Natural and Near Natural Tropical Forest Values

Daniel H. Henning

Abstract—This paper identifies and describes some of the values associated with tropical rain forests in their natural and near-natural conditions. Tropical rain forests are moist forests in the humid tropics where temperature and rainfall are high and the dry season is short. These closed (non-logged) and broad-leaved forests are a global resource. Located almost entirely in developing countries, where populations are expected to double in the next 25 years, tropical forests are extremely important to all life everywhere on the planet.

Introduction

Tropical forests are the richest and most diverse expression of life that has evolved on Earth. Their continuous history spans more than 50 million years in some areas. Tropical forests approximate the primeval forest biomes (communities of particular living organisms) from which they originally evolved, and contain more than half of the world's estimated 10-100 million species of plants and animals.

Tropical forests are complex and fragile ecosystems with webs of interlocking, interdependent relationships among diverse plant and animal species and their non-living environments. Irreversibly, tropical forests are literally disappearing within our lifetimes. Nearly half of the original areas of tropical forests have either been destroyed or degraded over the past 100 years. At the current accelerating rate, only fragments of tropical forests are expected to remain by the middle of this century. The Earth's closed or non-logged tropical forests currently occupy a land area equivalent to that of the United States. Each year we are destroying or degrading tropical forests approximately the combined size of England, Scotland, and Wales, at a rate of approximately 100 acres per minute, or the equivalent of one football field per second.

Daniel H. Henning was a Senior Fulbright Specialist, Southeast Asia Region, and Consultant/ Trainer.

In Memoriam, "Wilderness Dan" Henning (1931–2009).

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Major causes of this tropical forest destruction are:

1. shifting cultivation that is responsible for nearly half of the total of forests destroyed each year;
2. clearance for cattle raising, the second most important factor in forest destruction in Latin America (the majority of the meat produced on this land becomes North American hamburgers);
3. clearance for new settlements; and
4. timber extraction for fuel, paper, construction, furniture, and imports (Japan, South Korea, the United States and Western Europe are major timber importers).

Most tropical forests are too complex and their species too diverse to regenerate themselves from this destruction or to be managed on a sustained yield basis. Thus tropical forest destruction must be considered permanent and irreversible.

Worldwide recognition of the fact is growing that, in addition to the conservation efforts of the tropical countries, tropical forest destruction is an urgent *global and transnational problem* that requires international action and assistance. In addition, greater awareness of the value of tropical forests is required by the public, thought leaders, and decision-makers. It is vital to address not only the destruction but the reasons why we should not destroy the oldest, richest, most productive ecosystems on Planet Earth.

If we maintain intact tropical forests in as close to natural conditions as possible, they can make immensely diverse, productive, and valuable contributions to all life on Earth, and on a long-range basis. Present and future protected areas and natural or near-natural parks and wildlife refuges may well be the only feasible and permanent way of saving some of the remaining tropical forests and their rich biological diversity. By permitting the rapid destruction of tropical forests, the human species contributes to rather than prevents the destruction of the vital means of survival on Earth. Because the loss of tropical forests is irreversible, so are the negative consequences, the most obvious being the removal of land from productivity, species removal, flooding, and erosion. These negative impacts on life-based values also need to be addressed.

Tropical Forest Values

Values are individual and collective concepts with emotional, judgmental, and symbolic components that we use to determine what is important, worthwhile and desirable. Thus values contain, and at the same time evolve from, judg-

ments and beliefs about what is 'good or 'bad' and 'right' or 'wrong.' Values, therefore, can significantly influence human behavior regarding the conservation or destruction of tropical forests. Values must also be considered when regarding the *consequences* of both the conservation and the destruction of tropical forests.

By their very nature, values are complex in both interpretation and influence. This is particularly true in regard to tropical forests, which involve both anthropocentric (man-centered) and biocentric (ecology-centered) values. The tangible as well as intangible values of tropical forests are difficult and sometimes impossible to define, formulate, and quantify. Tangible values may be more readily recognized because they involve greater demands on the environment in forms such as timber production and industrial use. Intangible values, such as water conservation and education, may be less discernible in terms of economic and other material benefits.

There are, however, numerous high-value interrelationships within intact and natural tropical forests that are as yet minimally disturbed by development. In addition to these varied and complex natural interrelationships themselves, some of the values manifest themselves as the very ecosystems that are tropical forests. These dynamically interrelated values cannot be listed here in any particular order of importance because each is so interdependent with all the others. The values discussed here emerge from interviews with experts, residents, and participants in tropical forest management studies (including recent studies in national parks and reserves of Costa Rica and Thailand) and from surveys of literature on the subject.

Biological Diversity

Tropical forests are the most diverse and complex biomes on Earth, from both an ecological and general biological perspective. More than half of all species on Earth live in tropical forests. Yet tropical forests cover only 6 percent of the planet's land surface. The Earth's tropical forests are estimated to contain between 10 and 100 million species of plants and animals. However, we are losing more than 250 species per day. No more than 1.5% of tropical forest species have been given Latin names, and most are as yet unknown. A typical four-square-mile area of a given tropical forest may contain up to 1,500 species of flowering plants, 750 species of trees, 125 species of mammals, 400 species of birds, 100 species of reptiles, 60 species of amphibians, and 15 species of butterflies. The tropical forests of Costa Rica (approximately the size of West Virginia) contain more than 12,000 species of plants, 237 species of mammals, 850 species of birds and more than 360 species of reptiles and amphibians.

As the most complex and diverse ecosystems on Earth, tropical forests are rich webs of interlocking and fragile relationships among plant and animal species, and among these species and their 'non-living' environment. Most species in tropical forests are scattered and highly specialized, with very low population density. For example, only one tree species may be present in a given sample area. Without adequate areas to sustain reproduction and vital ecological interrelationships, tropical forests are extremely susceptible to extinction. Tropical forest diversity also correlates directly with vulnerability in that even small areas are not comparable. If one species becomes extinct, or if a small area is damaged and destroyed, other interrelated and dependent species will also suffer extinction as the web of life of the ecosystem deteriorates.

In turn, the great variety of plant and animal species of any small area of tropical forest is a miniature version of the diversity found from area to area, region to region, and continent to continent. Virtually all leading scientists verify the incapacity of tropical forests to regenerate themselves in their former primary forms of diversity. It has even been found that tropical forests, with their high rainfall and high diversity, do not respond to any form of human intervention. Indeed, human attempts to restore damaged tropical forest ecosystems and parts of ecosystems have resulted in further destruction and even greater reductions in their diversity. This diversity may well be the tropical forests' most valuable contribution to humankind and other creatures and plants.

Regarding this phenomenon, Paul Ehrlich (1981) stated:

> Unfortunately, however, the most important reason for preserving diversity is also the least-known and least well-understood. That is that populations of species of other organisms are all working parts of the vast ecological systems that provide humanity with an irreplaceable set of 'free public services.' Included among these are the maintenance of the quality of the atmosphere, the control of the hydrological cycle (and the supplying of fresh water), the amelioration of the climate, the generation and maintenance of soils, the disposal of wastes, the recycling of nutrients essential to agriculture, the control of the vast majority of pests of our crops and carriers of human disease, and the maintenance of high-yield agriculture. Therefore, when humanity exterminates populations of species of other organisms, it is in essence 'popping the rivets' on its own spaceship.

In order to understand biological diversity better it will be approached here from two perspectives: (a)genetic diversity, and (b)species diversity. A consideration of each follows.

Genetic diversity—Existing within biological diversity, genetic diversity is extremely important. Tropical forests have the highest range of genetic material of all the Earth's organisms. The world's scientists are unanimous in their conclusion that tropical forests are the largest reservoir of unexploited genetic traits on the planet. Only 1.5 million of the estimated 10-100 million species (mostly insects) in tropical forests have been catalogued, while only 15 percent of tropical forest species have been screened and examined for their medicinal and other benefits and values to society and the world's economy. However, because of the rapid rates of tropical forest destruction, many thousands of species and their genetic material (DNA) are disappearing before they can be biologically studied.

Preservation of this as yet unquantified genetic diversity and range of genetic material is, alone, vital reason enough for preserving and maintaining intact tropical forests. The protection of genetic material is a matter of insurance and investment for continued life on Earth. Genetic diversity provides the materials necessary for breeding programs that are necessary for the protection and improvement of

cultivated plants and domestic animals, and for sustaining and improving other forms of agriculture, forestry, wildlife, and fisheries. In addition to keeping options available in the future, the genetic pool in tropical forests serves a vital buffer against as yet unforeseen harmful environmental changes. Especially with numerous recent and complex breakthroughs in genetic engineering, genetic diversity provides innumerable raw materials for scientific and industrial innovations, as well as security for industries that depend on living natural resources. These realties and potentials exist only because the Earth's genetic resources are the very foundation of the evolutionary process.

Species diversity—Because the diversity of species is dependent on biological diversity, species diversity is determined by the quality of maintenance and stability of the ecological processes of tropical forests. Each specie is bound together with all other species in a maze of complex interactions in tropical forest ecosystems. The abundance of different species of plants and animals is the central determinant characteristic of tropical forests and the source of their innumerable benefits.

Yet, the GLOBAL 2000 report to the president (an international environmental study by the Council on Environmental Quality and the U.S. State Department (1980)) estimates that at least one million tropical forest species will become extinct before the end of the century if current deforestation rates continue. This disappearance of species would not only result in the loss of Earth's most complex biological communities, but also millions of years of evolution that is not yet understood.

Species diversity, the uniqueness of species and populations, is essential for the ecosystem functions of tropical forests. Some species may serve as 'keystone' species in the complex structures and diverse interactions with other species. The removal of a 'keystone' or link of these counteractions and interactions may result in numerous other species becoming extinct, thus producing a 'domino effect' of negative consequences for the entire ecosystem. Ironically, because of the uniqueness of each species, its population, and ecosystem, these complex repercussions and their impacts are difficult to research and predict.

Species Protection

The value of preserving known and unknown species of plants and animals is of rapidly growing importance. The intimate and complex linkage of tropical forest species to numerous others requires more attention given to habitat preservation than is necessary in temperate areas. The protection of species and their natural habitat is one and the same process.

Each species is a unique original, just like a rare and original painting— and for each, extinction is forever. While the good and potential good that tropical species provide are justification enough for their protection, many believe that plants and animals have a right to exist for no higher value than for their own sake. Also, the better known or more spectacular species (flagship species like elephants and tigers) attract public support for the habitat of the lesser-known or unknown species.

Charles Elton (1958) believed that a primary reason for conservation is an almost spiritual one. He writes:

> There are some millions of people in the world who think that animals should have the right to exist and be left alone, or at any rate, that they should not be persecuted or made extinct as a species. Some people will believe this even when it is quite dangerous to themselves.

As the current results of millions of years of evolution, tropical forest species continue to evolve and to provide useful and inheritable genetic resources. Besides the species themselves, populations within species must be saved from extinction so that they will continue to evolve. By remaining contestants in the co-evolutionary race, plant and animal populations continue to develop and strengthen the genetic variability necessary for natural selection. In turn, this provides the evolving diversity within each species necessary for its contributions to the world's genetic resources, including the variability of genetic types required for human developed artificial selection.

The loss of individuals as well as populations of a given species will profoundly and negatively affect this process. In addition to species and genetic relationships, each plant and animal is a unique and contributing representative of its species, with its own individual characteristics. Most individual species in tropical forests, particularly trees, are rather sparsely distributed among the millions of other diffused species. Each individual of any given species is one of many possible participants in the vast pool of species and their interactions.

This unfathomable diversity of genetics, species, and individuals requires unfathomably dynamic conditions that cannot be duplicated outside of undisturbed tropical forests. Each individual tree, for example, is genetically different from any other tree of the same species. Thus, it has its own unique contribution to make to genetic variability and co-evolutionary interactions.

Agriculture

Only about 20 of the many thousands of edible plants provide most of our human food. Plants that are currently cultivated require large genetic pools for the development and production of more useful strains or for restoration of vigor to inbred varieties. This narrow and vulnerable range of food crop species does not come close to representing the rich potential of the world's great storehouse of plant species: tropical forests. Despite these known facts, the vast scale and rapid speed of tropical forest destruction virtually guarantees that more than a million species of plants and animals will have recently become extinct before the beginning of this century. If this destruction is not stopped soon, much of its genetic diversity and variability will be lost forever.

The International Union for the Conservation of Nature (IUCN 1980) states:

> Tropical forests may harbor some 50 million species, representing huge stocks of genetic resources of immense value, both actual and potential, to agriculture, medicine, and industry….The now famous perennial corn (*Zea diploperennis*) was recently discovered growing in a montane forest area of southern Mexico. A promising new food crop

> is the fast-growing, protein-rich winged bean (*Psophocarpus tetragonobolus)*, which is native to the humid forest ecosystems of Southeast Asia. Tropical forests are also a source of many plants, fish, and wildlife that are an essential source of food for local people…. Tropical forests are important also to advances in forestry and other fields of applied biology.

The genetic material or 'capital' in tropical forest species is essential for breeding programs for domestic crops and animals. Continued improvements in pest and disease resistance, adaptability, yields, nutrition, durability, flavor and other qualities are dependent upon genetic diversity and variability. This is particularly true in plant breeding to protect against pests and diseases that develop resistance to pesticides used on standard crops.

Because many tropical plants are adapted to living without direct sunlight below the canopy and adapt well to indoor situations, they are also of high ornamental value or can be bred for home or garden. Tropical forests are also rich sources of biological controls such as predatory insect insecticides from plants such as the tuba root.

With more accurate identification and scientific analysis, many more applications of tropical forest species will become available for agriculture and other financially profitable uses, certainly including new species of plants more resistant to diseases and pests than present crops. Although the economic value of many tropical plants is unknown— either in fact or potential— we are continuing to lose uncounted and uncountable species at an increasing rate, even before they can be discovered and studied. It is estimated that over one third of the tropical forest species will be extinct within this decade, and their extinction will accelerate the loss of many more species in ensuing decades.

Medicinal

More than 40% of the world's drugs—with a commercial value of more that $50 billion per year—are obtained from wild plants or are synthesized from wild derivatives, yet only a very small percentage of plants and animal species have been examined for their medicinal value. Herbal traditional medicine provides the primary health care for 80-90% of the rural population of the world. The World Health Organization has identified over 20,000 medicinal plant species. Plant drugs are usually inexpensive as well as an accepted part of the culture of many countries.

It is estimated that only one percent of tropical forest species have been scientifically investigated for possible medicinal benefits. Tropical forest plants provide valuable medicines for treating diabetes, high blood pressure, schizophrenia, and chemical prophylactics. Because armadillos, found in the tropics, are the only animals apart from human beings to contract leprosy, armadillos are proving to be valuable aids in medical research into curing this disease. An example of another surprising and recent discovery is the Madagascan Periwinkle (*Catharanthus roseus*), a tropical plant that yields drugs used in the treatment of leukemia and lymph gland cancer. Annual sales of these drugs total several billion dollars.

Members of the periwinkle and other plant families have been used to treat cancer since the time of Hippocrates who lived four centuries before Christ. We do not know how many other undiscovered tropical plant species produce their own unique mixture of chemicals with current and potential medical use.

Animal species also offer unique and reliable contributions to medicine, including anti-cancer compounds produced from insects, and medical research conducted with tropical forest monkeys. Clearly, unless both plant and animal species (particularly the as yet unknown ones) are protected within natural or near natural tropical forests, they will not make their medical contributions to human health.

Industrial

Tropical forests provide a wide range of materials for industry, including diverse genetic materials necessary for industrial innovations. A partial list of the most common of these materials includes rubber, gum, camphor, resins, tannins, turpentine, dyes, rattans, bamboos, and essential oils— used in the production of many oils for modern living, such as foods, polishes, lubricants, furniture, glue, gums, detergents, and deodorants. Although known and unknown tropical forest species undoubtedly hold a great deal of potential for new materials and products, their extraction from their complex and delicate ecosystems must take place with only a minimum of ecological disturbance, which may or may not happen.

As petrochemical costs increase, the global chemical industry is also increasingly seeking alternate supplies of organic raw materials. Worth more than half of the global armaments industry, the global chemical industry is now turning to tropical forests in particular as sources of phytochemicals (plant compounds). As Norman Myers (1980a) notes, "Technology is available to manufacture 95 percent of synthetic products from selected plant materials. Salient instances include plastics, fibers, adhesives, polyisoprenes, and surface coatings." An example of the potential for industrial products from tropical forests species is illustrated by the tree *Copaifera langsdorfii*, a tree that grows in the Amazon basin. It was recently discovered that the sap from this tree can be used directly as fuel in diesel engines.

Tropical Forest People

Approximately 200 million people live within or on the margins of tropical forests. Tropical forest environments provide these people with food, (e.g. fruits, wild animals, nuts, fish, and honey) and raw materials for fuel, wood, clothes, buildings, and medicine. Indigenous forest-dwelling tribal people are distinguished by their special relationships with tropical forests; they are completely dependent upon tropical natural forests for their livelihood and welfare. Their cultures have evolved in harmony with this environment and their identity and lifestyles are tied to living in tropical forests permanently. Development in tropical forests brings pressures on traditional forest dwellers with disastrous results for their survival and culture. Inevitably, native tribes fall prey to outside diseases, weapons, technology, alcohol, and drugs imported by outside cultures. Thus, entire tropical societies and their native knowledge and wisdom about their tropical forest environment are rapidly disappearing as their natural role in these ancient ecosystems is destroyed.

These tribal people are an irreplaceable source of vital information about the natural history and use of tropical forest species. Their detailed and sophisticated knowledge of tropical forests is respected and sought by scientists. Local tribal people's knowledge of not only the diverse plants but of the periods of their life cycle stages when they are most useful is unobtainable from any other source. A classic example is curare, from the Brazilian vine (*Chondrodendron tomentosum*), which was originally used as a poison by tribal forest hunters. Curare contains tubocurarine, which is now essential as a relaxant in delicate surgery. Not incidentally, the Paraguayan Indians prepare food with a forest plant that tastes 300 times sweeter than sugar but contains virtually no calories. This wealth of intimate and growing knowledge is rapidly being removed forever with the loss of tribal people as their tropical habitat is damaged and destroyed. Their knowledge and lifestyles need special protection.

Maintenance of the Web of Life

Ecological interactions in tropical forests impact life and conditions throughout the world. Destroying a link in these delicate interactions produces repercussions that can sometimes be observed, such as serious disturbances in bird migration far into the northern and southern hemispheres. Most repercussions are, however, difficult to predict. For example, the removal of a tropical forest may result in increases in insect, rodent, and other pest infestations in nearby crops, grazing areas, or other human settlement areas. Natural predators of these pests may also have depended on forests for their survival. The economic wealth and security of entire nations are related in many ways to tropical forest ecosystems. The maintenance of ecological processes that depend on intact tropical forests ensures the sustainable utilization of natural resources.

The Office of Technology Assessment (OTA) (1984) reports that many U.S. funded development projects are currently being undercut by flooding, pest outbreaks, and other problems directly associated with deforestation. Food and jobs in developing countries are also impacted as a result of deforestation. The OTA states:

> Tropical forests also provide habitats for many of the world's migratory birds and various endangered species. About two-thirds of the birds that breed in North America migrate to Latin America or the Caribbean for winter. Some of these migratory birds play an important role in controlling agricultural pests in the United States.

Scientific Research

In their natural or near-natural states, tropical forests represent the oldest, most diverse and complex ecosystems for scientific research. Charles Darwin and Alexander von Humboldt are only two of the many great scientists whose scientific contributions depended primarily on their tropical forest experiences. These forests offer insights into the ecological and evolutionary processes for basic and applied research, such as a specific relationship between a fig tree species and a particular wasp that pollinates it. Investigations at La Selva Biological Station indicate that few trees were self-pollinated, and that most rely on cross-pollination. One tree species was even found to be pollinated by a mouse. The fact is clear: tropical forests contain the answers to basic scientific questions that have not yet been formulated.

Regarding applied science, research of tropical forests can contribute knowledge of plants, animals, genetic material, and chemicals for agriculture, medicine, industry and many other areas. Studied tropical species have already made valuable contributions to society, such as agricultural crops, anti-cancer drugs, and insects used in integrated pest management. Unstudied species thus offer great potential for pest control, plant breeding, and other biotechnologies.

Although scientists are developing techniques for cloning plants and micro-organisms to screen for production of useful new chemicals, Peter Raven (1982) cautions:

> Several speakers have mentioned that two-thirds of all species live in the Tropics. Of these, about 500,000 have been named, meaning that there are millions unnamed, uncatalogued, and uncharted species in the Tropics. There are at present in the entire world only about 500 systematic biologists-taxonomists capable of dealing with these unknown species. The rate of forest destruction leads most of us to conclude that virtually all of them will be gone in 30-40 years. Many of us have concluded that one-quarter to one-third of this diversity might be gone in the next 30-40 years. This means that if we want to learn anything about these unknown plants or press any of them into our service, we are going to have to set some very definite priorities."

Gerald Budowski (1972) believes that the loss of tropical forests to the scientific community would be irreparable. He considers tropical forests to be "living laboratories" and a "factory and storehouse of evolutionary diversity," that contains "incredible variations of which we know very little at present….(where) new discoveries take place every day."

It is only in natural tropical forests that the full range of species and an undisturbed ecosystem can be scientifically studied in its true evolutionary and ecological uniqueness. Thus, tropical forests present exceptional opportunities for scientists to work on the 'cutting edge' of research. Much of UNESCO's Man and Biosphere (MAB) Program is based on biosphere reserves, with many of them located in tropical forests. This international MAB Program is directed at the application of human scientific knowledge to harness biological processes that can improve human conditions. But the scientific community is extremely concerned that entire 'laboratories' for this vital research—the tropical forests themselves—are being destroyed long before their highly promising research can even begin.

Climatic Global Warming

By their physical presence on the planet's continents, tropical forests make essential contributions to local, regional, and global climate. The influences of tropical forests on climate is another area that is not fully understood. It is recognized, however, that tropical forests serve as moderating and maintenance influences on climatic stability. Through their role in evapotranspiration, tropical forests may generate local rainfall in some countries. At the global level, however, destruction of tropical forests will adversely affect climate by increasing the level of atmospheric carbon dioxide and by increasing the amount of reflected sunlight. These climatic

changes will very likely result in severe consequences for worldwide agriculture, as well as a substantial rise in ocean levels as the Antarctic, Greenland, and other global ice fields melt. With increasing global warming concerns (and crises) on a worldwide basis, it would appear crucial and timely to intensively investigate and implement tropical forest protection programs.

Myers (1980a,b) believes that tropical forests create a "buffering effect" that stabilizes a number of important environmental processes, including water flow. However, he considers the role of tropical forests as safeguards of the global climate to be most significant. If tropical forest cover is maintained, predictable and historical climatic patterns will continue, while any changes will be modulated by the forests' effects. With the removal of this forest cover, climatic changes can be abrupt and extreme. Yet, little knowledge is available with which to predict the nature and scope of these climatic changes from deforestation. The clearing and burning of tropical forests releases their stored carbon dioxide, adding to the ambient atmospheric carbon dioxide. Scientists fear that this is causing the still mysterious and feared 'greenhouse effect' that could trap heat and adversely warm the Earth.

Water Conservation

Tropical forests protect watersheds. In their natural or near-natural states, they retain water and release it gradually throughout the year. Tropical forest watersheds are thus able to maintain and restore reliable supplies of high quality water that benefits surrounding and downstream agriculture, industry, human consumption, and hydroelectric facilities. More than 40% of farmers in developing countries live in villages that depend on the sponge-like effects of tropical forests to absorb and slowly release water.

Mangrove ecosystems within intertidal zones provide a nursery area for marine life and reduce coastal erosion and storm impacts. Mangrove areas also provide protective habitat for many plant and animal species, including fish, shrimp, and oysters.

Tropical forests reduce the frequency and extent of floods and droughts. Deforested areas are particularly noted for their flash floods that can cause serious damage to human life, agriculture, and property. In southern Thailand, a flash flood due to illegal logging resulted in the deaths of 200 villagers and the destruction of two villages and their crops. Indonesia has experienced numerous similar flooding events due to tropical forest logging.

Deforested, unprotected slopes do not absorb and transmit water into the soil, thus rapidly increasing the sudden impact as well as the long-term damage sustained whenever there is a prolonged dry spell in lower areas. The campaign to save the tiger in India resulted in the establishment of forest reserves that contain valuable watersheds. This single conservation decision also assured the steady flow of water for agriculture and other uses as well as a significant reduction in age-old flood problems. Protecting and maintaining tropical forests in as natural a condition as possible is the most effective method of protecting watersheds, and is the least costly in terms of both money and effort.

Soil Protection

Tropical forest soils are poor quality, fragile, and unsuited for agriculture. Almost all the nutrients are found in living vegetation rather than in the soil. With deforestation, the thin layer of topsoil washes away quickly. The remaining soils rapidly deteriorate and lose their fertility, leaving hard-packed clay or sand that is limited to only one or two more poorly nourished crops or to very short-term grazing. Thus, the very productive land of tropical forests becomes a virtual desert when its poor soil is exposed.

Tropical forests shelter the soil from rain, stabilize it, and prevent erosion. Soil erosion renders land unfit for agriculture or other uses. IUCN (1980) stated: "It has been observed that many tropical countries which would not wish to give up a square meter of their land are watching thousands of tons of soil wash away each year because of deforestation." Soil silt though erosion can destroy river and delta fisheries and fill reservoirs, greatly reducing hydroelectric production. The life span of a reservoir basically depends on forest cover to prevent erosion.

Outdoor Recreation

National parks and reserves of selected areas of tropical forests can provide outdoor recreation for the general public. With increased hours of leisure available, people find time to experience the unique form of outdoor recreation available in tropical forests. Increasing pressure and tensions from crowded and urban areas make it important to have natural areas of tropical forests conserved for public relaxation, enjoyment, and renewal. Although outdoor recreation in tropical forests is in its early stages, visits have increased significantly. The Caribbean National Forest near San Juan, Puerto Rico, has almost one million visitors annually. Tropical forest parks in Rancho Grande (Venezuela), Poas (Costa Rica), and Tijuca (Brazil) attract hundreds of thousands of visitors annually, to cite only a few examples in Latin America. Outdoor recreation in natural areas like this can draw on the rich diversity, superlative wonders, and unique scenery of tropical forests.

Education

The U.S. Interagency Task Force on Tropical Forests (1980) noted:

> On a worldwide scale, tropical forests have unequaled scientific and educational value. The complexity of tropical forests for years attracted scientists and students in search of answers to basic questions about life processes. No other region on Earth offers so much material for study. The interactions among the components of tropical forests, and particularly the behavior of observable animal life such as mammals, birds, and insects, constitute assets of great scientific and educational value. As investigations enrich knowledge of the relationships and the findings are interpreted by laymen, visits to tropical forests by the general public are expected to increase greatly. Improved standards of living in developing countries also will expand this resource use.

Tropical forests can serve as living museums and inspiring classrooms for a variety of formal and informal educational activities. Developing naturalist interpretive programs for tropical forests and the general public may include self-guiding nature walks. New knowledge of the ecology and natural history of tropical forests will greatly contribute to and enhance the understanding, appreciation, and enjoyment of the public. This type of knowledge also motivates and increases public support for conservation in general, and for tropical forests in particular. Use of tropical forests for formal education is rapidly increasing in the form of field trips and studies at various levels. The Organization of Tropical Studies (1985), a consortium of four Costa Rican and 29 North American research universities, has provided advanced training in tropical ecology to more than 1,500 graduate students, field research access to thousands of scientists, and published literature on tropical biology. The OTS' La Selva Research Station and Biological Reserve provides unique courses and study opportunities for graduate students and faculties in natural tropical forest settings. The diversity and abundance of species and their complex ecology in these settings attract students from many areas of the life sciences.

Ecotourism

The new concept of combined tourism and nature (ecotourism) in tropical forests holds a great deal of promise. The focus of such tours is on ecology and natural history; university professors and naturalists from the tropical countries often serve as naturalist interpreters or nature guides. Budowski (1976) observed:

> The appeal of the rain forest rather is in the diversity of forms it has to offer, the multitude and sometimes extraordinary relationship between plants and animals, often the small but nevertheless spectacular features found in insects, flowers, fruits, roots and branches of the life along the river banks. The incredible variety in birds and orchids, for example, the feeding habits of the forest animals, the dependence of some plants on some insects or birds for pollination or dispersal. Actually, some of the animals and their movements can be watched if a minimum of knowledge and care is displayed. Along the rivers and lagoons and lakes, there is a fascinating web of life and food chains which again must be seen with an eye of understanding. For there are thousands of features appealing to different tastes and different backgrounds, all able to give pleasure and entertainment to a large variety of people who might be attracted by this vast "firework in diversity."

Ecotourism could certainly engage large numbers of academics, tourists interested in natural history, and scientific visitors to tropical forested countries. Thousands of scientific visitors, some of them graduate students, annually 'invade' Costa Rica, and use it as a living laboratory and educational center. Ecotourism provides general and financial support for a tropical-forested nation's efforts to protect and to profit from their natural tropical forests. Natural tropical forests are often an undeveloped resource of great economic value as an export to the entire world, sometimes compared to the animal life of Central Africa in uniqueness. These forests, the world's most complex ecosystems, are valuable classrooms that interest students from around the world.

Cultural

Tropical forests are intimately related to the cultures of tropical peoples through diverse influences on the entire range of knowledge, traditions, and values of the cultures. These tropical forest influences may range from concrete, economic uses such as firewood to less tangible values such as scenery and 'atmosphere' in the lives and well-being of tropical people. Thus, tropical cultures are very much a product of the unique interface between people and tropical forests.

If present trends continue, many countries will lose almost all of their tropical forests in the not-too-distant future, beyond small pockets of protected areas which, in turn, are poached and illegally logged. With the continuation of these trends, it is estimated that tropical forests in South and Southeast Asia would be greatly reduced or removed by the year 2050. Thailand today has established protected areas in about 12% of its natural or near natural forest lands, but these protected areas, like those in other Asian countries, are severely poached and illegally logged.

About 70 years ago, Thailand was approximately 80% tropical forests with similar stories in other Asian countries. Damage to and loss of tropical forests is related to a measurable loss of significant cultural values and institutions. The most obvious damage is the destruction of tribal people and their lifestyles through deforestation, with obvious impacts on nearby villages. The impacts extend a ripple effect throughout entire cultures, removing and eroding original, authentic characteristics. The natural heritage of native plants and animals, the undisturbed landscape, and native identity disappear forever. Tropical countries and peoples lose much of their cultural and national identity in the absence of their tropical forests.

Creativity

The art, writing, photography, and other creative endeavors of a country draw upon its nature and environment. Tropical forests provide a unique, mysterious, and natural environment of complex, constantly changing, beautiful mosaics with great potential for stimulation of the soul as well as the senses, and as a source of artistic inspiration. The wide diversity of tropical forest life forms and colors produces aesthetically rich landscapes and myriad images that can inspire one's natural sense of wonder and innate creativity, and refresh the human connection with nature. Contemporary tropical artists such as Deidre Hyde and Edwardo Stapelfeld of Costa Rica regularly seek the diverse beauty and essence of tropical forest life for their detailed paintings of its unique natural creatures and plants and incomparable scenery.

Joseph Conrad (*The Heart of Darkness*), Garcia Marques (*100 Years of Solitude*) and many other novelists have been drawn to forest settings and have depicted the majesty and power of the environment as a major element in their novels. A popular motion picture 'The Emerald Forest' dramatizes the lifeful energy and drama of tropical forests and tribal people. Primitive art in the form of rock paintings, carvings, and ceramic art are products of the unique blending of tropical forests and indigenous tribal people.

Spiritual

Human beings are innately spiritual creatures capable of and drawn to abstract thought. Although they are intangible, spiritual values and influences are clearly present and appreciated by human beings who travel in tropical forests. The prolific diversity and enormous variety of life forms in tropical forests create a powerfully spiritual environment, endlessly different and surprising, 'the essence of the magnificence of nature…the most mysterious of all natural worlds.' This spiritual response obviously has significant impact on virtually all human beings, regardless of their spiritual, social, or cultural backgrounds.

Spirituality connotes for each of us a broad and deep range of relationships that define our underlying sense of identity with ourselves, others, life, the Earth, the universe, and with a higher power. As with all human societies, tropical forest people have their own spiritual beliefs. Developed during the course of humankind's evolution, many of these spiritual beliefs and wonderments reflect and include the deep connections with nature found so abundantly in tropical forest surroundings. These spiritual beliefs take the form of myths and rituals that help to explain natural phenomena or to provide spiritual protection. Spirituality in tropical forest cultures is often expressed in an elegant complexity of tribal activities that include dances, decorations, prayers, and rituals. Many of their spiritual beliefs and activities explain mysteries of life in the tropical forests, maintain order and cooperation for survival, and provide hope, tradition, and meaning to visitors and observers as well as to native participants.

Non-tribal people from host or other countries often find tropical forests to have spiritual significance that blends into their own spiritual heritage and beliefs. Myers (1980b) observed, "Perhaps what most stimulated me about a tropical forest is the notion that its diversity, its interactions, its sense of wholeness, all are so advanced that it (*sic*) is far beyond the scope of my imagination—let alone my intellect—to grasp how advanced they are. I feel cut down to size, even as I feel I stand taller than before." Often, the luxuriant beauty and teeming life of a tropical forest awakens a deep sense of satisfaction in the realization of one's role in the natural scheme of the forest, the planet, and the universe.

With their settings of stunning natural beauty, free from the pressures of civilization, tropical forests provide undisturbed solitude and tranquility where human beings feel closer to creation or discover many dynamic aspects of spirituality. These types of experiences awaken in some people a renewed belief in a supreme creator whose energy is somehow responsible for the grandeur of tropical forest life, and a profound appreciation for the presence of life itself on this planet. In this regard, Karl Eymert (1985) comments: "The value of the tropical forest is the very essence of life for all. It is God's creation. They are part of me. They are part of my beingness, part of God—a vital part of physical, mental and spiritual life that sustains all life on earth."

Scott Heywood (1985) also comments on "the power of a unique ecological system to spiritually refresh a chaotic, hectic, confused mind, body, and soul…the humbling reminder of man's frailties, vulnerabilities, and mortality by comparing them to a system's natural and unique past, its existing presence, and its living future."

Future Generations

Concerns and responsibilities for tropical forests must extend to future as well as present generations because these threatened ecosystems are highly susceptible to irreversible removal or very serious and damaging reductions, resulting in loss of human and other natural values and options for survival and quality of life. It is not possible to predict what tropical species may be discovered as useful before they are destroyed. However, the moral obligation to protect tropical forests for future generations of one species in particular, *homo sapiens*, must extend to future generations of all species, known and unknown. In short, the active, ongoing protection of natural tropical forests for their own sake is essential.

Future generations of all forms of life require that tropical forests must be protected in an intact and natural state. Humankind needs tropical forests. But tropical forests could survive quite well—in fact, better—without human presence and impact. It is only within an intact natural tropical forest environment that diverse and interdependent forest species can carry on their struggle for survival and evolution. In addition to any conservation measures to protect Earth's tropical forests, efforts need to be increased to safeguard tropical forests for future generations by establishing and maintaining national parks and reserves.

The following situation, described by Iltis (1981) continues to repeat itself in various forms everywhere in tropical forest countries:

> Let me take you to the foothills of the Andes, in a Peruvian valley, overwhelming in its greenness, where I stood in 1963, and watched from a narrow hanging bridge as a troop of spider monkeys jumped from one tree to the next, eating orange fruits from a gigantic fig tree a hundred feet up, as brilliantly blue giant Morpho butterflies sailed erratically and iridescently through a sun-flecked opening in the forest, as a pair of toucans sat motionless on a branch, watching a scene straight out of Genesis. No more of this, today. None of it, for with a U.S. AID development grant, some eager young man bought the land and the Indians living on it cut down the forest and planted coffee on 45 degree slopes. In three months of field work, we saw only one spider monkey—a pet on a silver chain in a tourist lobby.

The Organization for Tropical Studies (1985) warned, "A hundred years ago, tropical forests blanketed an area about twice the size of Europe. Today, way less than half remains, and it's going fast."

The values associated with tropical forests deserve understanding, appreciation, and emphasis, for in them we find deep values for the immediate present and for countless future generations of all life: the protection of natural tropical forests as a vital part of Earth's biosphere. We must ensure that generations to come benefit from tropical forests and share their dynamic values for the survival and quality of all life on Earth.

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The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.