COMMENTARY

# The Effects of Tropical Deforestation on Human Health

Roger L. Shapiro, M. D.*

As the twenty-first century approaches, the role of the physician continues to expand. Health issues, population pressures, and environmental problems have begun to merge on both a local and global level, and this process will accelerate in the coming years. A recent World Health Organization report states that "human health is a vital cross-sectoral issue, dependent on the continued availability of environmental resources and on the integrity of the environment." The report also calls for all health professionals to assume a central role in the process of environmental protection [1].

Here tropical deforestation is examined as it affects human health. Although many environmental issues are associated with significant health problems, the consequences of deforestation alone sufficiently serve to exemplify how health issues and environmental degradation are inextricably bound. Deforestation, particularly in the world's tropical rain forests, has both an indirect and direct impact on human health. The loss of biodiversity as a result of deforestation has far-reaching ethical, medicinal and agricultural, and ecological implications, and a deforested landscape contributes directly to human disease through change in disease vectors and influence on urbanization and poverty.

Conversion to agricultural and grazing land, as well as commercial and local logging operations have the largest impact on global deforestation. In the tropics, 60% of deforestation results from new agricultural settlements, and in all developing countries, logging represents nearly 20% of forest loss. Unfortunately, less than 1% of tropical logging operations are sustainably managed, and logging roads allow farmers and grazers access to new areas of the forest [2]. Poverty and population pressure lie beneath the surface causes of worldwide deforestation. A Brazilian farmer will resort to slash and burn agriculture to feed his family, even though nutrient-poor rain forest soil remains productive for only a few years. Similarly, Somalis will scour a barren landscape for scraps of firewood when that wood is their last remaining asset.

On the basis of satellite data and ground estimates, a reasonable figure for tropical rain forest loss in 1989 was 1.8% per year. These forests currently cover about half of their prehistoric area, and this rate of loss would again cut their area in half by the year 2022. According to the latest estimate by Harvard biologist E. O. Wilson, surviving tropical rain forests in 1989 occupied an area approximately equal to the continental United States, and the area disappearing each year was roughly the size of Florida [3]. Outside the tropics, many of the world's other forests have fared no better. In Nepal, half of the forest cover has been lost in the last decade, and population pressure and poverty in India threatens to destroy all of its remaining forests by the turn of the century [4,5].

## DEFORESTATION AND BIODIVERSITY LOSS

The issue of biodiversity loss is intimately connected with deforestation, especially in tropical rain forests. Habitat destruction is by far the leading mechanism of extinction, and conservative calculations estimate that one half of all species exist solely in tropical forests [6]. The most serious problem facing scientists attempting to quantify species loss is that we simply do not know how many species exist. There are currently about 1.4 million named species on the planet, but most estimates place the true num-

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*RLS is an intern in internal medicine, Beth Israel Hospital, Boston, MA. Address correspondence to Roger L. Shapiro, M.D., Department of Medicine, Beth Israel Hospital, 330 Brookline Avenue, Boston, MA 02115

ber between 5 and 30 million [6]. At the present rate of deforestation and the conservative estimate of 10 million rain forest species, Wilson estimates that between 10% and 22% of species in the rain forest may become extinct in the next thirty years, representing between 5% and 10% of the total species on Earth. This rate is equivalent to a loss of approximately three species per hour [6]. The World Commission on Environment and Development, in its landmark book *Our Common Future*, further estimates that at 1987 deforestation rates, 15% of all plant species will become extinct by the year 2000, and that without the creation of new reserves or a change in this trend, up to 66% of all plant species and 69% of all bird species will eventually be lost [7].

These estimates of species loss are conservative. They are based on area estimates alone, which do not account for specialization and localization of species within rain forests, and they do not account for the weakening of species by reduced genetic variation among survivors. Furthermore, the potential change in rain forest ecosystems due to deforestation is not addressed. For example, loss of half the forest might well reduce the remaining half to an open woodland because of an inability to maintain enough moisture [6]. This process, combined with human pressures on selected species and the encroachment of "common" weeds and animals from adjacent regions, may drive up the extinction rate even further. On the basis of Thomas Lovejoy's Minimum Critical Size of Ecosystems Project in Brazil, E. O. Wilson concludes that "an Amazon forest chopped into many small fragments will become no more than a skeleton of its former self" [3,7].

Critics of these statistics state that we do not have precise information about the number of species in the rain forests or a model reliable enough to make such grim predictions. Ariel Lugo of the Institute of Tropical Forestry in Puerto Rico points out the resiliency of many tropical ecosystems and notes that following massive deforestation diversity has returned to islands like Puerto Rico, leading to the creation of new "native" plants. Others contend, however, that this represents the secondary invasion of common "tramp" species and not a true return of biodiversity [8,9]. The most challenging and pervasive of all arguments against acting to prevent tropical deforestation is: "So what?" In the last 500 million years there have been five mass extinctions on the planet, and about 99% of all species that have ever existed are now extinct. What, one might ask, is the danger? To address this question, an obvious starting point is the fossil record, which indicates that following each of those periods it took tens of millions of years for diversity to return to pre-extinction levels. Modern *Homo sapiens* have existed for less than 100,000 years, and our tenure may not extend into the millions. Thus, as humans accelerate the process of extinction on the planet, we condemn our future generations to a more isolated—and perhaps precarious—existence. Another consideration is the current speed and scope of species loss due to human activity; it is estimated to have increased the baseline extinction rate in tropical rain forests between 1,000 and 10,000 times [3]. These figures demand our attention and deny us the comfort of historical precedent. As we remodel the planet in the blink of an eye by geological time, and as we create the environment of our descendents, we relinquish the right to say "so what" or to throw our arms skyward and ask, "why?" The responsibility for the changes lies with us.

In their 1991 article "Biodiversity Studies: Science and Policy," Paul Ehrlich and E. O. Wilson outline three reasons why everyone should be concerned with the loss of biodiversity: 1) ethical and esthetic reasons, 2) economic benefits in the form of medicine and food, and 3) the essential services provided by natural ecosystems [10]. Each of these reasons has significant implications for human health, as will become more clear in the following discussion.

## ETHICS

The ethical and esthetic arguments for species protection run deep, particularly for physicians. The process of human evolution involved (and involves) complex interactions with the other species on Earth; all of our instincts, all of our patterns of behavior, have been shaped within this environment. To separate ourselves from this complexity, and to ignore that we are an integral part of it, weakens us as a species in many ways. Physicians above all should recognize that we evolved *with* the apes (as well as the mosquitoes, bacteria, and fungi), and not from them; of course, this is implicit in our use of animal models in medical experiments. As caretakers of our own species, doctors should recognize the ties that bind us to those species that surround us.

Even if one were to take the stance that through our consciousness we are special and apart from nature, there remain ethical and esthetic reasons to preserve other species for our own well-being. It seems impossible to ignore the moral obligation to act as benevolent caretaker to the rest of creation that this discussion of consciousness implies—although most of Judeo-Christian history provides striking examples and justifications to the contrary. But there need be no religious conflict in this matter. It is doubtful that by giving us "dominion over all," God intended us to destroy the other elements of creation. One theologian writes that "to wipe out unnecessarily whole species of those creatures over whom we exercise stewardship is to betray that stewardship and to impoverish the experience of God. It is a crime against our Creator" [11].

Humans respond deeply to the esthetics of our environment and its diversity. Ehrlich and Wilson point out the popularity of ecotourism and other activities designed to seek out diversity on the planet. As a species, humans are curious; we search out the unusual and try to understand it. Since the fossil record shows that widespread "weedy" species have been the survivors of past extinctions, our future vacations and scientific forays may remain closer to home—we can find rats, cockroaches, and common weeds in any major city. We also depend upon our diverse environment psychologically, and the retreat to natural surroundings has long been advocated for ailments of both body and spirit. Through experiencing ecological diversity we escape everyday uniformity and feel that we are an integral and connected part of the natural world with a sense of place within our universe. In *A Sand County Almanac*, Aldo Leopold makes a plea to preserve wilderness because it provides "definition and meaning" to life, and for the benefit "of those who may one day wish to see, feel, or study the origins of their cultural inheritance" [12].

Conservationists, such as Aldo Leopold, Henry David Thoreau, or John Muir, often write about the value of wilderness and diversity for its own sake, completely apart from its value for humanity. Unfortunately, the rate of global deforestation does not afford us the time it will take to raise public consciousness to this level of awareness and action. According to James D. Nations, Research Director at the Center for Human Ecology:

> The day may come when ethical considerations about biological diversity become our most important reason for species conservation. But in the meantime, if we want to hold onto our planet's biological diversity, we have to speak the vernacular. And that vernacular is utility, economics, and the well-being of individual human beings [13].

## MEDICINE AND FOOD

In the past decade, there has been a resurgence of interest in exploring tropical rain forests for their medicinal value. As well publicized studies by Norman Farnsworth and others have shown, up to 25% of all prescription drugs contain a plant-derived active ingredient, and there are 18 drugs currently used in the United States that are obtained directly from forest plants [14]. Among the most important of these drugs are vincristine and vinblastine, which are antimitotic alkaloids derived from the rosy periwinkle plant. Vincristine is used as part of the MOPP chemotherapy regimen, and has helped increase the rate of remission in acute childhood leukemia from 20% to 90%. On the international level, quinine, from the bark of the cinchona tree, is another indispensable drug in our pharmacopoeia. It is the treatment of choice for the acute stage of *Plasmodium falciparum* malaria, and has remained effective despite widespread resistance to chloroquine and other synthetic derivatives. Plant-based antioxidants are among the many natural products being screened to fight HIV, and even the inhabitants of the forests are now being studied for their medicinal value; leeches, snakes, ticks, and vampire bats are currently being used to develop new anticoagulants [15].

Tropical and temperate forests have provided us with some of our most valuable pharmaceuticals in the past, and they remain a potential site for new discovery. Most drug development programs turned towards synthetics and molecular modeling beginning in the 1940s, and there is no doubt that biomolecular engineering remains the most valuable tool in current development programs. However, there are both imaginative and scientific limitations to this approach. Natural products, particularly tropical rain forest plants, remain an essential source of bioactive compounds. Following the lead of the National Cancer Institute, many major pharmaceutical companies have recently modernized their natural product screening programs. Merck has signed an agreement with the National Biodiversity Institute in Costa Rica to screen rain forest plants for medicinal value. Shaman Pharmaceuticals, a small company in California, is using the knowledge of people who live within rain forest regions to search for new drugs, and as a consequence has an antiviral agent in development. In fact, there are 107 companies in the United States now doing research on plant-based medicinals, and many more are involved world-wide. One reason for this renewed interest in natural product screening is the rapid destruction of the world's rain forests. Although 65% to 75% of higher plant species are indigenous to rain forests, Cornell biologist Thomas Eisner estimates that less than 2% have been explored for their medicinal potential [16,17]. The present rate of destruction, as well as the loss of local knowledge as indigenous cultures are destroyed, may prevent any meaningful exploration in the future.

Despite our ever-advancing technology, it is impossible to replace the scientific information locked within the DNA of the rain forest since it has evolved over millions of years of complex co-evolution in a highly competitive environment. Whether a product is used directly, a molecule provides a new idea to a biologist, or a new gene is spliced into a strain of *Escherichia coli* makes little difference. We run the risk of burning down this vast library just as we are finding the proper keys to use it. In what he calls "an urgent race against time," Michael Balick of the New York Botanical Garden states: "As tropical forests are destroyed and tribal peoples accultured, our ability to discover new pharmaceutical agents and bring them into everyday use is being seriously compromised" [18].

Crop diversity is also critical for the protection of the world's food supply, and deforestation threatens both the wild relatives of major crops and the supply of alternative foods in times of famine. Fifteen thousand years ago, humans used thousands of kinds of plants as nourishment. With the domestication of crops, this diversity in kinds of plants eaten decreased dramatically, but the diversity within each crop increased as a result of their exposure to new environments and the rise of traditional farming practices. Today, this diversity is threatened. As the result of high-yielding seeds and well-meaning distribution programs, food crop diversity has declined dramatically on the planet. Two decades ago, Garrison Wilkes said:

> Suddenly. . .we are discovering Mexican farmers planting hybrid corn seeds from a midwestern seed firm, Tibetan farmers planting barley from a Scandinavian plant breeding station, and Turkish farmers planting wheat from the Mexican wheat program. Each of these classic areas of crop-specific genetic diversity is rapidly becoming an area of seed uniformity [19].

The global consequences of diversity loss could dwarf the nineteenth century regional example of the Irish potato famine. Then, the reliance on only two strains of potatoes allowed the potato blight *Phytophora infestans* to decimate the potato crop for five years. One to two million people died of starvation and its related diseases, and as many more migrated to North America. Only the discovery of resistant wild strains in the Andes and Mexico has allowed the world's potato crop to thrive today [20]. As crop failure and disease occur, we must often look to the tropics—and often the tropical forests—to cross-breed the genetic information of wild and semi-domesticated relatives of commercial species. One species of wild rice from India already serves to protect the crops in Asia from the four major rice diseases, and in Africa and India the introduction of wild Brazilian cassava genes to provide disease resistance has increased the yield of this important food crop by 18-fold [21]. High in the Peruvian Andes tomato seed No. 832 was collected in 1962; when backcrossed 10 generations with a commercial variety, it proceeded to yield a larger tomato with an increased sugar content—a discovery worth about $8 million per year to the tomato industry as of 1986 [22].

In 1981 it was estimated that 80% of the world's food supply was based on fewer than two dozen species [13]. Revised estimates, based on national supply rather than production data, more accurately estimate that 103 species contribute about 90% of the national per capita supplies of food plants [23]. Although this revision should not undermine the important argument for preserving the genetic diversity of the world's major commercial crops, it does serve to introduce a new aspect of the discussion. The conservation of plant species diversity remains important for its direct nutritional value as well as the value of maintaining genetic variants. This nutritional diversity depends largely on tropical forests. In Nigeria, up to 150 species of woody plants are used locally for nutritional purposes, and over 1,500 wild plants from forests are used in the tropics as leafy vegetables [24]. In sub-Saharan Africa, wild plants from the forests are relied on nutritionally in three ways: 1) minor but sustained use for diversity and variety, 2) major use at specific times in the agricultural year such as the months preceding harvest, and 3) major use during times of drought, since forests survive low rainfall when domestic crops do not [25]. According to biologist Laurence Roche, "Scientists, planners, and politicians have not simply grasped the fact that the survival of a number of small-scale peasant farming systems over much of sub-Saharan Africa depend on the continued existence of natural forest vegetation, woodlands and trees" [24].

The move away from traditional agriculture and forestry practices in Africa has had profound effects, and the continent is fast losing the ability to feed itself. It is estimated that in some areas, the shift to mechanized, large scale monocultures has reduced the human carrying capacity of the land from 25 to 40 individuals per square kilometer to fewer than 10 to 20. These trends are at least partly responsible for the massive human migrations away from small villages and for the increasing spiral of debt and food importation [24]. Similar findings in the Brazilian Amazon document the value of traditional systems of food production and their dependence on forest diversity. For example, by preserving forested river margins, the Tukano Indians of the upper Rio Negro Basin maintain the aquatic diversity of their fisheries. Rather than deforesting these areas for agriculture, they derive significant animal protein through this practice; no experiments can demonstrate comparable agricultural potential on these blackwater soils [26].

## ECOLOGICAL SERVICES

The ecological services provided by diverse forest ecosystems are essential for human health. In the years to come, climate change, disruption of hydrological cycles, soil degradation, and water availability will mediate many of deforestation's health effects. Deforestation affects global climate by contributing to the greenhouse effect, and it has important local effects as well. Although the rising level of carbon dioxide in the atmosphere is primarily caused by the consumption of fossil fuels in industrialized countries like the United States, the burning of tropical forests contributes up to 25% of $CO_2$ emissions. Furthermore, a net loss of forest biomass reduces the effect of the "carbon dioxide sink" that is provided by tropical rain forests [27,28]. The average temperature rise of 0.6°C in the last one hundred years is well documented, and a further increase of 2°C to 5°C is predicted for the next 50 to 100 years as carbon dioxide levels double from their pre-industrial levels [29]. This predicted temperature increase would equal the difference in temperature between the last ice age and the present. The question is, therefore—what are the health implications of such a temperature change?

The direct health effects of global warming will range from an increased mortality among the elderly because of heat waves, to likely changes in the vectors of many tropical diseases such as malaria, dengue fever, arbovirus encephalitis, yellow fever, and Rift Valley fever [1,30]. The indirect effects, though, may be even more dramatic. The expected one meter rise in sea level because of thermal expansion and melting icecaps could reduce coastal land area by 3% and total crop land by one-third, creating up to 50 million environmental refugees in the process. Coastal cities will be jeopardized, and large portions of low-lying countries such as Bangladesh might disappear, leaving displaced populations nowhere to go in areas already stressed by crowding and overpopulation. As the salinity of water tables rises, more and more land will become unfit for agriculture [30].

Precipitation will increase as the world's climate heats up, but it will change in distribution and there will likely be an intensification of the extremes of the hydrologic cycle. According to a model designed by the National Aeronautics and Space Administration Goddard Institute, the greenhouse effect will lead to greater frequency and intensity of drought and more intense wet and stormy conditions on the planet. The model predicts no regional "winners;" droughts increase in virtually all low- and middle-latitude land areas, and increased rain occurs in the form of high-intensity storms [31].

If these models prove true, the effect of global warming on agriculture will be disastrous. Climate changes will prevent irrigation from providing the crop protection and yield enhancement we depend on today, and it is unlikely that lost crop area will be offset by the creation of new agricultural belts [32]. Physicist John Holdren predicts that a carbon dioxide-induced climatic change could lead to the death of up to a billion people by famine before 2020 [33]. While this value may seem extreme, the severity of recent famines in Ethiopia and Somalia, combined with trends of decreasing per capita food production worldwide (per capita food production dropped 13% between 1984 and 1988 alone), must cause us to take any further climate-induced stresses upon the world's food supply very seriously [34].

Regional climate changes induced by deforestation will also be substantial. Retreating forest cover has been implicated in rainfall decline in India, Peninsular Malaysia, the Ivory Coast, the Philippines, and in the Panama Canal area. In the Amazon, which recycles between 50% and 80% of its water, deforestation threatens to reduce rainfall across the entire Amazon basin and even into the agricultural lands of southern Brazil. In addition, the albedo effect from removal of vegetation could lead to a new self-perpetuating steady state of cooler soil, lower rainfall, and sparser vegetation [35]. A model by the Center for Ocean-Land-Atmosphere Interactions predicts a longer dry season for deforested Amazonia, thus suggesting that complete and rapid destruction of these tropical rain forests could be irreversible [36].

These changes in the hydrological cycle have global health effects. Severe flooding results from the increased runoff and decreased recycling of rainfall following massive deforestation. In India, the area subject to flooding has more than tripled since 1960, and water tables are going down even where rainfall has been ample. Throughout much of the country, however, droughts have also intensified during this time [37]. In 1988, Bangladesh suffered its worst flood on record when two-thirds of the country was underwater for several days. Up to 25 million people were left homeless, and disease lingered in the flood's wake. Many scientists point to the half deforested middle mountain ranges in Nepal and India as the cause, and also note that the "50 year floods" now seem to come every few years [38]. However, Jack Ives, who coordinates the United Nations Mountain Ecology and Sustainable Development Project, disputes this link between flooding and deforestation in the Himalayas. He states that the evidence is inconclusive, and warns of the danger of blaming the subsistence farmers of the Himalayas for the woes of those on the flood plains below [39].

Deforestation and its associated biodiversity loss also contributes to soil erosion and land degradation throughout the world. Along with overgrazing, overcultivation, and salinization, deforestation reduces the water-absorbing capacity of the soil and accelerates runoff. In western Africa, Eneas Salati demonstrated that runoff rates recorded from some cultivated and bare soils were 20-fold higher than those from forests [40,41]. Erosion then leads to further decrease in water retention and a decrease in nutrients, land productivity, and the ability for roots to take hold. Rivers, lakes, and reservoirs silt up, leading to decreased storage area and increased flooding [28]. The U.S. Department of Soil and Water Conservation estimates that between 30 and 75 tons of soil are washed away annually from each hectare of deforested land in Nepal [24]. Similarly, in Ethiopia's regions of endemic famine, massive soil erosion has resulted from deforestation of whole mountain catchment areas. Complex nutrient cycles are affected as well, and World Bank ecologist Kenneth Newcombe notes that when land is without trees, mineral nutrients are not recycled from deep soil layers and soil fertility declines [42]. The end result of this erosion and degradation is famine. Lester Brown writes that in Africa, which has the world's fastest population growth rate, "a combination of deforestation, overgrazing, soil erosion, and desertification contributed to a lowering of per capita grain production by some 17% from the historical peak in the late 1960s" [42].

Lastly, the issue of water availability is crucial to human health, and it is affected by each of the previously mentioned changes in climate, hydrological cycles, and soil degradation. The WHO report, *Our Planet, Our Health*, states that nearly 50% of the world's population suffers from diseases associated with insufficient or contaminated water, and that four million children die of waterborne and foodborne diarrheal diseases each year. Typhoid, cholera, amebic infections, bacillary dysentery, and other diarrheal diseases cause morbidity representing as much as 80% of all sicknesses [1]. The World Commission on Environment and Development states, "In the developing world, the number of water taps nearby is a better indication of the health of a community than the number of hospital beds" [7]. Norman Myers, in his book *Primary Source*, notes that tropical forests make a substantial contribution to public health by assuring dependable supplies of good-quality drinking water. In many deforested regions, the quality of drinking water has dropped as sources shift from fresh forest streams toward contaminated rivers or ponds [28]. Decline in the quantity and quality of water supplies because of deforestation has set back public health programs in major cities such as Bangkok and Manila. In Malaysia, the price of water from a catchment with undisturbed forest increases twofold after the forest is subject to controlled logging, and fourfold when uncontrolled logging is allowed [43].

Ehrlich and Wilson point out that there is no way to replace the various ecological services provided by natural ecosystems. Virtually all attempts at large-scale inorganic substitution have failed: synthetic pesticides, inorganic fertilizer, chlorination of water for purification, dams for flood and drought protection, and even air-conditioning cannot measure up against natural counterparts provided by forest cover and ecosystem diversity. In addition to short-term problems, these measures generally require large energy subsidies, and thus add to our long-term environmental impact as well [10].

Perhaps the best summary of the ecological impact of deforestation comes from a French forester in

Africa more than 50 years ago. In *The Disappearance of the Tropical Forests of Africa*, A. M. A. Aubreville writes prophetically:

> We are witnessing the death struggle of a plant world, slow stages in the drying up and degeneration of tropical Africa. . . it is probable that the wholesale destruction of inland forests will accelerate deterioration of vegetation and soil in Africa and bring acute desert conditions. . . The insidious thing about it is that, generally speaking, nobody seems to realize it. In much the same way that the friends of a sick man, who has been an invalid for years, get used to seeing him in an ailing condition that they forget he was once in perfect health. They cease to perceive the slow encroachment of the disease until one day the sick man dies [44].

## DIRECT HEALTH EFFECTS

The health effects directly associated with deforestation have received little attention from either environmentalists or the medical community. This is understandable, given the difficult task of raising public awareness about even the most global issues such as climate change or species loss. However, diseases caused by tropical deforestation can undermine development schemes, and, when combined with associated health problems from urbanization and poverty, have a significant impact upon the world's health. Malaria is currently the most important disease associated with deforestation, particularly in the Amazon.

Malaria spreads at the forest fringes, and deforestation has increased transmission in tropical areas ranging from Southeast Asia to the Amazon. *Anopheles dirus*, one vector of the most deadly type of malaria, *Plasmodium falciparum*, has been shown to breed in pools around partly cleared forests [1]. New roads into the Amazon have likewise created ideal habitats along their flooded embankments for the *Anopheles darlingi* mosquito, which is the most important malaria vector in the region. Soil erosion from farming and mining also creates breeding sites around the forest [45]. One study of hospital records from three rural areas of the Amazon basin reveals that the number of cases of malaria increased fivefold from 1983 to 1987; that the predominant parasite changed from *Plasmodium vivax* to *Plasmodium falciparum*; and that increased malaria followed increased immigration and colonization of the forest. This same epidemiological data showed malaria rates of 1% to 2% in the most stable community, 8% to 9% in a growing community, and 14% to 26% in the new forest settlements [46].

Regional data support these local observations. In 1983 there were 287,000 cases of malaria in the Brazilian Amazon, and this figure rose to 500,000 by 1988. Aside from the massive migration of settlers into the region and the creation of new breeding sites for mosquitoes, there are new problems facing public health officials battling this epidemic. Spraying dwellings is no longer an effective control measure, since for unknown reasons the Amazonian variety of *Anopheles darlingi* prefers the outdoors between feedings. New World Bank loans include money for indoor spraying with DDT and other insecticides to control the problem, but evaluating the impact of this strategy will prove difficult since little is known about the habits of forest mosquitoes [45].

In his book *Rainforest Corridors*, Nigel J. H. Smith demonstrates that in addition to the current malaria problem, deforestation and settlement of the Amazon pose a number of potential public health risks [47]. Onchocerciasis was first documented in Brazil in the 1970s, and if it were to take root in the Amazon it could become a major health concern; in parts of Africa, it has forced people to abandon villages and cultivated land. The vector for Bancroft's filariasis thrives along the Transamazon Highway, and the disease threatens to become more significant as population in the region increases. Schistosomiasis has occurred in isolated areas of the Amazon, but could easily spread as humans alter ecosystems (as happened in Africa following hydroelectric and irrigation projects) and as both infected individuals and appropriate vectors are introduced along the Transamazon. New settlement and new highways will likely increase the transmission of Chagas' disease; vectors already exist, and the spraying programs designed to control malaria may aid their further spread by wiping out natural predators in the rain forest. Finally, the conditions along the Transamazon are appropriate for an epidemic of yellow fever, and this disease could present yet another public health problem as settlement increases.

The existing malaria epidemic in the Amazon raises the issue of how little attention has been paid to the impact of development on public health. The World Bank acknowledges that nobody understood the intricate factors contributing to the malaria epidemic in the Amazon until it was already well-established. However, they maintain that the control of adverse health effects from development projects is up to the particular country concerned [45]. Environmentalists disagree and hold the World Bank directly responsible for disasters such as the malaria epidemic. One senior attorney with the Environmental Defense Fund says of the latest $99 million World Bank loan to control the epidemic, "For a country like Brazil, that's a very expensive way of standing still" [45]

Along with the spread of disease vectors, there are other ways in which deforestation has direct impact upon human health. Lack of firewood creates significant public health problems, particularly in the rural Himalayas and the African Sahel. In the Himalayan foothills, forests have been pushed so far back that women now spend an additional 1.4 hours per day to collect firewood than they did just 10 years ago. This is time spent away from the farm, and there has indeed been a concurrent decline in agricultural production by 24% and a decrease in per capita food consumption by an average of 100 calories per day in these areas [43]. Boiling water has become a luxury in many parts of the world, and quick-cooking cereals have replaced more nutritious, slower-cooking foods such as beans. As dried dung is used as fuel for cooking rather than fertilizer for the fields, soil fertility suffers; this diversion has been blamed for a 15% decrease in Nepal's crop yield [41].

Another example of deforestation's direct health effects is the increasing number of landslides in deforested hills surrounding many large cities. More than 500 died in one slide in Colombia in 1987, and in 1989 landslides left over 18,000 homeless on the outskirts of Rio de Janeiro and 70,000 homeless in Thailand [38]. Illegal logging was blamed for the flash floods and mudslides that killed 6,000 people following typhoon Thelma in the Philippines in 1991 [48]. In all of the above cases, deforestation combined with both natural forces and urbanization with devastating results.

## URBANIZATION AND POVERTY

One hundred years ago the Earth's urban population was 200 million, by 1990 it had reached two billion. The growth of urban areas by migration from the countryside, particularly in poor and developing countries, is in part related to deforestation. Land degradation—which we have seen is tightly linked to deforestation—has been the major factor in this movement of subsistence farmers into the shantytowns of major cities. This is especially true in the African Sahel, where thousands of villages have been abandoned in recent years. According to Lester Brown, "The drying out and desertification of the Sahelian region probably account for the largest source of environmental refugees in the world today" [42] The situation is similar in southern Africa, where deforestation accompanied by soil erosion and the depletion of water supplies have forced tens of thousands from their farms and into towns, cities, or relief camps [38].

As yet, there has been little study of the many known and potential health problems associated with such migrations. Transmission of disease may occur either from those who are migrating (active transmitters), or to those who are migrating (passive aquirers). Overall, the trend in Africa has been an increase in "urban" diseases such as TB, water-borne enteric illnesses, and other diseases associated with malnutrition—although cause or effect in urbanization's relationship to disease often remains unclear [49]. As urban growth without improved urban services has occurred, water shortages and problems of waste and sewage disposal have resulted. Paul Epstein points out the link between recent cholera outbreaks in South America and recent urbanization (Lima's shantytowns, for example) [50]. The World Health Organization warns of future health problems as new roads, reservoirs, drains, land clearance, and deforestation lead to changes in local ecology. They believe that natural foci for disease vectors may be incorporated into the urban sprawl, creating new ecological niches for zoonotic animal reservoirs. Even without appropriate vectors, human migration from rural areas to the Federal District of Brazil has made Chagas' disease one of the leading causes of death in that region [1]. Lastly, a word about AIDS—not its future, but its past. Evolutionary biologist Jared Diamond has presented three theories to explain why AIDS emerged in Africa only recently; one of these speculates that conditions for efficient spread between populations have occurred only in modern times, with the rise of cities, prostitution, venereal diseases, use and reuse of hypodermic syringes for medical care, and movements of people over long distances [51].

## TOWARD A SUSTAINABLE FUTURE

Deforestation illustrates the connection between environmental problems and human health. The effects of global forest losses are far-reaching; biodiversity loss threatens our ethical and esthetic senses, our supply of medicine and food, and the ecological interactions we depend on to regulate our environment. Deforestation also has direct health effects, by, for example, altering disease vectors and increasing the vulnerability of marginal populations to disasters such as landslides and floods. Deforestation also helps drive the downward spiral of migration, urbanization, and poverty.

Environmental stresses are closely linked with each other, with patterns of economic development, and with social and political factors; all of these issues affect human health. Looming in the background is overpopulation. By the year 2020 the United Nations predicts a world population of eight billion [1], and any environmental or health program must account for this exponential growth. The downward spiral of poverty and environmental destruction is fueled by population pressures, and to break this cycle these pressures must be controlled. The World Health Organization advocates the same steps to reduce both infant mortality and to decrease fertility—improved maternal health and education; improved water supply, sanitation and nutrition; and family planning integrated with health care programs [1]. Others feel this argument is flawed and advocate more stringent measures following the Chinese model of strict birth control [52]. In either case, population control must play a central role in any sustainable public health policy.

"Sustainability," as applied to the discussion of rain forests, implies attractive alternatives to the problem of short-term destruction for lumber and agriculture: forest products can be renewably extracted such that the forest is worth more standing than cut, and local economies are bolstered in the process. Biodiversity can also be preserved and studied, with the economic gains from discoveries partially returned to local economies. However, when the word "sustainability" is applied to public health, it is more troublesome: Should all practical public health interventions, designed to sustain human life, be pursued regardless of their long-term demographic consequences? Is there a danger of increasing population and environmental pressures through these interventions, and if so can we justify inaction under some circumstances? These are complicated questions, and at their heart lie conflicting ethical premises and policy missions. Ecological approaches imply giving priority to populations, not individuals. As hard choices are forced upon us in the future, we must search for an inclusive definition of sustainability through the integration of economic, environmental, population, and public health policies.

We are now standing at a crossroad. We know enough about the earth's environmental problems to be concerned for our future, but we debate how much action is justified and remain unsure how to prioritize these actions. In *The Youngest Science*, Lewis Thomas examines our limitations:

> We do not know enough about ourselves. We are ignorant about how we work, about how we fit in, and most of all about the enormous, imponderable system of life in which we are imbedded as working parts. We do not really understand nature, at all. We have come a long way, indeed, but just enough to become conscious of our own ignorance. ... It is a new experience for all of us [53].

Admitting ignorance yet struggling against it is a difficult task, but important. We must learn to become comfortable as working parts in nature's imponderable system, even as we endeavor to manage it wisely. ❧

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