control in one year.

Assessments like these are not lost on real estate agents. Property with trees commands higher prices than property without trees, ceteris paribus. Older, larger trees are prized most, but, according to the U.S. Forest Service, suburban homeowners can boost property values by up to 20 percent - an average increase of 30,000 dollars - by adding trees to their lot.

Growing concern about the greenhouse effects and global warming may also increase the value of trees. Because trees shade buildings, they decrease the need for air conditioning, which decreases the use of electricity, much of which is derived from fossil fuels - main sources of greenhouse gases that contribute to global warming. AFA estimated that planting more trees in cities could cut 4 billion dollars a year from national energy costs. Even three strategically placed trees around a house can shave home air conditioning costs from 10 to 50 percent.

Moreover, the tree is a central image in our cultural heritage, radiating its power through the many and various religions, myths, and dreams of our species. Even today's great monotheistic religions, rooted as they are in the experiences of desert peoples, look on trees as a great good: in Islam, as in the Judeo - Christian world, the earthly paradise is a garden. The French naturalist Jacques Brosse once meditated on the ties between humankind and trees; as he wrote in such an imagery fashion:

> **All over the world, there lingers on the memory of a giant tree, the primal tree, rising up from the centre of the Earth to the heavens and ordering the universe around it. It united the three worlds: its roots plunged down into subterranean abysses, its loftiest branches touched the empyrean. Thanks to the tree, it became possible to breathe the air; to all the creatures that then appeared on Earth it dispensed its fruit, ripened by the sun and nourished by the water which it drew from the soil. From the sky it attracted the lightning from which man made fire and, beckoning skyward, where clouds gathered around its crown, it bade the life-giving rains to fall. The tree was the source of all life, and of all regeneration.**

For millennia, this reverence for trees served humankind well. But now it has faded and half of the world's tropical forests are cleared or degraded. Every hour, at least 4500 acres fall to chain saws, machetes, flames, or bulldozers, and another four plant or animal species die out, most of them in the tropics.

When forests die, so do traditions and livelihoods. Where land is truly well suited to agriculture or other development activities, some forest clearing makes sense. Certainly, not every tree is sacred. But at the current deforestation rate, a quarter of the earth's species could be gone before today's preschoolers retire. Looking deeper, it is clear that the fate of the forest is written in population growth, poverty, and the short-sighted policies of governments and international agencies, as well as decisions made by commercial interests.

The mighty forces of national debts and international trade imbalances push some developing countries to sell off their forest assets to pay their national debts. As one land use leads to another, species losses accelerate. But is this acceleration inevitable? The answer is a No period because there are lot of things we can do about it. If we are to save what is left of nature, we must change the way we value things. We cannot continue to look only at immediate financial values; many things have little financial value but incommensurable use value. Biodiversity enters this last category for its immense untapped material wealth in the form of food, medicine, and amenities. The same thing applies to forests. To return to the question of what a forest is worth, we then must look at alternatives which will prevent the logging of trees and forests. The best alternative is to use the rain forest as extractive reserves, for the harvesting of "minor" products such as edible fruits, oils, latex, fibers and medicines.

6.2 Forests as Extractive Reserves

The key question from an economic point of view is whether the income from minor products is high enough to justify preserving rain forests as extractive reserves. The answer is yes, at least in some regions, even with the limited knowledge at hand. Charles Peters, Alwyn Gentry and Robert Mendelsohn (1989) demonstrated that not only are minor products in the Peruvian Amazon potentially more profitable in the long run, but considerably more so than conventional one-time logging. Among 275 kinds of trees they identified in a one hectare plot near the town of Mishana, 72 (26 percent) yielded fruits, vegetables, wild chocolate and latex that could be sold on Peruvian markets. The annual net yield, after deducting costs of collection and transportation, was estimated to be 422 dollars. The Mishana plot contains enough timber to generate a net revenue of $1,000 on delivery to the sawmill if cut once, as is the usual practice. Within a short time then, sustained harvesting of fruits and latex can be made more profitable than clear-cutting, and the forest is left intact. Even if trees of high profitability were removed at intervals, then allowed maximal yield of their timber, the long-term income would still be less than one-tenth that from fruit and latex harvesting.

These are the unmined riches of the Mishana plot (1 hectare):

PRODUCT	NUMBER OF PLANTS	ANNUAL PRODUCTION PER PLANT	VALUE (US $)
Palm Fruits			
Aguaje	8	195.8 lbs	177.60
Aguajillo	25	66.15 lbs	75.00
Sinamillo	1	3000 fruits	22.50
Ungurahui	36	80.48 lbs	115.92
Other Edible Fruits			
Charichuelo	2	100 fruits	1.50
Lachehuaya	2	1060 fruits	70.67
Naranjo podrido	3	150 fruits	112.50
Nasaranduba	1	800 fruits	3.75
Tamamuri	3	500 fruits	11.25
Other Edible Products			
Sacha cacao (wild chocolate)	3	50 fruits	22.50
Shimbillo (legume)	9	200 fruits	27.00
Rubber-tree products			
Shiringa (latex)	24	4.41 lbs	57.60
TOTAL	**117**		**697.79**
Cost of Harvesting and Transportation			**276.00**
Net Value			**421.79**

The computed yield of extractive products is actually the most conservative for the Mishana plot, since it was based exclusively on the inventory of commercially tested materials and a still poorly developed market. Little effort has been made to perform bioeconomic assays of whole ecosystems, identifying the species that can produce food and pharmaceuticals, as well as serve as agents of pest control and as resources and enrichers of the soil. On the other hand, almost all of the potent species are destroyed when the forest is clear-cut for timber and agricultural land. The irreversible nature of this pattern of expoiting the natural environment should be seriously considered before a forest is chosen for clear cutting.

6.3 Ecotourism Value of Forests

Forests also have touristic value inside and abroad. More and more people from developed countries are willing to pay to experience, however briefly, the prehuman earth . In 1990, tourism had risen to become the second most important source of external income in Costa Rica, ahead of bananas and closing fast on coffee. Rain forests used for this purpose have become many times more profitable per hectare than land cleared for pastures and field. Ecotourism was, prior to the civil war there, the third most important source of income in Rwanda, rising fast behind coffee and tea, largely because that tiny, overpopulated East African country was and probably still is home to the mountain gorilla. As Rwanda protects the gorilla, the gorilla will help to save Rwanda.

Another value is illustrated by the vast Amazonian rain forests which create half of their own rainfall. As the forests are cut, the water supply is diminished by a corresponding degree.

6.4 The Forest as an Ecosystem

Without so-called ecosystems, Earth would be uninhabitable to people and most other animals. We need plants to convert sunlight into usable energy, and we need nature's billions of tiny unsung decomposers - primarily insects, fungi, and microorganisms- to keep us from drowning in our own wastes. Indeed, an estimated 95 percent of the 6 billion tons of organic waste generated by Americans each year is degraded by organisms, while only 5 percent is burned. Plants and animals also help cycle carbon, nitrogen, oxygen, sulphur, and phosphorous, all of which are essential to life. In the United States, each year some 154 million tons of nitrogen are sapped from the soil by crops. Nitrogen-fixing organisms return about two-thirds of this lost nitrogen fertilizer to the soil. Forests can temper droughts, flooding, and the flow of water to farms, factories, and homes.

Without forests and other natural ecosystems, these cycles would unravel, forcing our children to wrestle with survival issues that we barely have to think about. But at what point do ecosystems stop providing the essential ecological services people need to survive? Unfortunately, we probably will not know the answer until it it too late to avoid the damage. Considering this uncertainty and the drastic consequences of losing these basic functions, the conservative approach would be to keep as many natural systems together and whole as we can. Aldo Leopold said it best in 'Sand Country Almanac' in 1949: **"If the biota, in the course of aeons, has built something we like but do not understand,**

then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intellingent tinkering."

Our tinkering so far has been less than intelligent and certainly less than enlightened. But the good news is that with a change of heart and ways, we can still save most of the enterprise. All is definitely not lost.

Chapter 7.

7. CONCLUDING REMARKS

This study has emphasized the efficient uses of biodiversity resources. In response to biological diversity and habitat loss, a new global initiative has been launched to promote both national and international legal instruments on forests. Forests, as we have seen in a one-hectare lot of Mishana rain forest, have a substantial economic value. Peters et al (1989), in a detailed calculation, have indicated that a hectare of forest in Brazil, harvested sustainably for fruit, latex, and a small amount of timber, could yield US$ 8,890 per annum whereas its value if harvested for pulpwood was US$ 3,184 and as cattle pasture US$ 2,960. Therefore, protected areas have provided the most effective mechanism for conserving biological diversity. Particular focus has been put on the devastating effects of deforestation, which have stimulated both the protection of the remaining areas and the implementation of reafforestation schemes. Brazil has set aside 15 million hectares in a series of forest parks and conservation areas, while Costa Rica has protected about 80 per cent of its remaining wildlands. Many countries have taken steps to improve forest management: some have restricted the harvesting of timber while others have improved harvesting techniques. However, considerable tracts of land in many tropical countries continue to be converted for agriculture and pasture, regardless of the fact that nutrient levels in the soils of cleared areas are low, and the resulting land use is unsustainable. Even in Europe and North

America, ancient (old growth) forests continue to be destroyed, despite their importance as reservoirs of biodiversity and the fact that what remains is just a residual fragment of their original riches.

Reafforestation activities are in progress in many parts of the world. Food and Agriculture Organization (FAO,1991) estimates the annual rate of successful tree planting at 1.1 million hectares. The total area of man-made forests in tropical countries alone is estimated to have reached 25 million hectares in 1990. China, Cyprus, and Zambia are among the countries with substantial reafforestation programmes. However, despite these efforts, the reafforestation programme remains below the annual rate of deforestation.

Biological diversity has global, national and local dimensions, but actions at these levels are not well coordinated. The new task will require concerted action at all levels.

Chapter 5 has provided some examples of how to address the biological crisis; this list can be easily extended. The fact that the developed world stands to lose a great deal if natural areas are not effectively protected, provides a good reason for it to compensate countries that must sacrifice the use of resources to maintain these benefits. International compensation in the form of bilateral and multilateral aid, such as debt-for-nature swaps, transfer of technology, and provision of training and supplies are all necessary.

At the international level, in 1992, Global Biodiversity Strategy - an organisation supported by the World Resource Institute (WRI), United Nations Environment Programme (UNEP), and International Union on Conservation of Nature (IUCN), has prepared a document which highlights five important points for tackling the loss of biological diversity. These are:

. Develop national and international policy frameworks that promote sustainable use of biological resources and the conservation of biodiversity.

. Create conditions and incentives for effective conservation by local communities.

. Increase the number and effectiveness of protected areas, gene banks, zoos, and botanic gardens.

. Develop environmental awareness and strengthen the human skills and training needed to conserve biodiversity, particularly in developing countries.

. Catalyse conservation through international agreements and national planning.

Now it is more than time for governments, development aid agencies, as well as scientists to muster the will to transform these words into actions.

In democratic societies, people may think that their governments are bound by an ecological version of the Hippocratic oath to take no action that knowingly endangers biodiversity. However, that is not enough. The commitment ought to be much deeper - to let no species knowingly die, to take all reasonable action to protect every species and race in perpetuity. The governments' moral responsibility in the conservation of biodiversity is similar to that in public health and military defense. The preservation of species across generations is beyond the capacity of individuals or even powerful private institutions. Insofar as biodiversity is deemed an irreplaceable public resource, its protection should be bound into the legal canon.

REFERENCES

ARROW, K.J. and A.C. FISHER (1974): "Environmental Preservation, Uncertainty and Irreversibility"; Quarterly Journal of Economics 88:312-19.

CHARLES M. PETERS, ALWYN H. GENTRY and ROBERT O. MENDELSOHN (1989): "Valuation of an Amazonian Rainforest"; Nature, 339:655-656 .

DARLING, F and J.P. MILTON ed.(1966): "Future Environments of North America, Transformation of a Continent"; Garden City, N.Y.

DASGUPTA, PARTHA (1982): "The Control Of Resources"; Harvard University Press.

FALUDI, ANDREAS (1987): "A Decision-Centred View of Environmental Planning", Pergamon Press.

FISHER, A.C.(1981): "Resource and Environmental Economics" Cambridge University Press.

FISHER, A.C. and J.V. KRUTILLA (1985): "Economics of Nature Preservation"; Handbook of Natural Resource and Energy Economics, Vol.I.

FISHER A. C., J.V. KRUTILLA and C.J. CICCHETTI (1974): "The Economics of Environmental Preservation: Further Discussion"; American Economic Review Vol.64 No 6.

HENRY, CLAUDE(1974): "Option Values in the Economics of Irreplaceable Assets"; Review of Economic Studies, Synmposium on the Economics of Exaustible Resources p.89-104.

KRUTILLA, J.V.(1967): "Conservation Reconsidered"; American Economic Review Vol 57:777-786.

MALER, K.G.(1974): "Environmental Economics"; Baltimore: Johns Hopkins Press.

MCEVOY and DIETZ (1977): "Handbook of Environmental Planning"; The Social Consequences of Environmental Change.

NEHER, PHILIP A.(1990): "Natural Resource Economics: Conservation and Exploitation"; Cambridge University Press.

ORTOLANO, LEONARD (1984): "Environmental Planning and Decision Making";John Wiley & Sons.

SOLOW, R.M.(1974): "Intergenerational Equity and Exhaustible Resources"; Review of Economic Studies, Symposium on the Economics of Exhaustible Resources 29-45.

THE WORLD ENVIRONMENT; 1972 - 1982

THE WORLD ENVIRONMENT; 1972 - 1992

WILSON E.O. and F.M. PETER eds, (1988): "Biodiversity"; Washington, D.C: National Academy Press.

TIETENBERG, TOM (1988): "Environmental and Natural Resource Economics"; Scott, Foresman and Company.