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Forests and Human Health

Assessing the Evidence

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Donors

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Executive Summary

This study has two central concerns: the state of human health in forests, and the causal links between forests and human health. Within this framework, we consider four issues related to tropical forests and human health. First, we discuss forest foods, emphasizing the forest as a food-producing habitat, human dependence on forest foods, the nutritional contributions of such foods, and nutrition-related problems that affect forest peoples. Our second topic is disease and other health problems. In addition to the major problems—HIV/AIDS, malaria, Ebola and mercury poisoning—we address some 20 other tropical diseases and health problems related to forests. The third topic is medicinal products. We review the biophysical properties of medicinal species and consider related indigenous knowledge, human uses of medicinal forest products, the serious threats to forest sustainability, and the roles of traditional healers, with a discussion of the benefits of forest medicines and conflicts over their distribution. Our fourth and final topic is the cultural interpretations of human health found among forest peoples, including holistic world views that impinge on health and indigenous knowledge. The Occasional Paper concludes with some observations about the current state of our knowledge, its utility and shortcomings, and our suggestions for future research.

Chapter 1

Introduction

1.1 Why This Review?

People living in and around forests suffer from many illnesses, both acute and chronic, and outside pressure on their social and cultural systems often adversely affects their mental and spiritual health. The role of forests in sustaining or worsening human health has been the subject of debate. Elements of these debates span numerous topics and disciplines—anthropology and human ecology, economics, epidemiology, ethnobotany, forest ecology, pharmacology, politics, economics. Such a breadth of issues makes it hard for scientists, let alone policymakers, to be clear about what to do.

Between 1994 and 1998, about 20 international and interdisciplinary teams of experts concluded that human health was important for the sustainability of forests managed for timber, in large scale plantations, and by communities. These teams generally agreed that human health was linked to how forests were managed (see e.g., CIFOR 1999), though the exact mechanisms remained unclear.

In the interim we have discovered a large body of anecdotal and case material from anthropology, ethnobotany, community development, and other field-based disciplines showing how human health and forests are related. Some studies emphasize people's reliance on forest foods and medicines; others point out the significance of cultural coherence and control over the pace of change for people's mental health and maintenance of global cultural diversity. Still others emphasize the health risks that emerge as the forest environment is degraded, the lack of access to formal health services, and the marginalized position of forest dwellers. Forests can present dangers for both forest dwellers and those outside forests.

We wanted a better handle on the causal relationships between health and forests. We anticipated two major issues. First was the health of people living in and around forests—important both for maintaining or improving those people's health in general, and for defining the causal connection from people's health to forest sustainability. Second was the direct causal link between forests and human health: How do forests affect people's health? We knew, from long-term experience, that people living in remote areas are often marginalized, their health needs ignored and underreported. We were convinced that missing information and related misunderstanding often contributed passively to inaction with regard to such people's health.

The first issue—*health conditions in and around forests*—is important because one of our goals is to clarify and publicize these people's health status, as a first step toward seeking more effective health solutions. Some of the literature we examine, therefore, looks at the health of people living near forests or in recently converted forest areas. We have tried to look at health and forests in a holistic manner and identify the policy implications of the poor health of forest peoples.

The second issue has to do with the precise *links between forests and human health*. In addressing this question, we have also tried to take a critical approach. Conservation-minded observers believe that forests matter to people's health (and many also believe that local people's health matters for forest maintenance). But the specific links and issues are not clear. There is perhaps a tendency—driven by concern over forest loss—to romanticize and perhaps exaggerate the benign nature of tropical forests. The challenge for researchers striving for objectivity,¹ and for policymakers concerned with credibility, is to

examine the evidence and question any weakly grounded assumptions. We think a skeptical approach not only is good science, but also should ultimately benefit forests by boosting the credibility of the causes we highlight.

The purported roles of the forest as shelter from disease, producer of vital medicinals and source of abundant food can be juxtaposed against the anxiety of field researchers to make sure their inoculations are up to date, compile a well-stocked medical kit and stock adequate stores of food before setting out for forest-based fieldwork. As we examine the policy implications of the links we find between forests and human health, we assess the positive and negative implications of forest-human interaction. Just how much benefit do forests actually provide? How much harm to humans comes from them?

We begin by clarifying what we mean by *health*. We have accepted the World Health Organization (WHO) definition: “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” We understand those who reject the biomedical definition of disease as too narrow and/or ethnocentric,

wanting to address the various forms of affliction from witchcraft and spirit possession to infestation by various nonhuman agents (discussed in Nguyen and Peschard 2003). We see some people’s cultural systems as intimately connected with the forest, their health dependent on its maintenance. We also find Nguyen and Peschard’s view that social hierarchy adversely affects health pertinent for tropical forest dwellers, who are among the world’s poorest peoples.

This review pays particular attention to the cultures of forest peoples because of the centrality of the maintenance of a culture to its adherents’ health, and because in the case of forest dwellers, the forest itself is part of the cultural system. The link is very direct. Highlighting cultural diversity recognizes its importance for addressing the health of forest peoples more effectively, as well as providing a clear connection between forests and human health—our two central concerns.

We define the *people* of our study as the 250 million to 350 million people living near forests. These include indigenous agricultural communities, in-migrants (such as transmigrants or settlers) and forest workers—all of whom have quite different relationships with the surrounding or adjacent forests. We have not dealt explicitly with plantation or ecotourism workers. On a broader scale, we consider buyers of forest products and those infected by diseases emanating from the forest or affected by potentially forest-related global processes like climate change. To some extent, we are concerned about the implications of forests for the health of humanity at large. However, as we move out from the forest, our attention dilutes. And although health status can be greatly influenced by economic status, we scarcely touch the vast literature on the economic status of forest dwellers.

Throughout this review, we also highlight the health situation of women living in and near forests. This is partially motivated by the several Millennium Development Goals that emphasize the importance of improving gender equity.² Our own field observations support the need for special attention to the health of women (as well as other marginalized groups).

We have avoided an explicit definition of *forest* because of the slipperiness of the concept. In anthropological jargon, ‘forests’ are part of numerous discourses, with varying conceptual implications and baggage. Even



3 healthy young boys, living in the forests of Bengkulu, Indonesia
(Photo by Carol J. P. Colfer)

foresters have difficulty providing globally relevant definitions, and dictionary definitions can even include “previously forested areas.”

We began our review focusing on tropical rainforests, partly because of biodiversity and cultural diversity considerations, but also because people in such areas are typically far from conventional health services and may be more reliant on their own local health systems. However, the review also considers sparsely forested areas (e.g., the miombo woodlands in southeastern Africa or the drier areas of India), the sub-Saharan dry forest areas, forests in transition, and recently forested areas (such as sites of dams in Ghana). Many of these dry forest regions have comparatively high population densities (and thus a large number of people affected), and the relationships between forest cover change and human health are significant. We do not explicitly address plantation or agroforestry situations, though such land uses are commonly interspersed in forested areas, and therefore do receive some marginal attention.

We hoped to find systematic, thorough studies casting light on the specific links between human and forest health.³ We wanted to know, for instance, whether the loss of forest foods and medicinal plants through forest degradation inevitably compromised human health. In the subsequent sections, we review the abundant case material and draw out what conclusions we can.

This review begins with a brief description of our methods and a summary of our conclusions (also presented separately, at the end of each chapter). We then look at peoples’ role as storehouses of knowledge about foods, medicines and forests. We examine the literature on the nutritional (Section 2) and medicinal (Section 4) roles of wild⁴ forest products.⁵ And we provide an introduction to the literature on diseases and other health problems common in forested areas (Section 3). In Section 5, we further discuss the role of forest-based cultures in maintaining the mental and physical health of forest-dwelling peoples and global cultural diversity; this is the direct link between forests and human mental (and sometimes general) health, and these are the people who are most underserved by formal health care systems. Our final section extracts some implications of our findings and specifies three important areas for further research on human health and forests.

Few studies have taken a sufficiently systematic, comparative, interdisciplinary and/or longitudinal approach to offer clear answers to our questions about the direct links between forests and human health. Information about people’s health in forested areas is more available, and we were able to get a reasonably good idea of their health problems. We consider this review to be part of a process of ‘progressive approximation,’ from which we hope to go forward by finding additional literature and conducting research of our own.

1.2 Our Methods

We used a variety of methods to find pertinent literature on forests and human health. Initially, our focus was on nutrition and medicinal plants, but as the review progressed, we included cultural factors and forest-related disease and health problems. We began with our own knowledge (medicine, public health, ecology and anthropology), then searched Medline and TreeCD for journal articles on the subjects, using keywords. Google.com was a valuable aid in finding articles and studies not published in peer-reviewed journals. Kishi also contacted people in various organizations, including universities, nongovernmental organizations (NGOs), international organizations, and governmental agencies, in search of research and literature on nutritional and medicinal roles of forests. Colfer mined the online health-related journals at Cornell University in 2003 (finding 175 articles published between 1994 and 2003). Experts were contacted and relevant information was also searched via email listerves. Twenty-two people responded to our queries and provided 201 publications and numerous web addresses on nutrition and medicinal plants, and we eventually developed a library of more than 12 file boxes of hard copy references. We also expanded our purview by organizing a workshop with two invited experts at CIFOR, by drawing on our colleagues’ knowledge⁶ and by eliciting critical and constructive comments from reviewers and at a panel discussion on health and forests organized by Edmond Dounias at the International Union for Forestry Research Organizations in Brisbane, Australia, in August 2005. Despite the availability of information over the Internet, some problems with access to the literature (particularly social science literature) derive from our location in Bogor,

Indonesia, at a forestry institution. Since many studies that provide information on human health and forests were not conducted with that link in mind, we have included some cases, based on our own knowledge of particular areas (leading to a somewhat disproportionate amount of material on Borneo, where all three of us have worked). For a few studies, we made educated guesses about whether they were truly in forested areas.

Information on relevant topics is spread over a vast literature in a wide range of disciplines.⁷ We found very few general syntheses. For many topics only single case studies have been identified, offering useful examples but not enough comparative analysis to allow broader conclusions regarding human health and forests. Important studies have almost certainly been missed. We welcome critique and input from readers.

Representing three quite different disciplines, we were confronted from time to time with the different assumptions, orientations, goals and operating procedures of our respective fields. We have tried to address and incorporate these differences in this study, which is intended for an interdisciplinary audience. But this experience, including the peer-review process, has reminded us that durable barriers—in assumptions, academic traditions, language and goals—can divide disciplines. We remain convinced that the effort to overcome these barriers is worthwhile.

1.3 Our Policy Recommendations

We present these up front to highlight their importance. For each of our four topics, we present the policy recommendations pertaining to the state of forest peoples' health and the causal links between forests and human health. These recommendations are repeated at the end of each relevant chapter, to facilitate comparison between the findings and the policy recommendations (given the inevitable role of value judgments in the development of policy recommendations).

1.3.1 Forest Foods and Nutrition

A. Human Health Conditions

Recommendations for health professionals

- Recognize that foods from forests may be deficient in particular nutrients, with

potentially negative implications for people's nutritional status.

- Evaluate local forest foods' nutrient content and adjust advice on nutrition accordingly.
- Learn more about the health needs of forest dwellers, from the local people themselves.

Recommendations for educational and health personnel

- Counter cultural prescriptions that disadvantage females, particularly during vulnerable periods like pregnancy and lactation and during childhood.
- Educate field personnel about the links between women's status and the health of families.
- Offer free or inexpensive family planning services, and seek win-win mechanisms that discourage in-migration and encourage out-migration to reduce pressure on food resources and improve family health.

Recommendations for forestry and health professionals

- Increase efforts to communicate with women and value women's views, thus contributing to a rise in women's social status, as a strategy to improve overall health.
- Collaborate effectively among disciplines and develop early warning systems about food availability and people's nutritional status.
- Share databases in efforts to avert local health crises due to seasonality and 'development'.

Recommendations for development planners and foresters

- Ensure that local people's subsistence needs continue to be met when commercialization efforts are underway.
- Consider biodiversity values for forest inhabitants and costs to their livelihoods when proposing alternative uses of forests.
- Support households seeking to switch from fuelwood to more efficient, less polluting fuels and use various media to inform people of the pros and cons of each.
- Encourage silviculture of cleaner fuelwood species near people's homes.

B. Policy Implications for Causal Links between Forests and Health

Recommendations for natural resource specialists

- Analyze soils as they relate to health problems, such as deficiencies in iodine, calcium, iron and vitamin B-12.
- Monitor wildlife likely to be disease vectors.
- Encourage a shift from fuelwood to alternatives to enhance forest sustainability and reduce respiratory diseases, especially in dry forest areas.

1.3.2 Diseases and Other Health Problems

A. Policy Implications for Human Health Conditions

Recommendations for health professionals

- Establish facilities along transportation routes to provide education on AIDS and the potential dangers of wildlife-human interactions.
- Conduct site-by-site investigations to understand the unique factors contributing to malaria incidence.
- Work with government agencies planning large-scale movements of people into malarial areas to address the greater vulnerability of such non-immune populations.
- Encourage people to seek alternatives to consumption of piscivorous fishes from rivers contaminated by mercury.
- Expand health care delivery in forested areas.

Recommendations for government agencies

- Ensure the availability of active epidemiological monitoring and trained field teams for use in forested areas.
- Expand efforts to strengthen the status of marginalized groups, including women and girls.

Recommendations for health and natural resource specialists

- Work together closely to ensure continuing (or new) access to forest foods and medicines for families affected by HIV/AIDS.

- Pressure extractive industries to use best management practices and control the use of mercury in gold processing.
- Monitor soils for mercury levels.

B. Policy Implications for Causal Links between Forests and Health

Recommendation for land-use planners

- Mitigate the adverse health impacts of major land-use changes and provide ameliorative services where needed.

Recommendations for forest managers

- Incorporate into management plans the increased dependence of families afflicted with HIV/AIDS on local forest products, perhaps through collaborative management of woodlands.
- Acknowledge that forestry activities help spread HIV/AIDS (via road networks and separation of families) and contribute to solving the resulting problems.
- Use best management practices for logging and avoid leaving standing water; when pools and ponds are unavoidable, ensure that mosquito larvae do not proliferate and spread malaria.

Recommendation for government agencies

- Encourage techniques for extracting gold that do not pollute local rivers with mercury.

1.3.3. Medicinal Products

A. Policy Implications for Human Health Conditions

Recommendation for pharmaceutical industry managers

- Explore equitable distribution of the profits and benefits from forest-related knowledge.

Recommendation for natural resource managers

- Acknowledge the importance of medicinal plants and include their protection in management plans.

Recommendation for health care professionals

- Exert greater efforts to marry traditional and 'modern' health care systems in and

around forested areas by working with traditional healers, assessing traditional medications, and understanding traditional health-related worldviews.

B. Policy Implications for Causal Links between Forests and Health

Recommendation for health personnel

- Assess the healing qualities of forest-based medicinal plants and incorporate effective ones in the repertoire of medicines.

Recommendation for government agencies

- Make greater efforts to maintain forest ecosystems, keeping in mind the current and potential value of medicinal plants and animals.

1.3.4 Human Culture

A. Policy Implications for Human Health Conditions

Recommendations for health care providers, foresters and other policymakers

- Acknowledge the mental health implications of external attack—whether cultural or environmental—on local forest systems.
- Develop institutional mechanisms that encourage beneficial ‘marriages’ between local and formal knowledge systems.

- Using formal studies or participatory approaches, build feedback mechanisms into policy formulation and service delivery to account for different cultures.
- Assess the wider utility of local, indigenous medical and public health knowledge, and use it where appropriate.

B. Policy Implications for Causal Links between Forests and Health

Recommendations for health professionals

- Examine the effectiveness of indigenous health systems (including mental and spiritual health), compared with existing and planned alternative services.
- Use relevant indigenous knowledge to improve health care.

Recommendations for natural resource managers

- Study indigenous forest management mechanisms that have allowed tropical forests to be used sustainably.
- Use relevant indigenous knowledge to improve forest management.
- Protect forest products, services, and other uses that contribute to human health.

Recommendation for government agencies

- Protect forest-based cultures as part of a global effort to maintain cultural diversity.

Chapter 2

People, Forests and Food

The significance of forests for food security is a controversial topic. Pimentel et al. (1997), for instance, estimate that some 300 million people (a figure that seems low to us) obtain part or all of their livelihood and food from forests, that nontimber forest products worth about US \$90 billion are harvested each year, and that forests play critical roles in maintaining the productivity of agricultural and environmental systems. Although we find such global generalizations suspect almost by definition, these figures do give some idea of relevant magnitudes. Most of the studies we review here examine microlevel contexts.

A good diet requires food availability, reasonable access, diversity, hygiene and appropriate processing. Inadequate nutrition makes a person more susceptible to disease and reduces energy levels, potentially affecting activity and productivity. Particularly in the very young, inadequate food intake and dietary diversity can lead to an increase in the burden of disease and early death.

Any discussion of nutritional significance of forest products has to confront a variety of complexities. Nutritional contributions are dependent not only on the individual food item, but on the overall composition and adequacy of the diet, the presence of specific dietary shortfalls and the interchangeability of products. In addition, few if any human societies are wholly dependent on wild forest products: virtually all trade or cultivate to some degree. Forest products may be key only in specific times of hardship such as crop failures. Few studies deal adequately with all these aspects.

We look first at the forest as a food-producing habitat (Section 2.1), including the roles of soils and forests as genetic reservoirs. Section 2.2 focuses on landscape change, including processes (like deforestation or

climate change) that affect the quality of forest habitats for human use. In Section 2.3 we discuss questions of food availability and human dependence on forest foods. Section 2.4 considers serious food and nutrient problems that beset forest-dwelling populations. At the end of the chapter, following a wrapup in Section 2.5, we summarize the conclusions from each subsection and the policy implications for the state of people's health and the forest-human health linkages.

We focus on well-being, emphasizing issues of sufficiency and adequacy rather than the overconsumption patterns that have come to dominate some nutrition discussions in richer countries and in some subpopulations in developing countries. Besides the physical availability and use of potential foods, we are also interested in who has access to food and the related social and institutional factors. Food and food production have practical and symbolic, social and political implications in all cultures, adding greatly to the complexity of the subject, but access to income—which can substitute for direct access to forest foods—is beyond the scope of this review.

Forest-based peoples have developed sophisticated knowledge of forest products and how they can be collected, processed and eaten. Their use of the resource has had profound impacts. The intensification of food production has led, in some places, to enriching the forest (e.g., Leach and Mearns 1996; Fairhead and Leach 1996). In others, people have learned to harvest and manage forest resources extensively, while still other forests have been lost to more intensified forms of land use. These transformations have been a response to both competition for resources and the opportunities and innovations (indigenous, endogenous and external) that have arisen.

2.1 Forests as Food-Producing Habitats

A critical determinant of a forest's capacity to produce foods is the quality of soils, which can affect human health through deficiencies or pollutants (Abrahams 2002). Areas with the very best soils (usually volcanic regions or seasonal floodplain systems) have often been more thoroughly cleared for agriculture (e.g., Java, Nigeria, western Kenya). Where the soils are poor, intensive agriculture is not viable. Most peoples living in forests on poor soils practice a land-extensive and forest-dependent swidden system (e.g., Borneo, Cameroon, Peru). In such systems the regrowth vegetation provides important environmental subsidies that contribute to production of valued goods (foods, fibers, timber and medicines).

In some regions—such as part of central Zaire, inland Kalimantan and the white sand forests of Guyana—the soils are so unsuited to agriculture that little opportunity exists for sustained cropping. Human inhabitants depend largely on the forests and rivers for their foods.

Amongst the largest remaining tracts of rainforests, good soils are rare and much of the land is poor in nutrients needed for agriculture. The reason that these areas remain remote and support small populations is clearly related to this low inherent potential. In black-water forests, for instance, there are few nutrients for any living thing, plant or animal, human or nonhuman. Indeed, in the poorest soils, even animals and fruits are scarce (Janzen 1974). Ecologists have shown how plants invest more in physical and chemical defense as soil nutrients decline. The result is that in these regions most rainforest plant species offer little direct food—unless one can penetrate and disarm the defenses. In these areas, animals are scarce and must supplement minerals through whatever inorganic sources may be available, such as licks, which become focal points for hunters and animals alike.

In those few areas where good soils and forests coincide, a culture of relative plenty is often found, with subsidies from the sea or unusually productive food plants such as sago or bread-fruit (Smith et al. 1992). Another feature of many tropical food species—fruits and seeds, migratory and other animals—is seasonality, leading to periods of plenty and also to periods of scarcity (see e.g., Dove 1993; Caldecott 1988; Aunger 1994; discussed further in Section 2.4). Nonetheless, in some

regions some important resource species—sago in Melanesia, being a good example—are available 12 months a year.

Forests themselves provide ecological services that benefit human beings, sometimes indirectly. Forests house the pollinators required for crops and fruit gardens (e.g., bats required for pollination of durian (*Durio zibethinus*), a major trade item in Southeast Asia; Salafsky 1995). Forests can provide an important nursery role to some animals that range more widely. The clearest example is mangrove forests, which maintain crucial fisheries in many areas inhabited by poor people. These mangrove areas are seriously threatened, with worrying implications for human health (e.g., Barbier and Strand 1998).⁸ Hunting grounds are also not usually strictly delimited; local people can benefit from animals arriving from much larger tracts of productive source habitat (Bodmer et al. 1994). The ranges of some migratory animals are considerable (e.g., Caldecott 1988).

Redford (1995, 1996) focuses on the animals themselves but points out a whole host of ways in which animals interact with their forest ecosystem and with humans, to mutual benefit. From the standpoint of forests, he focuses on the roles of animals in seed dispersal, seed predation, herbivory, pollination and predation—all playing a role in maintaining (or altering) the forest as a genetic reservoir.

Wild genes can and do play a major role in the 'improvement' of many cultivated species, and wild species are sometimes domesticated. This genetic reservoir value links to crops used by both forest and urban dwellers. Genetic conservation is consequently a concern for the Consultative Group on International Agricultural Research, which has invested heavily in *ex situ* conservation (seed banks and the like). As part of the effort to address food security, the economic role of these genetic resources is also addressed in the Convention on Biological Diversity (CBD), which calls forest areas the largest single store of genetic diversity (FAO 1989). Domestication tends to reduce the genetic variation present in wild plants, with implications for sustainability and resilience.

Such issues confirm the importance of protecting wild and semiwild varieties, often seen as a major conservation goal, in both *in situ* and *ex situ* genetic conservation. One good example comes from the wild varieties

of maize (*Zea mays*). The wild species (known as teosinate; Wilkes 1967), whose genes are already being used in breeding resistance to disease, grows in a small and restricted area. Sánchez-Velásquez et al. (2002) report the important role of ongoing shifting cultivation in maintaining these populations. Threats to the wild variety include genetic contamination from domestic types—including, in one recent well-publicized but disputed story, varieties that have undergone genetic modification (GM) (Doebley 1990). Clearly, the source areas need to be managed.

These kinds of conservation needs should be able to pay for themselves, since the economic utility of such a gene bank is well established (see Section 4). Forests provide a larger genetic contribution to future farming options—providing potentially important biocontrol agents in fighting weeds, plant diseases, and pest infestations (e.g., Mathias 1997). Wasps have been used to control cassava (*Manihot* sp.) top eaters in Africa and Asia (e.g., Bellotti 1999). This control project, which requires an *in situ* approach, is considered a highly successful investment in technical solutions. Most past efforts to use wild species to improve domestic varieties have relied on the ability to cross-breed close taxonomic relatives. However, this limit has technically been lifted: GM technology offers the potential to utilize almost any gene, and the enormous number of species in forests makes them potentially a prize heritage for future generations. The use (and abuse) of GM is beyond the scope of this study, but it is the subject of many debates, and the field is very

fast moving (e.g., Quist and Chapela 2001; Matthews 2002; Editor 2002; McAfee 2003).

2.2 Landscape Modification and Food

On a broader scale, landscapes can be managed and modified for various purposes. This is as true in tropical forests as elsewhere. Ellen (n.d.) describes some of the ways in which various forest-dwelling peoples manage their landscapes to increase food production and maintain a steady supply of desirable food (and other) species. Some authors suggest that food systems based on wild species and their potential for domestication have influenced the historic spread of cultures (Diamond 2000).

Forests and their food-producing potential are subject to both immediate negative impacts and longer-term threats to ecology (see Cunningham 2001, on how and why to evaluate landscape change, from an ethnobotanical perspective). Direct impacts include clearance, fragmentation, logging and fire. Longer-term threats, with effects that are less immediate but may be more profound, include defaunation, invasive plants and climate change. Such changes are not necessarily negative; degraded forests can be richer in certain valued species.

In the case of conversion to agriculture we must recognize and consider the relative values of the alternatives, which are themselves often motivated by the need for food.



A landscape mosaic,
Bengkulu, Indonesia
(Photo by Carol J. P. Colfer)

Döös (2000), for instance, examined the extent to which food production could be increased by conversion of forest lands to agricultural lands and concluded that to achieve a constant annual increase in food production, the area of forest removal would have to be increased each year.⁹ Various authors have looked at the relative food production potential of different stages of forest regrowth. Piperno's (1989) contention that secondary forests are more productive of human foods is confirmed by Bennett and Robinson (2000b) with regard to wildlife.¹⁰ Richards (1996) found that the people of the Gola Forest of Sierra Leone obtained many more useful products from bush fallows than from high forest. Indeed, he writes, "Mende [the local ethnic group] rural society is as surely built on the concentrated ecological power of rain-forest secondary succession as modern industrial society is built upon energy from oil." Colfer and others (1997; Colfer and Soedjito 2003) have found old-growth forest to supply more food than secondary forests in two Kenyah Dayak swiddening communities in Borneo—but this proportion undoubtedly changes as the forested landscape diminishes. Other Bornean ethnic groups (Punan and Merap) also self-report that primary forest is the most important (actual and potential) source of foods (both plant and animal; Sheil and Liswanti, in press). In those parts of the

world where deforestation is largely due to small-scale farming and the 'landless,' the demand for food may be directly opposed to the protection of the forest.

However, in some low-intensity management systems, forest modification is the direct result of enrichment with (or selective tending of) food-producing species, such as durian. In many forest regions, fruit groves may occur on and along well-established forest paths (Sheil, personal observation), in regenerating former rice fields (Colfer, personal observation), and in other human modified landscapes (cf. Chin's 1984 comparisons of the useful products in varying stages of forest regrowth with those from undisturbed forests in Borneo). Such modifications have their own food value.

Clearance of forests produces distinct ecosystems, with differential impacts on people's diets (and access to other forest benefits). The various stages of forest regeneration—purposely manipulated by many forest-dwelling peoples—yield a wide range of goods and services to local people, including plant and animal foods and medicines (de Jong 1995; Colfer et al. 1997; Sheil et al. 2003). Forest fragmentation can lead to loss of some species and increases in others while making the forests more susceptible to fire and other damage. The implications for foods and medicines are variable.



Logging can be the first step in forest degradation, Brazil
(Photo by Patricia Shanley)

Logging affects plants and animals in forests, as does any silvicultural treatment. In some cases these activities affect food and medicinal plants (Sheil et al. 2003). In Malinau, East Kalimantan, droughts and floods mean that communities have, even in recent times, been dependent on wild food resources such as palm starch (sago) for subsistence. The main local sago (*Eugeissona utilis*) grows on ridgetops, where heavy machinery is used to extract logs destroying the palms. At the same time logging drives away wildlife and encourages increased hunting to provision camps (Meijaard et al. 2005).

Fire is sometimes used purposely to control and modify resources (Dove 1986; Colfer 2001; Dennis et al. 2000; McDaniel et al. 2005). Uncontrolled forest fires, generally associated with drought and forest degradation, are often disastrous—for biodiversity, wild-food resources and medicinal plants (see also Tufts 1999, for nutritional impacts on local populations; or Jayachandran 2005, for the impacts on infant mortality in Indonesia).

Defaunation, invasive plants and climate change can also cause significant changes in forests and have negative impacts on local communities. The loss of larger mammals can result from several processes, including hunting—leading to the ‘empty forest syndrome’ (Redford 1992; Williamson 2002), discussed in more detail below (Section 2.4). The ecology of the forest starts to break down, leading to changes in species and forest-related services. The threat is widespread, but the implications for food and medicine remain unclear, since different forests provide different kinds of products.

Invasive plants are creating major ecosystem changes and threatening local biodiversity in many parts of the world, including tropical forests. Problems have been noted mostly on oceanic islands but are also increasing in continental settings. Some invasive plants and animals are themselves edible, however (e.g., *Psidium* spp., *Leucaena leucocephala*). Epstein et al. (1997) discuss the implications (and biological control) of invader fauna that successfully colonize new areas. A careful review of the topic would doubtless show many links between various exotics (rodents, snails, snakes, mongoose, cats and pigs) and local food concerns, but again, patterns vary from place to place and defy simple summary.

Climate change is very likely to alter where species can and cannot persist and is viewed

as a major threat to biodiversity, though Jutro (1991) believes that the greatest changes will be in high latitudes rather than the tropics. The implications for forest-derived foods, medicinal species and local people are likely to be complex and severe but remain difficult to predict.

De M. Santos (2005), taking note of impacts of El Niños, stresses the likely dangers from loss of predators and increases in rodents and other pests (see also Epstein 1994). Chivian (1997) expands on these, also discussing stratospheric ozone depletion, toxic pollution, habitat destruction and loss of indicator species as these relate to human health (see also Patz et al. 2000).

Forests can of course also have a negative effect on food production by increasing predation on surrounding fields (though also bringing prey closer to hunters). Damage from primates, large vertebrates, birds and fruit bats is commonly higher next to forests that harbour these animals (e.g., Naughton-Treves et al. 1998). This issue is a common cause of conflict between conservationists and local people. Some wild animals also kill people, of course.

2.3 Nutrition and Forest Foods

In this section we first look at the nutritional status of hunter gatherers, in an attempt to ascertain how healthful a forest-based diet is and whether one can subsist solely on forest foods. Next we examine the contribution of forest foods to the diets of people living in and around forests. These two emphases relate to our two policy concerns, the link between the forest and human health, and the state of forest peoples’ health, respectively.

2.3.1 Nutritional Status of Hunter-Gatherers

The nutritional value of forest foods and the nutritional status of hunter-gatherers are the subject of considerable debate. Some have argued that the small stature of many remote forest-dwelling peoples is caused by poor nutrition. Protein, fat and carbohydrates have all been proposed as limiting factors in human occupation of rainforests. Headland (1987) and Headland and Bailey (1991) proposed that rainforest ecosystems had insufficient carbohydrate plant foods to support human foragers (a proposal contested by Bahuchet

et al. 1991, and Dwyer and Minnegal 1991). Endicott and Bellwood (1991) offer a Malaysian case where people appeared able to subsist without agriculture or significant trade. Hladik and Dounias (1993) emphasize the importance of wild yams as a perennial source of nutrition for forest dwellers (see also Dounias 2000a, on management of yams by Baka pygmies¹¹). Sago starch, from certain palm species (e.g., *Metroxylon sagu*), is another good source of carbohydrates and may account for the absence of seasonal famines among Papuan forest peoples (Sheil, personal observation). Hill and Baird (2003), prompted by the carbohydrate controversy, examine the role of aboriginal fire management in Australia's rainforest areas in protecting carbohydrate sources. Management of carbohydrate resources appears to be one critical aspect in the occupation of rainforests by hunter-gatherer peoples (Sponsel et al. 1996).

Bailey and Peacock (1988) hypothesized that energy resources in general, including fat and other nutrient sources, were limited, both agreeing with Piperno (1989) that these were more important limiting factors than protein.

Bailey and Peacock (1988) came to the same conclusion, based on their study of the diets of the Efe of northeastern Democratic Republic of Congo (see also Lee and Devore 1968; Hladik et al. 1990).

Another argument revolves around the health of hunter-gatherers. Several authors, focusing on the nutritional superiority of wild meats, maintain that hunter-gatherer diets are healthier than average (cf. <http://www.paleodiet.com>; Cordain et al. 2002). Milton (2000) provides a convincing critique of the importance of meat, arguing instead that hunter-gatherers' consumption patterns are dominated by plant-based foods (observed by other authors as well), which she considers healthier. She has also argued (1999) that the diets of present-day nonhuman primates—new leaves, ripe fruits, seeds, exudates, nectars, flowers, pith of tropical plants—offer insights for improving human nutrition. Specifically, she notes that the kinds of sugars in many wild fruits are healthier, the amount of protein in wild fruits may be higher, vitamin B-12 and other micronutrients are often more plentiful in wild than domesticated plants, and vitamin C is in some cases dramatically more available in wild fruits.

Cobbaert et al. (1997) examined serum lipoprotein (Lp(a)) levels among pygmies and Bantus near the Dja Reserve in eastern Cameroon. The study unexpectedly found dramatically higher levels of Lp(a) than among healthy Asians and Caucasians, despite low levels of coronary heart disease in these Cameroonian populations—suggesting a need for further study, including attention to genetic, lifestyle, and nutritional factors. Several studies emphasize the interactions of Lp(a) with elevated levels of total cholesterol or an increased ratio of total cholesterol/HDL-C (Cantin et al. 1998; Hopkins et al. 1997; Maher et al. 1995).

Jenkins and Milton (1993) describe a hunter-horticulturalist group in a remote area of Papua New Guinea whose consumption of animal protein was adequate and superior to that of their neighbours, yet they still suffered high rates of infant mortality, low growth rates, and chronic ailments. Pagezy (1988) found in Central Africa that the hunter-gatherer Twa were in a worse nutritional state than their agriculturalist neighbours, the Oto. Conversely, Dounias et al. (2005) found the nutritional status of forest-dwelling Punan (of Borneo) to be superior to that of nearby



Cassava is important in the diet of the people of Makokou, Gabon (Photo by Carol J.P. Colfer)

government-settled Punan, though Levang et al. (2005) stress the high infant mortality rates of remote forest dwellers in the same area—this is a contradiction only if nutrition is seen as the only important variable. See Voeks and Sercombe (2000), whose findings parallel those of Dounias' other studies of hunter-gatherers in transition; or Newson (1998), who describes the advantages of small, dispersed populations in stopping the spread of disease. Pasquet et al. (1993) reported that the pygmies they studied had amongst the highest protein intakes in the world but low life expectancy and various chronic health problems, suggesting another, nonprotein source of the health problems (see Section 3).

2.3.2 Food Availability and Human Forest Dependency

We begin by looking at the controversy over whether forests are safety nets or poverty traps and the extent to which communities are dependent on forests in general. We then address dependence on forest foods, dependence on forest animals for both food and income, and dependence on other forest materials that indirectly contribute to access to food and nutrition. We conclude with a discussion of the commercialization of forest products, focusing on its impact on human health.

'Safety net' or 'poverty trap'? Most observers recognize the role of forests as insurance during times of environmental, political or personal stress (e.g., FAO 1996a, b; Etkin 1994; Cox 1994; Scoones et al. 1992). People's uses of forests as food sources during times of stress can be very important. Colfer heard many stories from the people of Long Segar, East Kalimantan, about their reliance on forest foods during droughts (though in 1998, the effects of the fire were so severe that even these sources were not available, Colfer 2001). In the years following the El Niños of 1972, 1983, and 1998, dramatic rat invasions further devastated people's livelihoods and reduced food availability in this community (Colfer and Dudley 1993). This pattern appears general in the region: All seven forest communities examined in Malinau—ranging from recently settled Punan, to long-term swidden farming Merap—report having been dependent on the forest for food in the recent past when crops have failed or been lost to drought, floods or pests (Sheil et al. 2003).



Despite the seasonal availability of wild fruits such as bacuri (*Platonia insignis*) a child from Quiandea, Pará, Brazil demonstrates the potbelly characteristic of malnutrition (Photo by Patricia Shanley)

Takasaki et al. (2004) analyze coping strategies in the Amazonian rainforests, focusing on covarying flood shocks and idiosyncratic health shocks among riverine peasants. Based on results from a bivariate probit model, the authors conclude that nontimber forest product collection, including foodstuffs, represents an important asset for poor people coping with floods, and that interventions should focus on promoting sustainable forest resource use to ensure continuing availability to people with few alternative sources.

Forest foods also provide nutrition during emergencies and between agricultural harvests. Falconer (1990/1) gives examples, primarily from Africa, showing how forest foods supplement other sources and fill seasonal gaps. Ogden (1991) and Hoskins (1990) also note that forest foods represent important supplements to agricultural staples, increasing dietary variety for local people and providing foods under emergency.

Others, proceeding from an assumption that money is necessary for subsistence, have maintained that forests are a kind of trap, difficult to escape (see, e.g., Levang et al. 2005; Arnold 2001; Angelsen and Wunder 2003). Yet many of those who write about forests as poverty traps recognize the function of forests as safety nets as well. Homma (1996), for

instance, analyzes the prospects for nontimber forest products in the Amazon (including some foods), based on their economic value and on their stage in the process from new discovery through a 'boom economy' to exhaustion of the resource and finally cultivation. Homma clearly considers domestication a more viable alternative for forest peoples than *in situ* management of forest products. Angelsen and Wunder (2003) focus on the low value and low density of most nontimber forest products and the likelihood that more powerful people will be able to capture any significant benefits (cf. Dove 2003); they conclude that poor access to markets and poor infrastructure limit income-earning potential, and that marketing chains tend to be nontransparent and manipulated by outsiders.

We find that forest-dwelling hunter-gatherers, shifting cultivators, and smallholder and landless households living near forests rely on the forest in their survival strategies (Bailey and Peacock 1988; FAO 1989; FAO 1996b; Hladik et al. 1993; Lindstrom and Kingamkono 1991; Madge 1994; Missano et al. 1994; Saowakontha et al. 1994). According to both our own research and the literature, dependence on forest resources varies greatly. In-migrating smallholder and landless households may be minimally dependent on forest resources, often because of ignorance of the resources; or they may be thrust unwillingly into dependence on forest resources because of a lack of alternatives (see Section 3.1 on HIV/AIDS, for instance). Hunter-gatherers and integral shifting cultivators are likely to have in-depth knowledge of forest resources and their uses, whereas newcomers like transmigrants, settlers, the landless, and refugees come to forested environments without such understanding. The literature rarely differentiates these groups, however.

Scoones et al. (1992) provide an annotated bibliography of nearly 1000 references pertaining to human use of wild foods (many from forests), and Ogden (1990b) has an annotated bibliography of 81 works on the subject of forests and tree foods, as well as a reader that includes many pertinent publications by FAO and others (Ogden 1989). Virtually all these sources provide further evidence of the dependence of people on their surrounding forests.

Many authors stress the often disproportionate dependence of poorer people on forest resources (e.g., Mainka and Trivedi

2002; de Merode et al. 2003; or Melnyk 1995, and Melnyk and Bell 1996, for the Huottuja of Venezuela). Some emphasize gender inequities (Dangol 2005). Some stress the comparatively nutritious nature of forest-based diets (Vickers 1994, on the Siona and Secoya of northeastern Ecuador). Others emphasize the centrality of open-access resources for the poor (Cavendish 1997; Jodha 2000). Ogle (1996), for example, reports the results of a four-country FAO study (Thailand, Vietnam, Bolivia and Tanzania) that clearly shows the importance of forest foods for the poor. Including both plant and animal products, they found that the forest foods used by local people numbered from 90 in Vietnam to more than 100 in Tanzania and Thailand. In Thailand, where the government closed off access to the forest at the time of the study, a sudden deterioration in the diets of poorer households was documented.

Shaanker et al. (2004), in search of 'win-win' solutions in the people-environment balance, estimate that more than 50 million people in India are directly dependent on forests for their subsistence. They examined three groups in southern India, determining their dependence on nontimber forest products (particularly the fruits, *Phyllanthus emblica*, *Terminalia chebula* and *Acacia concinna*), their level of ecological knowledge and their market organization. They concluded that these three factors together were likely to determine whether people's resource use patterns would be consistent with maintenance of the resource.

There is a rich literature on the uses to which Borneo's people put their forests (e.g., Colfer and Dudley 1993; Colfer et al. 1997; Colfer et al. 2000; Colfer and Soedjito 2003; Dove 1985; Peluso 1994; Puri 1997; Sheil et al. 2003; see Box 1). Reading such works, one is continually struck by the dependence of the people on their surrounding forests, the many uses to which it is put, and the strategies that function to sustain it, given low population density and minimal contact with powerful outsiders intent on extraction.

Dependence on forest foods. Populations residing in or near the forest are in most cases dependent on both agriculture and forest-based food sources. Virtually no people depend on the forests alone, but large numbers of people depend on it as a supplementary source. To understand this relationship fully requires not just an understanding of what forests provide, but also what is available and

Box 1. One Forest Community's Nutritional Status, 1979–2001

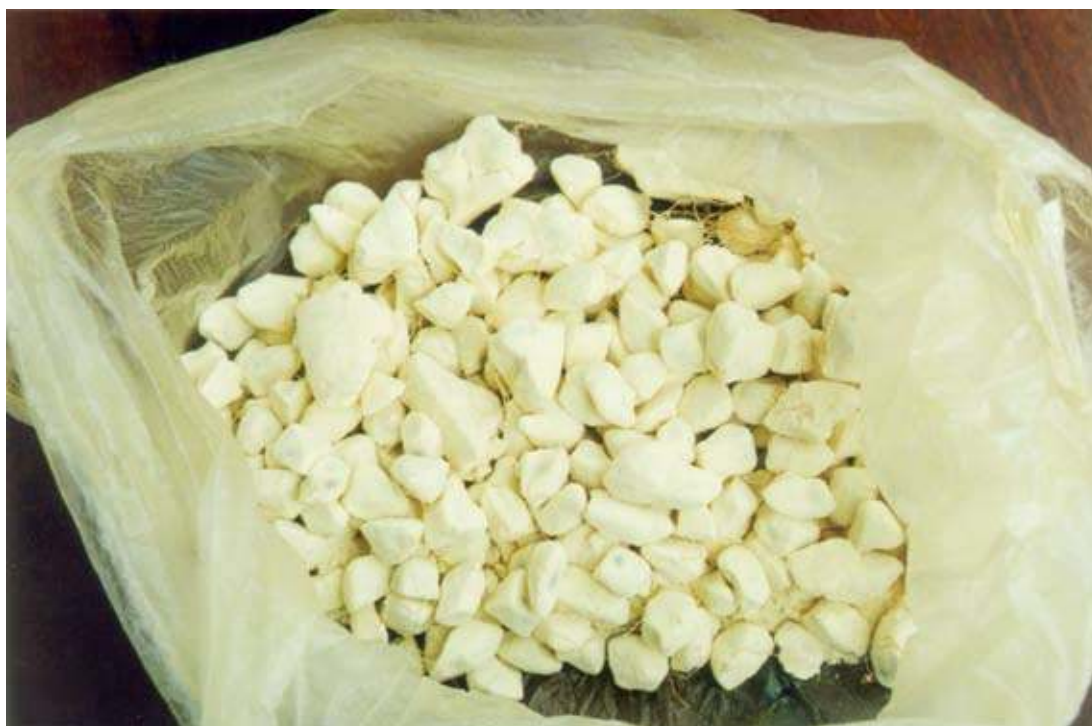
In 1979, Colfer began conducting ethnographic research in the community of Long Segar in East Kalimantan, Indonesia. The people of Long Segar had migrated on their own initiative from the remote Apo Kayan (in the center of Borneo) down to a somewhat more accessible area on the Telen River, beginning in 1963, in search of consumer goods, medical and educational benefits, new lands and an appealing view. They were also prompted to leave their home village of Long Ampung because of religious and resource conflicts. In 1972, the government declared the community a 'resettlement community' and gave them assistance (seeds, agricultural implements, a few cattle, an agricultural extension agent) for five years. The people had no tradition of care of large animals and were mildly afraid of the cattle, which ran wild, ruining home gardens and generally being pests. The extension agent was tasked with converting the people from shifting cultivators to settled paddy rice farmers. However, there was no way to control water, as needed for paddy rice; and there was no mechanism for changing the mandate of the extension agent, so everyone participated in carefully choreographed trickery whenever government officials came by, to protect the extension agent's job and reputation. The people subsisted on the rice and other products grown in their upland fields, using slightly adapted traditional techniques, supplemented by forest foods. Whereas households had previously planted one field nearby for easy access and another farther away, they began planting one field in an upland area (in case of flooding) and one in a lowland area (in case of drought), both usually at some distance from home. Their access to foods other than rice was reduced because the village was laid out according to a resettlement program plan that put most houses farther from the forest and because the marauding cows damaged home garden crops.

In the spring of 1980, Colfer made a visit to Long Ampung, in the remote interior, with virtually no access to 'modern' medicines or agricultural extension. There appeared to be far lower infant mortality; almost no children with the brownish hair that can indicate malnutrition; and generally healthier people than in Long Segar. The diet seemed much more varied. Whereas in Long Segar, the family with whom Colfer stayed ate primarily rice and leaves, in Long Ampung, pork and fish were also frequent parts of daily meals.

Colfer returned to Long Segar periodically over the next two decades, and found a continuing reduction in people's reliance on forest foods (Colfer and Soedjito 2003). In 1980, foods collected from the forest accounted for 26% of nonrice foods; by 2001, that figure had dropped to 15%. The percentage of bought food, accounting for 8% of nonrice food in 1980, remained the same in 2001 despite dramatic changes, particularly in the landscape, which had seen major fires in the 1983 and 1998 El Niños. The community now has a permanent medical practitioner, and a road network allows access to the provincial capital, Samarinda, sometimes within a few hours (versus two days and a night in 1980).

Although based on less intensive study, Colfer's recent impressions are that people's diets in Long Segar may in fact have reached a level similar to that in Long Ampung in 1980. There is more awareness of the importance of a good diet, and meals appear generally to be more varied, with a better balance of foods other than rice. Infant deaths are now extremely rare.

See Colfer (1981).



Fruits of the baobab tree, Romwe, Zimbabwe (Photo by Carol J. P. Colfer)

used from other sources—and where shortfalls might occur (see Vedeld et al. 2004, for a useful meta-analysis of 54 case studies in 17 countries, demonstrating the importance of forest-derived vis-à-vis other income—a topic that lies outside our purview; and Sheil notes the significance among the Punan of direct trade, *gaharu* for rice).

A huge variety of edible plants grow in forests (see e.g., Hoskins 1990; Ogden 1990b; Smith et al. 1992; Falconer and Arnold 1991; FAO 1992). Fruits contain minerals and vitamins, and sometimes significant calories. Their seeds and nuts typically contain calories as well as oil and protein; their leaves contain fats, protein, minerals, and vitamins; roots and tubers are likely good sources of carbohydrates and minerals; and the gums and sap may also have nutritional properties.

Roots and tubers, such as cassava, yams, sweet potatoes, potatoes, and aroids that grow in and around tropical forests, as well as bananas and plantains, are often important staples, particularly for the poor. Other important staple foods include breadfruits, sago and other palms (Haynes and McLaughlin 2000). These have been comparatively neglected in research (cf. FAO 1990). Shanley and Gaia (2003), considering their experiences in Brazil, argue that the wild species that poor people use and prefer have been neglected by researchers. These authors use *uxi*, the ‘poor

man’s fruit,’ of Brazil as a case in point. Its oil, rich in protein and vitamins, is used for cooking and medicine, among other things (see also Shanley et al. 1998, for information on fruit trees and their many uses in the Amazon). The same issue comes up in East Kalimantan: Subsistence foods that have little market value, like sago, are generally neglected and even scorned. Eating sago is considered ‘primitive’ and ‘backward’, and the Punan children of Malinau are teased at school by other ethnic groups as ‘sago eaters’ (Sheil, personal observation). Local officials are ashamed to admit that people in Malinau might still eat sago and are likely to do little to protect the resource despite its value as an emergency food (Sheil et al. 2003).

Clay (1988) nicely summarizes some of the features of South American indigenous systems—including diversity, risk management, multiple use, and agroforestry—that researchers could build upon to help forest peoples increase the availability and dependability of foodstuffs (see also Redford and Padoch 1992). Bahuchet et al. (2001), writing about Central Africa, conclude that “[a]griculture provides the bulk of forest peoples’ diets, the forest supplies the quality.”

Useful reviews have shown the importance of forest foods for those living in and near the forest, and often for those further afield (cf. Morton 1987, on forest fruits). For

ethnobotanical literature on nutritional values and edible plants, see Cunningham (1997b) on eastern and southern Africa, and Dounias (2000b) on West and Central Africa (also covering French language material).

The nutritional value of many forest plants is poorly known. Evensen and Standal (1984) analyzed numerous tropical vegetables eaten by many forest dwellers and noted the rarity of such analyses; and Madge (1994), 10 years later, reiterated their complaint. Madge notes that Gambian women are encouraged to grow gardens to produce foods that are in fact inferior nutritionally to the wild foods they could be collecting. Table 1 shows the nutritional value of the edible parts of certain trees and shrubs common in and around forested areas.

Puwastien (2000) reports efforts to compile food composition databases for Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. Schonfeldt (2002) describes similar but early efforts in Africa. Information is limited but promising. The website http://www.naturalhub.com/natural_food_guide_nuts.htm, for instance, provides an enthusiastic endorsement of the value of certain nuts for human nutrition in Africa:

On the riverine alluvium and Kalahari sands of Botswana and South West Africa, an extremely valuable fruit and nut tree grows. The Manketti nut (*Ricinodendron rautanenii*) is covered by a sweet flesh that can be dried and stored. The kernel itself has a protein content of about 25%, and a fat content of about 50% (40% of which is linoleic acid, an 'omega 6' essential fatty acid, 18% the monounsaturated oleic acid, and the rest saturated fats). It has an extraordinarily high vitamin e content - around 560mg per 100 grams of kernel! The tree is not only found scattered in open woodlands—in some areas there are large stands, up to 60 000 hectares in extent. One such forest was estimated to produce (in a good year) a crop of 1 ton of nuts to the hectare! It is estimated that one hundred of these small (about 5 gram) dried fruits, with the kernel, would provide 71% of the daily energy requirement for an adult and 115% of the daily protein requirement. Examples of other African tree seeds that are used for food are the African Breadnut (*Treculia africana*) found from coastal west Africa to Sudan, and the African Brazilnut

(*Poga oleosa*), an abundant forest tree in equatorial West Africa which also easily yields an oil similar to olive oil.

Dependence on forest animals. Wild animals, including fish and birds, provide important nutrients, particularly protein and fat, for many tropical forest peoples (see Section 4 of Hladik et al. 1993; Bennett and Robinson 2000b; Mainka and Trivedi 2002). See discussion below on commercial use of bushmeat (Section 3.4); or Falconer and Arnold (1991), who survey various forest foods. Insects provide protein and B vitamins (DeFoliart 2003; Ramos-Elorduy 1993). Vantomme et al. (2004) report that Central African caterpillars have higher protein and fat contents than meat or fish and provide more energy per unit. In Amazonia, indigenous dwellers near large rivers take up to 85% of their dietary protein from fishing (FAO 1996b; see Section 3.3 on mercury poisoning and fish).

In Central Africa, local communities are particularly dependent on wildlife for protein. Dounias (2000) found that among the Mvae of Campo Ma'an National Park (then a reserve) in Cameroon, each household



Traditional fish drying methods on the Ivindo River, central Gabon (Photo by Carol J. P. Colfer)

Table 1. Nutrient Composition (in Compound Forms) of Edible Tree and Shrub Species

Species	Edible part	Calories	Percentage fresh weight (unless otherwise stated)			mg per 100 g fresh weight (unless otherwise stated)			Vitamin A (international units)	Thiamin (kg gamma)	Riboflavin (kg gamma)		
			Water	Protein	Fat	Carbohydrate	Ca	Fe				Nicotianic acid	Ascorbic acid
<i>Annona muricata</i>	fruit pulp												
<i>Artocarpus communis</i>	fruit pulp	109	70	1.5	0.3	25	25	1.0	—	15	35	200	—
<i>Carica papaya</i>	fruit pulp	38	89	0.6	—	9	10	0.5	0.1	60	2500	20	20
<i>Cola acuminata</i>	nut	309	12	9.0	1.0	66	—	—	0	—	—	—	—
<i>Cola nitida</i>	nut	—	83	1.5	0.6	—	3.1	1.4	0.7	9.8	31	11	47
<i>Daniellia oliveri</i>	dried leaves	—	9.4	5.5	—	—	—	—	—	—	—	—	—
<i>Ficus gnaphalocarpa</i>	dried leaves	—	11.6	13.8	—	—	—	—	—	—	—	—	—
<i>Invingia gabonensis</i>	dried kernel	—	—	—	54	—	—	—	—	—	—	—	—
<i>Monodora myristica</i>	residual seed meal	212	1.0	17.6	2.8	29	—	—	—	—	—	—	—
<i>Moringa oleifera</i>	fresh seeds												
<i>Moringa oleifera</i>	fresh leaves												
<i>Pentaclethra sacrophylla</i>	kernel	569	10	22	45	17	90	—	—	—	—	—	—
<i>Prosopis africana</i>	pod pulp	279	9.6	9.2	3	53	160	70	—	—	—	—	—
<i>Prosopis africana</i>	dried stems + leaflets	300	7.9	10.2	6.8	50	—	—	—	—	—	—	—
<i>Pterocarpus spp.</i>	dried leaves	218	10.1	17.1	2.4	32	500	70	—	—	—	—	—
<i>Spondias mombin</i>	fruit pulp	—	72.8	1.3	0.1	—	31.4	2.8	0.9	46.4	71	95	50
<i>Telfairia pedata</i>	kernel	517	6.6	19.6	36	28.5	—	—	—	—	—	—	—
<i>Vitex doniana</i>	dried leaves												

Source: Data extracted from Irvine (1961) [Reference information on Irvine (1961) is not available in the original document]; http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/1961/V7540e/V7540e15.htm (FAO 1995).

captured 111 kg per month, with 48% being sold, 18% circulating in social transactions and 34% consumed by the household (see also Bahuchet 2001, 331-63). Koppert et al. (1993; also cited by Wilkie 2001) found that the Mvae, Yassa and Kola of Cameroon eat more meat, primarily bushmeat, than the average person in Europe—73 kg versus 30 kg per capita per year. On average, people in the Congo Basin eat 47 kg per capita per year, and there are no readily available substitutes. In the Congo Basin, Wilkie estimates that hunting provides 30% to 80% of the protein consumed by forest-dwelling families, and that overall, both rural and urban people consume more than a million metric tons per year (equivalent to almost four million cattle).

Hoskins (1990; no page numbers) reports, ... communities living near a forest in Nigeria obtain 84 percent of their animal protein from bushmeat. In Ghana, approximately 75 percent of the population consumes wild animals regularly; in Liberia, 70 percent; and in Botswana, 60 percent (FAO 1991). In the Peruvian Amazon more than 80 percent of the animal protein is obtained from bushmeat, and the national average of those eating bushmeat in Peru, including those who live far from forest land, is 41 percent (Dourojeanni 1978).”

Nevertheless, she believes those figures underestimate wildlife consumption, which is often unreported because it is part of the informal sector.

Research in Borneo has also found strong dependence on wild meat for daily protein. Caldecott (1988) reports an average consumption of wild pig of 54 kg per capita per year for Dayaks living in the forests of Sarawak, as opposed to 12 kg per capita per year for those in periurban contexts. Wild pig represented 79% of captures in the Upper Batam area. Puri (1997), writing a decade later in nearby East Kalimantan, found pigs constituting 80% of captures (and 91% of edible weight), amounting to about 134 kg of pork per person per year. Dounias (2003) found wild pigs constituting between 47% and 83% of the captures among the Punan of the Tubu River in East Kalimantan. Based on careful dietary surveys, he found consumption of wild pig meat to vary seasonally from 109 g to 325 g per capita per day—meaning between 382 kg and 1259 kg per capita per month in the isolated



A Gabonese boy holds up a newly killed cane rat in Makokou (Photo by Carol J. P. Colfer)

village of Long Pada, with 100 inhabitants. The addition of other species brings daily consumption of wild meat to a total of 113 g to 392 g per day.

These levels of dependence on wildlife, both for direct nutritional inputs and for indirect inputs through increased incomes, become problematic when harvesting practices are unsustainable. Eves and Bakarr (2001) describe the state of our knowledge of several important species in West Africa, concluding that the most worrisome known declines are in duiker, elephant, primate and rodent populations. But they stress the inadequacy of our knowledge and suspect that some species may already be locally extirpated. Bennett and Robinson (2000a) raise the issues of naturally low reproductive rates and particular mating, nesting, predator avoidance or social behaviours, which can also render wildlife populations more vulnerable. See the edited book by the same authors (Robinson and Bennett 2000) for an excellent collection on hunting, with many data-rich

chapters on forest peoples' hunting practices and impacts around the world. Recurrent themes are human population growth, land-use change and 'development,' market access and demand, and new and more effective weapons: The outlook is grim for both the wildlife and those dependent on it.¹²

Mena et al. (2000) describe the changes that have occurred in the hunting practices of the Huaorani in Napo province, a remote Ecuadorian forest: In the past 15 years, the men have shifted from using primarily blowguns to primarily shotguns, resulting in a 15% increase in mean kilograms per unit effort—which may have led to short-term improvements in nutrition but also to unsustainable wildlife management. The kind of human population growth, mainly from natural increase, described by Stearman (2000) for the Yuqui (from 73 people in 1983 to 150 in 1996, or a doubling every 12 years) and for the Sirionó of Bolivia (from 304 people in 1987 to 459 in 1993, or a doubling in about 10 years) suggests serious pressures on the wildlife on which they depend for protein. Both groups are virtually completely dependent on their forested environment for their daily needs, and their remoteness makes finding alternative sources difficult. Their rates of natural increase are in marked contrast to low population growth rates among the Uma' Jalan Kenyah of East Kalimantan, Indonesia (Colfer and Dudley 1993).

Dependence on other forest materials. Forests also supply materials that contribute indirectly to food availability. Domestic animal production may be dependent on the use of fodder from the forest understory (e.g., in Mafungautsi, Zimbabwe, Matose et al. 2005; in Chimaliro, Malawi, Kamoto 2005; in India, Poffenberger 1996). Such grazing typically contributes to the nutrition of domestic cattle, which in turn contribute to human nutrition and/or income.

Wood is used to make beehives to produce honey (Kamoto 2002, for Malawi; Colfer et al. 1993, for West Kalimantan). Forest species supply leaves for wrapping food, wood for cooking fuel, hangars from which to suspend pots, poles to which spears are attached, blowpipe arrows, rattan for baskets to collect food and mats for drying foods for storage. See Colfer et al. (1997, appendices II and III), for long lists of ways in which forest wood and other products are used to support subsistence needs; López and Shanley (2004a, b) provide

readable summaries of selected nontimber forest products used in similar ways in Asia and Africa (2004b); López et al. (2004) take up Latin America. Permadi et al. (2004) describe a small industry (using about 600 m³ of wood per year) creating kitchen implements from wood grown on Java's timber plantations for sale within Indonesia. There are now substitutes for certain products (e.g., guns, chainsaws, plastic buckets, metal axes, polypropylene line), but the subsistence uses are consistently undervalued in assessing the value of forests to local peoples.

To this point we have concentrated on subsistence uses, but we do want briefly to address the commercialization of forest resources as it relates to human nutrition and, in some cases, subsistence losses to local communities. The true quantity of forest foods consumed in urban areas and outside the country of origin is unknown (see <http://www.bushmeat.org>; FAO 2002; Walter 2001). Townson (1995) has a brief overview and short annotated bibliography on the commercialization of forest foods, focusing on bushmeat, fruits and leaves, beverages, and leaf wraps and plates.

Bushmeat has become a sensitive issue over the past decade, particularly among international NGOs; and obtaining accurate statistics is difficult because the hunting of large forest animals is often illegal (Hoskins 1990). Much of the literature concerns the tropical forests of South America and Central and West Africa (Bakarr et al. 2001; Bakarr et al. 2002; FAO 1995), where commercialization of bushmeat is common. The information comes primarily from case studies.

Trefon and de Maret (forthcoming) identify economic crises, urbanization, demographic changes, cultural and symbolic factors, commercial logging and institutional constraints (see Table 2), along with a reduction in the traditional sharing patterns, as contributing to the shift from traditional rural consumption of bushmeat to the kind of highly commercialized regular urban use we commonly see now in Central Africa. Some of the commercialization of forest products is driven by faraway, specialized luxury markets (Adams et al. 2004; Brashares et al. 2004). Bennett and Robinson note that "Commercialization results in increasing harvest rates through increased hunting intensity by local people, and the entrance of non-resident commercial hunters" (2000b, vii).

Table 2. Overlapping Causes of Urban Bushmeat Consumption

Economic crisis	<ul style="list-style-type: none"> Unemployment Professionalisation of hunting and marketing Meat imports decline Eating habits evolve at home and in street restaurants
Urbanisation (demographic and spatial)	<ul style="list-style-type: none"> Half of Central Africans live in urban areas The number of very large cities is growing rapidly Urban populations abandon subsistence activities to engage in commerce or services (increased reliance on cash economy) Expanding road and rail networks facilitate transportation of game Physical and social proximity between cities and forests perpetuates reliance
Culture	<ul style="list-style-type: none"> Appreciation of the taste of game is deep-rooted Game is associated with the village environment and festive occasions Powerful symbolism attached to eating the flesh of certain animals Breakdown of traditional sharing practices Material culture (rifles and metallic snares replace traditional techniques, jack lighting on the rise)
Commercial logging	<ul style="list-style-type: none"> Roads and transects open up areas previously difficult to penetrate Loggers provide hunters with material and transportation Loggers help traders with transportation and transport game themselves Loggers themselves subsist on game in camps
Institutional constraints	<ul style="list-style-type: none"> Inadequate financial and human means to curb trade Local perceptions of conservation Failure of repressive measures Social dynamics inadequately understood Limited success in urban game breeding

Source: Trefon and de Maret (forthcoming).

Obtaining food for logging operations is an important impetus to commercialization in tropical forest areas. Hardin and Auzel (2001) report on a logging operation in northern Congo that employs about 650 people and consumes 390 tons of wild game (live animal weight), or close to 35 000 animals per year (see also Trefon and de Maret forthcoming). Bennett and Robinson (2000b) report data from Sarawak in 1996, in which a single logging camp of about 500 people caught 1,150 animals (29 tons of meat) per year. When extrapolated to all of Sarawak, the estimate was 55 045 animals or 1400 tons. These authors advocate

a complete ban on all commercial hunting, and a requirement that concessions provide adequate alternative sources of protein to their workers—a proposal that has now become law (see also Bennett and Gumal 2001).

Markets, demand and prices all play a role in commercialization. In Nigeria, Walter (2001) found bushmeat to be more expensive than meat from domesticated animals, but the reverse is true in some parts of South America. Demand for wild meat leads to higher harvest rates by both local people and nonresident commercial hunters (Bennett and Robinson 2000a).

Significant incomes, from a forest dweller's perspective, can be earned by selling bushmeat. Wilkie (2001) reports the range of incomes obtained in several Congo Basin contexts: Snare hunters trapping in the Dzanga-Sangha Special Forest Reserve in southwestern Central African Republic, for instance, earn US \$400 to \$700 per year (comparable to the salaries of park guards) from the sale of bushmeat. In a logging camp in northern Congo, residents sold 36% to 52% of all bushmeat captured and generated income of about US \$300 per household per year (thus contributing between 6% and 40% of a household's daily income). This author provides other similar examples from Cameroon. Vantomme et al. (2004) document the marketing of caterpillars by women and children for growing urban markets in Central Africa.

Commercialization of forest fruits and other plant products can also be important. Arman (2003) looked at the market for forest fruits in Pontianak (West Kalimantan, Indonesia) in 1992. His team found 38 fruit species sold in eight public markets, with several species generating annual sales revenues of more than US \$10 000; one fruit, durian, brought in more than \$200 000 that year. See also Yadama et al. (n.d.) on tribal women and their dependence on the sale of nontimber forest products in India.

CIFOR undertook a multiyear global comparison of commercialized nontimber forest products, some of which were foods (Sunderland and Ndoye 2004; Chupezi and Ndoye 2004, on African cases). Important commercialized foods included shea butter (*Butyrospermum parkii*) in Benin (Schreckenbergh 2004; Chalfin 2004); *Garcinia kola* nuts (Adebisi 2004) and *Dacryodes edulis* (Adewusi 2004) in Nigeria. Sunderland et al. (2004) emphasize the dominance of women in the harvest and sale of fruits and nuts in these three cases. Women's involvement is pertinent because of the widespread practice in Africa of keeping husbands' and wives' money separate, and the general tendency globally for women to spend their cash on livelihood and health-related costs. The nontimber forest products examined in the African studies were marketed at all levels, from local to international. Comparable studies are available from South America (Alexiades and Shanley 2004) and Asia (Kusters and Belcher 2004), all tracing the production and marketing chain of each product from harvest

to consumption. The cases vary enormously in their profitability, from minimal to significant, with varying implications for reducing poverty (with its links to human health).

Such sales also have implications for sustainability of forest resources. Exploitation of many species used as human foods, particularly bushmeat in Africa, raises concerns (see the collection by Bakarr et al. 2001; Section 2.1, above). Fa et al. (2003) also explain the links among increasing population, logging and commercialization, using national statistics from the Congo Basin. These authors predict that current rates of wildlife use will cause the extinction of significant numbers of faunal species in the near term. Eves and Bakarr (2001) provide species-by-species discussions, explaining the dire straits of many wildlife species. Peters (1996) warns of the difficulties of even assessing sustainable harvest levels of forest species in general, and gives some frightening examples, before providing some suggestions relating to improving management.

The wild meat trade for human consumption is part of local economies throughout the poorer tropics and is widely seen as one of the greatest threats to the persistence of tropical wildlife. Various authors have sounded alarm bells (Walter 2001, on commercial hunting in Liberia; Mainka and Trivedi 2002, more globally). Improved weapons and transportation systems have exacerbated the problems.

Cowlshaw et al. (2004) document the sustainable harvest of rodents and ungulates that account for 84% of total retail weight in the mature urban market of Takoradi, Ghana, but they note that primates and large ungulates have already been depleted. These authors recommend concentrating conservation efforts on new markets (like new logging concessions), for the greatest impact.

Some efforts to ensure sustainability of resources focus on improving our valuation of such products. Peters et al. (1989), Peters (1994, 1996, 1997), Sheil and Wunder (2002) and Campbell and Luckert (2002) note that fruit collection in Peru often involves cutting the trees down; this practice was also noted in Papua for the fruit matoa (*Pometia* sp.) (Wan, personal communication, 2005), and Vantomme et al. (2004) note the same practice for harvesting larvae in Central Africa: Such harvesting methods are likely to be unsustainable.

Both commercialization and unsustainable practices can adversely affect local people's health. Redford (1993) notes the general pattern of a decrease in nutritional status of hunter populations when game begins to be marketed. Ogden (1990a) observed the same result for access to forest foods more generally and emphasizes the adverse effects on the nutrition of young children and pregnant and lactating women.

When a forest product is determined to have value, outsiders are drawn to the area, and conflicts often occur with local people. Dove (2003) discusses this problem in detail with regard to other forest products in Indonesian forests, where local people consistently lose out to more powerful stakeholders. His conclusion: "The problem is not that the forest dwellers are poor, but that they are politically weak" –a conclusion shared by Sunderland et al. (2004) for their African cases.

2.4 Food and Nutrient Problems

Despite the many positive benefits from forests, local human populations encounter significant problems as well.¹³ In this section, we address intrahousehold food distribution, food-related diseases and dangers, unsustainable harvesting patterns, uncertainty and seasonality,

fuelwood, and the effects of 'modernization' on the health of forest-dependent peoples.

2.4.1 Intrahousehold Food Distribution

We begin with problems relating to women's and girls' access to food.¹⁴ Among some groups—both inside and outside forested areas—women are at particular risk nutritionally because of their reproductive roles and their lower social status within society (cf. FAO/SIDA n.d.; Messer 1997). Among the Lese in the Ituri Forest (Northeastern Democratic Republic of Congo), who experience periodic food shortages, for instance, the nutritional deficiencies of pregnant and lactating women are compounded by complex food taboos against meat consumption (Bentley et al. 1999). The women cope by sneaking foods, frequent snacking, and cultivation of larger vegetable gardens (see also Aunger 1994). A series of articles in Bourke et al. (2001) documents the abysmal health status of women and children in Papua New Guinea, a country with significant forest cover (though linking these datasets to particular forests would require intimate knowledge of the area). Gittelsohn et al. (1997) report Nepali women's reduced access to micronutrients that tend to



Healthy young girls of Baru Pelepat, Jambi (Indonesian), at the river collecting water (Photo by Carol J. P. Colfer)

be in favored foods that may be reserved for men, exacerbated by dietary restrictions for pregnant, menstruating or lactating women. Messer (1997) agrees with this observation more generally and quotes studies showing that neither food energy nor total food intake is a good indicator of nutritional status. Ralston (1997) assessed the responsiveness of intrahousehold calorie allocation to the respective labour contribution of girls and boys in a village in rural West Java, Indonesia (much of which is forested, though the study does not specify location). They conclude that girls are less highly valued but only marginally so, and that increases in girls' work contributions to the household result in their higher valuation within the family.

The findings of Hardenbergh (1997) on the border of the Ranomafana National Park in Madagascar are unusual: She found the nutritional status of boys (aged 0 to 9) to be worse than that of girls in the same age group among two ethnic groups, though adult women were more typically disadvantaged relative to adult men. She found the former finding difficult to explain, concluding that we need to fashion our interventions in ways that are consistent with local realities. Pagezy (1990a) also notes the special position of first-time mothers (and the advantages for their infants) among the Ntomba of Zaire. The mothers are fed better and become fatter than at any subsequent time in their lives. They are likely to suffer periodic negative energy balances with subsequent births.

Messer (1997) discusses a variety of rationales for the distribution of food within households in times of stress—with varying implications for the health of family members:

...allocation rules may aim toward 'equity' (each member entitled to a fair share of any resource); 'equal outcome' (resources distributed in such a way as to equalize the welfare of members so that the least endowed member gets the most); a 'household maximization rule' (each member is entitled to resources in proportion to his or her actual or expected material or prestige contribution to the household); or an 'individual maximization rule' (members most likely to benefit from a resource, and thereby benefit the entire household, get a larger or the largest share). (1677)

She contrasts the tendency of adults in some African pastoral societies and in Mexico to feed their children at their own expense with evidence of the reverse in other African and Latin American settings. Girls and women in some areas (Peru, South Asia), she finds, have reduced access to medical care. She also reminds us of the numerous studies showing the greater efficacy of channeling income intended to improve household food security through women, who have been found to be more likely to spend it on food and nurture. Hindin (2000) looked at the relationship between women's power within the household and both their body mass index and chronic energy deficiency, finding positive correlations in both cases, in Zimbabwe: 'When husbands have sole control, women are likely to be 10% thinner, and 1.93 times more likely to have [chronic energy deficiency]'. (1525)

Intergroup inequities also have nutritional implications. Among the Yuqui (Bolivia), Stearman (2000) documents the striking drop in protein intake, from 88 g per day to 44 g, following large-scale incursions by colonists between 1983 and 1988. Most of this reduction came from a reduction in fish catches (due to commercial fishing using dynamite) but some was attributed to targeted hunting of large species by colonists, who considered the capybara (*Hydrochaeris hydrochaeris*)—which is highly valued as game by the Yuqui—a crop pest, killing it indiscriminately and without eating it. A CIFOR team observed the same phenomenon in Papua, where fish were killed only for their bladders, which were then dried and sold for a good price; the flesh of the fish had previously been eaten by local people (CIFOR 2004).

2.4.2 Food-related Diseases and Dangers

Epidemics like HIV/AIDS can also create or exacerbate existing nutritional problems. Barany et al. (2001, 2002) make a convincing argument that nontimber forest products—both as forest foods and as sources of income for the poor—benefit HIV/AIDS-afflicted households. Many such families have lost their productive members because adults who could otherwise work have become caregivers or HIV/AIDS victims themselves. These authors (among others) note that children often obtain significant nutritional supplements by informal snacking on forest foods (also found by Colfer

et al. 1997; Gram 2001; Sheil and Wunder 2002; Shanley, personal communication 2004); and they note as an example the role of vitamin A (available directly from many forest foods) as a direct intervention in AIDS treatment. The authors suggest encouraging people to use and manage forests and tree systems, which have traditionally contributed to nutrition and health even with relatively low labour inputs.

But not all health problems in forested areas are as dramatic as HIV/AIDS. Many are mundane, chronic problems that plague many areas of the developing world. Table 3 shows some of the more common health problems of forest peoples and the forest foods that can contribute to solving them.

Christian et al. (1998) note the high incidence of vitamin A-related night blindness among pregnant women in the forested region of Nepal (the *terai*). These authors report rates from 8% to 46% in Nepal, as well as similar problems in Lao PDR, Bangladesh, India, Mali and Niger. The Nepali women in

this study considered it second in severity only to vaginal bleeding as a pregnancy-related health problem, interfering significantly with their ability to carry out child care, food preparation and agricultural tasks. They saw no connection between food intake and this ailment, rather attributing it to pregnancy, weakness, and 'hotness' (the latter reflecting the common hot-cold interpretation of foods and health, briefly mentioned in Section 5, in which one strives for 'humoral balance').

Iodine deficiency is a common problem in forested as well as nonforested areas, with incidence in some places as high as 95%. Soils, crops and drinking water in rainforest climatic zones with ancient weathered geology, well-leached soils and high rainfall are deficient in iodine content. Foods grown in or collected from such iodine-deficient habitats are also deficient in iodine. These conditions are particularly notable in the wet zone in Sri Lanka and in the wet, monsoon delta regions of Java and Bali where heavy precipitation results in a

Table 3. Some Common Nutrition Problems and the Potential Role of Forest Food

Nutrient-related problems	Forest food with potential for combatting deficiencies
Protein-energy malnutrition: inadequate food consumption causes reduced growth, susceptibility to infection, changes in skin, hair and mental facility.	Energy-rich food available during seasonal or emergency food shortages includes nuts, seeds, oil-rich fruit and tubers: e.g., seeds of <i>Geoffroea decorticans</i> , <i>Ricinodendron rautanenii</i> and <i>Parkia</i> spp.; oil of <i>Elaeis guineensis</i> , babassu, palmyra and coconut palms; protein-rich leaves such as baobab (<i>Adansonia digitata</i>) as well as wild animals, including snails, insects and larvae.
Vitamin A deficiency: in extreme cases causes blindness and death; responsible for blindness of 250,000 children/year.	Forest leaves and fruit are often good source of Vitamin A; e.g., leaves of <i>Pterocarpus</i> spp., <i>Moringa oleifera</i> , <i>Adansonia digitata</i> , gum of <i>Sterculia</i> spp., palm oil of <i>Elaeis guineensis</i> , bee larvae and other animal food. Fats and oils are needed for synthesis of Vitamin A.
Iron deficiency: in severe cases causes anaemia, weakness and susceptibility to disease, especially in women and children.	Wild animals (including insects, such as tree ants), mushrooms (often consumed as meat substitutes) and forest leaves (such as <i>Leptadenia hastata</i> , <i>Adansonia digitata</i>).
Niacin deficiency: common in areas with maize staple diet; can cause dementia, diarrhoea and dermatitis.	Forest fruits and leaves rich in niacin, such as <i>Adansonia digitata</i> , fruit of <i>Boscia senegalensis</i> and <i>Momordica balsamina</i> , seeds of <i>Parkia</i> spp., <i>Irvingia gabonensis</i> and <i>Acacia albida</i> .
Riboflavin deficiency: common throughout Southeast Asia; causes skin problems in those with rice diets.	Forest leaves high in riboflavin, notably <i>Anacardium</i> spp., <i>Sesbania grandiflora</i> , and <i>Cassia obtusifolia</i> , as well as wild animals, especially insects.
Vitamin C deficiency: common to those consuming monotonous diets; causes susceptibility to disease and weakness.	Forest fruits and leaves, particularly fruit of <i>Ziziphus mauritiana</i> , <i>Adansonia digitata</i> and <i>Sclerocarya caffra</i> ; leaves such as <i>Cassia obtusifolia</i> ; and gum of <i>Sterculia</i> spp.

Source: http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/V7540e/V7540e15.htm (FAO 1995).

dilution of iodine. Repeated cropping of poor soils sometimes contributes to iodine loss. Particular food crops can exacerbate problems with iodine—whether by fixing soil iodine in the soil and thus making it inaccessible to people eating the crop (Akhtar 1978) or by interfering with the body's ability to use iodine (Chapman 1982).

The International Council for the Control of Iodine Deficiency Disorders lists some of the effects of iodine deficiency:

Iodine deficiency is the single most common cause of preventable mental retardation and brain damage in the world. It also decreases child survival, causes goiters, and impairs growth and development. Iodine deficiency in pregnant women causes miscarriages, stillbirths, and other complications. Children with [iodine deficiency disorders] can grow up stunted, apathetic, mentally retarded, and incapable of normal movements, speech, or hearing. (<http://www.people.virginia.edu/~7Ejtd/iccidd/aboutidd.htm>)

Hetzel et al. (1987) conclude that some 800 million people live in iodine-deficient environments, 190 million suffer from goiter, more than 3 million have overt cretinism, and millions more suffer from some intellectual deficit.

A UN website, <http://www.unsystem.org/scn/archives/npp03/ch06.htm> - TopOfPage, identifies Bolivia, Ecuador and Peru (all well-forested countries) as having high levels of cretinism associated with goiter; and Costa Rica, Cuba and Uruguay have a prevalence of goiter of over 10% in schoolchildren. Practically all countries in Africa suffer serious iodine deficiency problems, with eastern Cameroon representing an extreme case: 85% of the female children aged 11 to 15 years have palpable goiters—though African data generally are scanty. Prinz (1993) discusses the role of goitrogenic agents in food in Central Africa, with special emphasis on cassava. He found up to 80% of the Azandé in his research area suffering from goiter, a recent phenomenon. He links the increase in goiter to increasing consumption of toxic cassava (due to the lack of effective detoxification procedures), a shortage of protein, and the substitution of table salt without iodine for plant ash salt, which contains iodine.

Iodine deficiency disorders are an important health problem for a large part of the Indonesian archipelago, including Java, Sumatra, Kalimantan (Borneo) and Sulawesi. Papua (Indonesian New Guinea) is also highly goitrous, with 20% to 63% of the general population afflicted in some way. In 1983, noniodised salt was prohibited in Indonesia by a decree signed jointly by the ministers of health, welfare and commerce with the aim of total prevention of iodine deficiency disorders (Hetzel et al. 1987). Since then, rapid progress in goiter prevention has been made in Java and Sumatra. Some forest peoples live in salt-deficient areas, far from markets; iodising purchased salt is not effective in such circumstances.

Aflatoxins, which are carcinogenic and immunotoxic (and cause growth retardation in animals), occur in foods (especially peanuts, corn) contaminated by fungal growth. Conditions that increase the likelihood of acute aflatoxicosis in humans include limited availability of food, environmental conditions (e.g., humidity) that favor fungal development in crops and commodities, and lack of regulatory systems for aflatoxin monitoring and control—all common conditions in tropical forests. Flours, nuts and seeds that are stored are susceptible to fungus attacks and aflatoxins, as well as household pests (rats, cockroaches, weevils, etc.). Such attacks are particularly prevalent and problematic in tropical forest environments, where the climate is conducive to the growth of fungi.

Evidence of acute aflatoxicosis in humans has been reported from many parts of the world, particularly developing countries (e.g., Uganda, India). Gong et al. (2002) linked levels of aflatoxin exposure in children to stunting and being underweight in Benin and Togo (see also Peden 2000, on the harmful effects of mycotoxins, especially *Aspergillus flavus* and *Fusarium verticillioides*, in sub-Saharan Africa). The syndrome is characterized by vomiting, abdominal pain, pulmonary edema, convulsions, coma and death with cerebral edema and fatty involvement of the liver, kidneys and heart. Access to fresh food (reduced reliance on stored foods) is one strategy for combating this problem.

Some foods are poisonous or indigestible if not cooked properly. Some tropical species with underground storage organs—yams, bulbs, roots, rhizomes, tubers—require long detoxification procedures before eating (Hladik

et al. 1984, or De Garine and Bahuchet 1990). When these procedures are ineffective or neglected, toxic effects can arise. The eating of raw cassava—containing varying amounts of cyanide—is believed to be widespread in some regions of Africa (where cassava is not native). Syndromes associated with this practice are best recognized in Nigeria (Osuntokun 1973, 1980, 1981). Bitter cassava is grown for various reasons, including good storage capabilities, resistance to pest infestations, and greater productivity (see Elias et al. 2004 for a good review of the issues and the literature). In its native range in South America, cassava is not generally associated with any such problems—apparently because of local knowledge and management of landraces with varying levels of toxicity and effective processing (see also Hladik and Dounias 1993 on toxicity in wild yams and local people's management thereof).

Begossi (1996) looks at the role of food taboos in a Brazilian forest in protecting human health. Local cultural beliefs hold that fish with certain culturally defined characteristics should be avoided by people in poor health. From a medical point of view, eating these fish is risky because they may be toxic or rot quickly.

Another food-related concern has to do with the emergence of viral diseases dangerous to humans in forests (discussed in more detail in Section 3). Hardin and Auzel (2001) discuss the implications of such diseases, with particular reference to the association between consumption of wildlife and the likelihood of contracting and spreading disease.

In humans, geophagy, the eating of soil, is sometimes linked to women's nutritional status. Geophagy is widespread amongst rainforest animals and is seen as a) a possible source of minerals, b) a means to reduce the toxic effect of certain plant defense compounds in the animals' diets, and c) a means to deal with parasites and diarrhea (e.g., Diamond 1999; also Gilardi et al. 1999; Wiley and Katz 1998). Some consider the practice in humans to be evidence of emotional problems. Hardenbergh (1997) describes it in Madagascar's Ranomafana National Park, and Anyinam (1995) refers to it in Africa more generally, as well as among rural peoples in the southern United States. The practice of geophagy is widely associated with pregnancy. Walker et al. (1997) conclude that a woman eating 100 g of white clay per day would obtain 322% of her recommended



Indonesian woman from Sungai Telang displays newly harvested cassava roots (Jambi) (Photo by Carol J. P. Colfer)

dietary allowance for iron, 70% for copper and 43% for manganese.

Mozafar (1994) found that vitamin B-12 could be obtained directly from the soil (though the doses are debatable). Such ingestion appears, however, also to be related to illness, particularly the presence of intestinal worms. The recognized association between iron deficiency and geophagy (pica) has led to debate as to which is cause and which effect. Harvey et al. (2000) discuss the complex interactions (and scientific uncertainty) about the possible effects of geophagy on the nutritional availability of soil-derived iron on the body. Iron deficiency, common in developing countries, is often related to consumption of foods that inhibit absorption of iron by the body.

Some recent studies tend to view earth eating as a negative practice that leads to worm infection (e.g., Luoba et al. 2005). The literature is diverse and conflicting, and we can only conjecture that earth eating may well reflect different issues in different cases and is not (in the case of human nutrition) clearly linked to tropical forest lands. We note, however, that the traditional cuisine of West Africa includes vegetable dishes prepared with clay as an ingredient.

2.4.3 Uncertainty and Seasonality

A recurring problem for people living in forests is the seasonality of food availability (see Ulijaszek and Strickland 1993, for a collection on seasonality in human ecology)—a problem that much of the literature appears to ignore.

Numerous authors (e.g., Bahuchet 1988; Bailey and Peacock 1988; Pagezy 1988, 1990b) have documented the seasonality of rainforest produce and the consequent uncertainty of food availability to those who inhabit some forests. Studies in Boomgaard et al. (1997) provide various examples of this kind of uncertainty. Godoy et al. (2000), for instance, note that the value of goods from the community of Krausirpe dropped inexplicably by one-third in two years. De Boek (1994) also notes seasonality as important in his study of hunger among the aLuunde of Zaire—hunger that can lead them to sell their children for food. Milton (1985) hypothesizes that differences in hunting techniques among Mbuti pygmies in the southwestern and northeastern parts of the Ituri forest derive from differences in seasonality—specifically, those in the southwest, where nets are used and game is routinely sold, have a greater seasonal need to supplement their diets. She compares the pygmy-Bantu relationship (in which the Bantu are patrons to pygmy clients) to the relationship she observed between the hunter-gatherer Maku and their patrons, the Tukanoans, in the Amazon. She suggests that the seasonal need for energy prompted both hunter-gatherer groups to seek this relationship to ensure food security during times of stress.

Ongoing research, already spanning 10 years in Pará State (Brazilian Amazon), indicates that phenological cycles can imply large year-to-year fluctuations in fruit collection, dropping to zero some seasons (Shanley, personal communication 2004). Caldecott (1988) makes the same point in dipterocarp forests, with serious implications for wild pig populations (and thus for human access to meat); see also Curran et al. 1999).

Testart (1988) makes a different case. He agrees that there is seasonality in rainforests but argues that there are no periods of extreme shortage—and thus no famines, traditionally, and no urgent need to store food. He contrasts this to the situation of more settled hunter-gatherers (like those in the forests of the American Pacific Northwest) who did store food because there were predictable periods

of both greater shortage and greater plenty. Bahuchet (1990) notes the role of cooperative sharing between Aka pygmy families and communities of the Central African Republic in overcoming seasonally induced uncertainty, and de Garine and Pagezy (1990, 43) note that the Mvae and Yassa of Cameroon “can hardly distinguish which period of the annual food cycle is the least favourable.” This seems true also in Mamberamo (West Papua) (Sheil, personal observation).

2.4.4 Fuelwood

Wood is the main energy source in most Third World rural communities (2 billion people are said to rely on it, Ezzati and Kammen 2002). Its connection to health, through both nutrition and hygiene, is highlighted in Barany et al. (2001). Although access to fuelwood is not a problem in most moist tropical forests, it is a problem in many dry forests (see Arnold et al. 2003 for a recent and thorough review of the fuelwood literature) and can become a problem in moist forests that are being degraded. Fuelwood shortages can affect the nutritional value of foods consumed. Hoskins (1990) points out that cooking releases the nutrients in some food, making them edible and appealing. Shortages of fuelwood can also lead to undercooked food, increasing the risk of food-borne diseases (FAO 1991). Food processing—smoking, drying or cooking—can also extend the shelf life of foods but brings its own problems (FAO 1991). All these activities need an energy source, with wood being the most common.

Fuelwood is associated with serious health risks from smoke inhalation. Ezzati and Kammen (2002) have stressed the respiratory dangers of the use of fuelwood. They have shown reductions in acute respiratory infections in children, after the introduction of several strategies to reduce exposure to smoke in Mpala Ranch in Kenya. Tucker (1999) provides an extensive survey of efforts to encourage solar cooking around the world; Environment Australia (2002) provides similar conclusions from an Australian survey on air pollution and toxins. Melnick et al. (2005) also describe high rates of indoor air pollution affecting mainly women and children. Kirk Smith, at the School of Public Health at the University of California, Berkeley, has recently mounted a major project examining such effects globally (see e.g., Smith et al. n.d.; or Warwick and Doig

2004 for a summary of health implications of indoor air pollution more generally).

Bailis and others (2005) anticipate nearly 10 million premature deaths among women and young children exposed to wood smoke from stoves in sub-Saharan Africa by 2030, if current trends continue (compared with 400 000 in 2000). These authors recommend a large-scale shift to burning charcoal, combined with sustainable forest management to ensure a continuing supply during the transition, plus use of more efficient charcoal-production technologies. Such a program, they calculate, could cut premature deaths by 1 million to 3 million and reduce greenhouse gas emissions by 45% to 65%, depending on whether it is implemented over a 50-year period or more rapidly, respectively. Tucker (1999) describes a project in Haiti intended to build on the Clean Development Mechanism to support efforts to switch from fuelwood to solar power.

Rathgeber (1990) reports findings from a project in Burkina Faso, which looked at the impact of fuelwood shortages on family nutritional intakes, finding that as women spent more time searching for firewood, they had less time for agriculture. This in turn led to lower crop yields and a reduced level of food for family consumption as well as a smaller surplus for sale in local markets. At the same time, women were cooking less frequently and serving their families nutritionally inferior store-bought foods or foods cooked several hours earlier and often stored too long and/or under unsanitary conditions. Fuelwood shortages generally force women to spend more time collecting wood and allow less time for food production and cooking (FAO 1996a).

2.4.5 'Modernization'¹⁵

The final problem discussed here, and one of the most important, pertains to efforts to resettle or 'modernize' forest populations. In Indonesia, for instance, the government has made repeated efforts to bring forest peoples out of the forest (and out of their 'savage' ways). Dounias et al. (2004) compare Punan living far upstream with those resettled near a small town and conclude that the nutritional status of those in the remote areas is better. These authors conclude, 'There is strong consensus among anthropologists who work among recently settled hunter-gatherers that the shift from nomadic to sedentary lifestyles generally compromises health and well being'



This Chinese woman is carrying a heavy load of fuelwood to the Jianquan paper mill in China (Photo by Manuel Ruiz-Perez)

(2). Work by Melnyk (1995) in Venezuela and Koppert et al. (1993) in Cameroon reaches the same conclusion.

Santos and Coimbra (1996) report negative nutritional and other implications for the Surui of southwest Amazonia, who were invaded by settlers in the 1970s and then partially integrated into coffee farming and the timber industry (see also Vickers 1994 on the Siona and Secoya of Amazonian Ecuador). Suarez-Torres et al. (1997) make many of the same points on a broader scale, critiquing the 'development' impacts on health in Ecuador generally, as do Moran and Fleming-Moran for the Amazon (and by implication, Ferguson 1990, for Lesotho).

Natsuhara and Ohtsuka (1999) describe the impacts of modernization in a village near Goroka in the Eastern Highlands Province of Papua New Guinea, looking at consumption of rice, tinned foods and snacks: Protein levels increased, but salt intake also rose, to excess. Many of these same issues arise in a comparative study (Umezaki et al. 1999) of two New Guinea communities (Wenani, which was adequately fed, and Heli, which was not) after heavy rains. Important issues included population increase in both communities; land tenure conflicts among the adequately fed people of Wenani (who demanded pig compensations, which spurred increased production); the

prevalence of *Imperata* grasslands in Heli and the agricultural use of swamp areas in Wenani; and the frequent absence of Heli men for wage labour as part of a gold rush.

Kuhnlein and Receveur (1996) argue strongly for maintaining the positive elements of traditional food systems. They summarize eight case studies examining changes in diets over time, of which four—from northern Ghana, Guatemala and Papua New Guinea—are probably forest peoples. The diets of the Ghanaians became more stable, with an increase in dietary variety. In Guatemala, there appeared to be an increase in dietary variety, but no change in children's nutritional status. The conclusions from Papua New Guinea appear to be conflicting, with some gains and some losses and considerable variation from place to place. Specific dietary changes included a switch from starchy tubers to rice, and from traditional sources of meat and fish to tinned produce, as well as increases in fat and alcohol consumption. These authors identify some general global trends as dietary change interacts with

lifestyle changes like smoking, disintegration of social networks, decreasing physical activity, and increased stress... [T]he major trends that appear in the literature relate to obesity, diabetes, and the complications of diabetes including cardiovascular disease. (434)

Very young
Gabonese boys
drinking beer in
Ivindo National
Park (Photo by
Carol J. P. Colfer)



Ohtsuka (1993) finds a similar pattern among the Gidra of lowland Papua New Guinea, where the incoming western diet brought some nutritional benefits but also health problems. Gracey (2000) compares aboriginal Australian diets in the past with their current diets and finds grave cause for concern about reductions in breastfeeding and increases in hypertension, alcohol consumption, cardiovascular disease and diabetes. Solomon (2000) notes, though, that most foods in the developing world are plant-based, a diet associated with high prevalence of deficiencies of vitamin A, iron, zinc, riboflavin and vitamin B-12. He argues for a development strategy that maintains and reinforces traditional eating patterns while improving delivery of micronutrients.

2.5 People, Forests and Foods: Conclusions

In this section, we first examined the forest as a food producing habitat, emphasizing the importance of soils, the interactions of various organisms (2.1) and the implications of landscape changes as these relate to human health (2.2). We then turned to the questions of food availability and human dependence on the forests for food (2.3), examining first the nutritional constraints to forest-based human subsistence (hunter-gatherer systems) and then looking at the more common situations where people rely differentially on both foods from forests and from other sources. The final section (2.4) identified five important problems: intrahousehold inequity in food distribution, food-related diseases and dangers, uncertainty related to seasonality, fuelwood issues and the nutritional impacts of social and environmental change.

A recurrent theme in the literature on food and forests is the need for greater interdisciplinary cooperation (e.g., Trefon and de Maret forthcoming). Egal et al. (2000) describe an effort to bring together nutritionists and foresters from Senegal, Mali and Burkina Faso. Successful aspects of their workshop included joint analysis of causes of malnutrition, use of a causal model of the system, a focus on possible interventions for a given objective (in this case, improving nutritional status of people in a particular place), development of indicators and visualization techniques, and an emphasis on the local level, all of which contributed to achieving consensus among divergent

participants. This workshop of specialists was followed by village-level workshops that used rapid rural appraisal techniques—an essential step, from Egal’s perspective. Ogden (1990a) reports on a similar effort bringing together nutritionists and foresters in regional workshops (one in Thailand and one in Zambia) to assess areas of mutual interest.

Despite the considerable scientific literature on the subject, there remains real uncertainty about the future importance (and possible substitutability) of forest foods in forest peoples’ lives. What is the relative health balance of traditional dietary systems vis-à-vis ‘modern’ ones? Can emergency food provision from governments or other actors moderate the impacts of seasonality? If forest degradation continues, will a mass exodus from forested areas follow? Will substitutes for the bushmeat, forest fruits, and other foods people now depend on become readily available? Who will ‘win’ and who will ‘lose’ if forest foods become scarce: forest communities vis-à-vis outsiders or urban dwellers, women vis-à-vis men, or other marginalized groups vis-à-vis dominant groups within communities?

Below, we summarize the conclusions from each section of this chapter and offer policy suggestions, categorized by our two central issues: the state of health of the population in forests, and the causal links between forests and human health.



Ecologist Patricia Shanley, working with Amazonian villagers, Brazil (Photo by Jurandir Galvao)

Summary

- 2.1 Forest habitats are often characterized by poor soils and plants whose defenses make them difficult for people to use as food. Forests often have little potential for supporting intensive agricultural production or large populations, but they serve as important genetic reservoirs for wild and semiwild plants and animals. They provide food to people now and have the potential to provide more food through selective breeding and also, more controversially, through genetic manipulation.
- 2.2 Landscape modification is often motivated by the need for food, though some manipulations maintain forest cover and increase food production at the same time. Logging, hunting and invasive species (plants and animals) change the composition of the forest but with location-specific impacts on food availability; different stages of forest regrowth may also vary in food productivity. Climate change is likely to cause location-specific and unpredictable impacts on food. The proximity of wild, forest-dwelling animals can be a mixed blessing, involving raids on crops but also easier hunting.
- 2.3 Hunter-gatherers’ access to nutrients from the forest has been open to considerable debate—particularly about the roles of protein, carbohydrates, and fats in their

diets—and such peoples' health status has been evaluated very differently in different places. Some are in better health than their neighbours, but few would be considered truly healthy.

There is widespread agreement that forests serve as important safety nets for people living in and near forests, but forests may also serve as poverty traps, since the potential for better livelihoods may be small. People residing in and near forests obtain nutritious foods from forests, in varying amounts: Hunter-gatherers and integral swidden farmers know more about finding food in the forest than, for example, settlers, colonists, refugees and other in-migrants. The nutritional value of many forest foods is unknown, despite indications that many forest animal, plant and insect species contain important nutrients. Efforts to develop relevant databases are in early stages.

Poor people, often dependent on common property resources, are particularly dependent on forests for food. Many have a reasonably varied diet. The consumption of meat can be very high, raising serious concerns about sustainability of wildlife populations in many places. Forests also supply goods that are indirectly important for the provision and preparation of food, like poles, fodder, and fuel.

Commercialization of forest products, spurred by growing urban markets and demand from logging camps and facilitated by improved weapons and transport, has threatened the sustainability of wildlife populations (both for biodiversity and for food). Sale of wildlife and other nontimber forest products represents a source of income for local families but also sometimes reduces the quality of local diets.

- 2.4 Distribution of food within households can be inequitable, with women and girls particularly at risk. Diseases can adversely affect people's access to foods. HIV/AIDS reduces the effective working adult population both through death and through caregiving responsibilities. Vitamin A and iodine deficiency, mycotoxin and other toxic exposure, viral diseases spread through contact with wildlife, and geophagy all affect the health of people living in forested areas. Uncertainty related to seasonality causes serious hunger in some areas. Use of fuelwood, common in forested areas, presents serious respiratory health hazards, particularly for women and children. 'Development' processes often have adverse effects (as well as some beneficial impacts) on people's health.

Policy Recommendations

A. Human Health Conditions

Recommendations for health professionals

- Recognize that foods from forests may be deficient in particular nutrients, with potentially negative implications for people's nutritional status.
- Evaluate local forest foods' nutrient content and adjust advice on nutrition accordingly.
- Learn more about the health needs of forest dwellers, from the local people themselves.

Recommendations for educational and health personnel

- Counter cultural prescriptions that disadvantage females, particularly during vulnerable periods like pregnancy and lactation and during childhood.

- Educate field personnel about the links between women's status and the health of families.
- Offer free or inexpensive family planning services, and seek win-win mechanisms that discourage in-migration and encourage out-migration to reduce pressure on food resources and improve family health.

Recommendations for forestry and health professionals

- Increase efforts to communicate with women and value women's views, thus contributing to a rise in women's social status, as a strategy to improve overall health.
- Collaborate effectively among disciplines and develop early warning systems about food availability and people's nutritional status.

- Share databases in efforts to avert local health crises due to seasonality and ‘development’.

Recommendations for development planners and foresters

- Ensure that local people’s subsistence needs continue to be met when commercialization efforts are underway.
- Consider biodiversity values for forest inhabitants and costs to their livelihoods when proposing alternative uses of forests.
- Support households seeking to switch from fuelwood to more efficient, less polluting fuels and use various media to inform people of the pros and cons of each.

- Encourage silviculture of cleaner fuelwood species near people’s homes.

B. Policy Implications for Causal Links between Forests and Health

Recommendations for natural resource specialists

- Analyze soils as they relate to health problems, such as deficiencies in iodine, calcium, iron and vitamin B-12.
- Monitor wildlife likely to be disease vectors.
- Encourage a shift from fuelwood to alternatives to enhance forest sustainability and reduce respiratory diseases, especially in dry forest areas.

Chapter 3

Health Problems in Forests

The ubiquity of disease in forested areas is an important consideration as we look at the state of human health in forested areas and the causal links between forests and health. In this section, we first survey the causes of disease in forested areas (summarized in Table 4). We then review some disease-by-disease studies. Rather than do a thorough review of all diseases that occur in forests, we provide some sense of the nature and extent of diseases and other important health problems of the recent past.

Macintyre et al. (2002) discuss theories about the impacts of place on health. Although they do not deal specifically with forests, diseases that thrive in forested environments would seem to fit within their theoretical framework. They find that “few investigators have attempted to hypothesize what features of the local social or physical environment might influence health, and then tested these hypotheses” (129). Descriptive information ascribes both positive and negative health effects to forested environments. These authors postulate three types of explanations for geographical variations in health: the characteristics of individuals in particular places, the local physical and social context, and the shared norms, traditions, values, and interests of communities. These authors also emphasize the long time lags that are likely to exist between cause and effect when looking at the relationship between place and health. See also Newson (1998) for further discussion of the interrelationships among disease, human behaviour, population size and environment.

Feldmann et al. (2002) note the significance of infectious disease in human mortality. They report that infectious diseases cause 48% of premature deaths and remain the biggest cause of disabilities globally; such diseases rank second as a cause of death for adults,

and first for children under the age of four. Tropical diseases (very common in tropical forests) afflict roughly half a billion people (a 10th of the world’s population) and claim about 20 million lives every year—particularly in tropical, less-developed countries. HIV/AIDS has claimed some 24 million lives. A handful of diseases (AIDS, diarrhea, TB, malaria, measles and acute respiratory infection) account for nearly 90% of all deaths. Drug-resistant agents, pesticide-resistant vectors and lack of antiviral drugs and treatments for protozoal, helminthic and fungal infections keep infectious disease a particularly challenging public health problem in developing countries.

Feldmann et al. (2002) also note the fear with which we confront emerging infectious diseases like Ebola. The unfamiliarity of these diseases means that our knowledge of control and treatment are by definition limited. Filoviruses, hantaviruses, paramyxoviruses, flaviviruses, *Yersinia pestis* and other agents of these diseases are transmitted via wild animals, either directly or sometimes via arthropods. Table 5 lists some recently discovered infectious diseases.

It is not only western cultures that fear forests for their diseases. It seems that fear of parasitic illnesses—presumably the local form of river blindness, which is associated with clean forest streams—caused forests to be avoided in various parts of Eastern Africa until the modern era when colonial authorities wiped out the disease (often with DDT).

Mayer (2000) urges a political-ecological approach to health—a deeper understanding of the interaction between population, environment, power and disease, including economic drivers. He traces some of the broader societal phenomena that affect disease incidence and geography, such as increased mobility and large-scale landscape changes.

Table 4. Diseases and Their Links to Forests

Disease	Environmental factors	Sources
Malaria (3.2)	Linked to dam building in Ghana	Hunter 2003
	Reduced by improved irrigation and water management in Côte d'Ivoire, Mali	Peden 2000
	Linked to war in Nicaragua	Service 1989
	Linked to dams, irrigation, urbanization, travel, deforestation	Gratz 1999
Ebola (3.3)	Linked to ecological degradation, Central and West Africa	Sommerfield 1994
	Linked to animal hosts in their own habitats	http://www.health.state.nd.us/EPR/public/viral/VHFeverFacts.htm
	Transmission among humans may not be linked to hunting	http://whyfiles.org/121emerg_infect/index.php?g=biblio.txt
Marburg (3.3)	Linked to ecological degradation, Central and West Africa	Sommerfield 1994
	Linked to animal hosts in their own habitats	http://www.health.state.nd.us/EPR/public/viral/VHFeverFacts.htm
Lassa (3.3)	Linked to ecological degradation, Central and West Africa	Sommerfield 1994
	Linked to animal hosts in their own habitats	http://www.health.state.nd.us/EPR/public/viral/VHFeverFacts.htm
Mercury poisoning (3.4)	Linked to gold mining	
Trypanosomiasis (sleeping sickness) (3.5.1)	Linked to cattle raising (through tsetse fly vector)	White 1995
	Linked to forests and shrubs in Uganda, Côte d'Ivoire	Molyneux 1998
	Difficult to control in Central African Republic, Sudan, Zaire, Angola (because of war, unrest)	Molyneux 1998
Chagas disease (3.5.1)	Linked to human migration and deforestation in Amazon	Coura et al. 2002
	Reduced by house spraying in Argentina, Bolivia, Brazil, Uruguay, Chile, Paraguay	Molyneux 1998
Onchocerciasis (river blindness) (3.5.2)	Linked to deforestation in West Africa, Central Africa, East Africa, Ecuador, Guatemala, Mexico	Patz et al. 2000
	Variable links to deforestation in Africa, Central America, South America	Walsh et al. 1993
	Linked to forest cover and land cover class in West Africa	Thomson et al. 2000
Loa loa (3.5.2)	Linked to deforestation in Central and West Africa	Patz et al. 2000
	Cannot survive outside forests	Walsh et al. 1993
	Vector <i>Chrysops</i> increases in deforested areas	Molyneux 2002
Yellow fever (3.5.3)	Linked to deforestation processes especially in West Africa	Galat and Galat-Luong 1997; Digoutte 1999
	Linked to strips of trees along river courses and potentially to forest clearing in Amazon in Brazil	Mondet 2001
Leishmaniasis, cutaneous (3.5.4)	Considered occupational disease of forest workers	http://www.who.int/tdr/diseases/leish/direction.htm

Disease	Environmental factors	Sources
	Linked to increased exposure to sand flies (new settlements, intrusion into primary forest, deforestation. Dam and irrigation construction)	http://www.who.int/tdr/diseases/leish/direction.htm
	Linked to <i>chicleros</i> (gum collectors), agricultural workers, men overnighting in forest in Yucatan, Mexico	Andrade-Narvaez et al. 2003
	Linked to deforestation and human colonization in South and Central America	Walsh et al. 1993
	Linked to deforestation, migration, and agriculture development in Latin America, Amazon, Nile	Patz et al. 2000
	Linked to afforestation	Molyneux 2002
	Linked to forest and pasture in northern Brazil	
	Linked to forest degradation in Pernambuco and to peridomestic habitats in deforested areas of Brazil	Peterson and Shaw 2003
	No reduction in disease incidence with tree cutting or insecticide spraying	Teodoro et al. 1999
Leishmaniasis, unsp. (3.5.4)	Linked to dams, irrigation, urbanization, travel, deforestation	Gratz 1999
Leishmaniasis, visceral (3.5.4)	Linked to neotropical outer-city zones, war and drought in Africa	Walsh et al. 1993
Lymphatic filariasis (elephantiasis) (3.5.5)	Linked to dam building in Ghana Probably reduced by deforestation in Malaysia, Indonesia	Hunter 2003 Walsh et al. 1993
Schistosomiasis (3.5.6)	Increased with dam building in Ghana	Hunter 2003
	Linked to irrigated agriculture in Mali	Brinkman 1994
	Linked to deforestation in West and Equatorial Africa	Walsh et al. 1993
	Linked to forest cover in Bahia, Brazil (via remote sensing)	Bavia et al. 2001; Brouwer et al. 2003; Ndekha et al. 2003; Uchoa et al. 2000; Patz et al. 2000; Izhar et al. 2002
Dracunculiasis (Guinea worm) (3.5.7)	Linked to dam building in Ghana Dramatically reduced by bore holes Control disrupted by civil unrest in Ghana, Sudan Control successful in Mali, Niger, Mauritania, Burkina Faso, Uganda, Nigeria, Ghana	Hunter 2003 Hunter 1997 Molyneux 1998 Molyneux 1998
Nipah virus (3.5.8)	Linked to forest habitat of bats and flying foxes	CDC 1999; Chua et al. 200, 2001; Eby 1991; Johara et al. 2001; http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/AC449E/ac449e04.htm
Chamorro brain disease (3.5.9)	Linked to cycad trees and flying-fox bats	Cox et al. 2003
Rabies (3.5.10)	Deforestation for cattle-ranching allows population of bat hosts to rise	Emmons and Fear 1997
Q fever (3.5.11)	Linked to residence near forest in French Guiana	Gardon et al. 2001

Disease	Environmental factors	Sources
<i>Taenia solium</i> cysticercosis (tapeworm) (3.5.12)	No forest links	Carrique-Mas et al. 2001
Dengue (3.5.13)	Linked to dams, irrigation, urbanization, travel, deforestation	Gratz 1999
Kyasanur forest disease (3.5.14)	Linked to deforestation in South West India	Sommerfield 1994; Nichter 1987; Walsh et al. 1993; Haggatt 1994
Emerging Vector-Borne diseases (3.5.18)	Likely links to climate change, global warming	Graczyk 2002
Plague (3.5.158)	Linked to dams, irrigation, urbanization, travel, deforestation	Gratz 1999
Oropouche (ORO) fever (3.5.18)	Linked to deforestation	Tesh 1994
General adverse health effects	Links to dams generally Links to deforestation	Lerer and Scudder 1999; Mayer 2000 Patz et al. 2000

Note: Numbers in the first column correspond to sections of the text where these health problems are discussed.

Table 5. Emergence of Selected Infectious Diseases Affecting Humans

Discovery	Agent	Disease in humans
2001	Human metapneumovirus	Bronchiolitis pneumonia
1999	Nipah virus	Encephalitis
1997	Avian influenza virus (H5N1)	Pneumonia
1996	New variant of Creutzfeldt-Jacob disease (nvCJD)	Creutzfeldt-Jacob disease (new variant)
	Australian bat lyssavirus	Rabies
1995	Human herpesvirus 8 (HHV8)	Kaposi sarcoma
1994	Sabia virus	Hemorrhagic fever
	Hendra virus	Hemorrhagic fever, encephalitis(?), pneumonia(?)
1993	Sin nombre virus	Hantavirus pulmonary syndrome
1992	<i>Vibrio cholerae</i> O139	Cholera
1991	Guanarito virus	Hemorrhagic fever
1989	Hepatitis C virus	Hepatitis
1988	Hepatitis E virus	Hepatitis
	Human herpesvirus 6 (HHV6)	Roseola (exanthema subitum)
1983	Human immunodeficiency virus (HIV)	Acquired immunodeficiency syndrome (AIDS)
1982	<i>Escherichia coli</i> O157:H7	Bloody diarrhea
	<i>Borrelia burgdorferi</i>	hemolytic uremic syndrome
	Human T cell leukemia virus (HTLV) 2	Lyme borreliosis
1977	<i>Campylobacter jejuni</i>	Campylobacteriosis
1976	<i>Cryptosporidium parvum</i>	Cryptosporidiosis
	<i>Legionella pneumophila</i>	Legionellosis
	Ebola virus	Hemorrhagic fever

He also briefly discusses *kuru*, a degenerative neurological disease that occurred primarily among forest women in New Guinea. After the demise of the practice of ritual cannibalism, the disease disappeared.

In their longitudinal study in northern Uganda, from 1992 to 2002, Accorsi et al. (2005) find important roles for war, population displacement, social structural loss or disruption, and breakdown of the health system in increasing the risk of infectious disease, malnutrition and war-related injuries. Vulnerable groups (infants, children and women) accounted for 80% of admissions, and malaria in children was “overwhelming” and increasing. Admissions related to HIV/AIDS and TB decreased with the implementation of community-based services, but these two diseases and Ebola still accounted for a heavy disease burden. These authors concluded that childhood diseases could be dramatically reduced by low-cost interventions.

Deforestation has been linked to several diseases (discussed further below), according to de M. Santos (2005, 5): ‘Deforestation and habitat destruction ... have a direct impact on [various] vector-borne diseases. In some cases, pathogens and vectors may be lost, but in many other situations, increased levels of disease have followed deforestation’.

Epstein (1994) makes general observations about the relationship between forest clearing, subsequent changes in rodent species (as disease vectors) and the introduction of vulnerable human populations, as important factors in the appearance of arenaviruses. Walsh et al. (1993) provide a more complete survey of diseases exacerbated by forest clearing. Petney (2001) provides a long list of factors that can influence health and then examines them in the context of northeastern Thailand (a deforested area). His findings, like those of many others, are mixed: Some of the changes have resulted in worse health, some to improved health.

People’s understanding of disease and its spread is also important. MacLachlan and Namangale (1997) conducted a study of college students in Malawi (a country whose landscape is characterized by miombo woodland—a dry forest type), looking at their perceptions of four common diseases: AIDS, malaria, schistosomiasis and the common cold. The students had some misconceptions. Although malaria was still the major killer in Malawi when the study was done, they clearly

identified AIDS, which by 1994 affected 12% of the population, as the most dangerous. Neither malaria nor schistosomiasis was seen as terribly serious, implying some difficulties motivating people to try to overcome them.

An edited volume by Wilson et al. (1994) provides a good overview of issues relating to emerging diseases, primarily from a medical perspective. Dobson et al. (1997) provide a nice introduction to the topic of frightening human diseases in their ecological context—discussing HIV/AIDS, Lyme disease,¹⁶ hookworm, cholera and Ebola in passing—and conclude by urging better interdisciplinary collaboration between ecologists and physicians. Epstein et al. (2003) give examples of complex interactions and specific diseases, concluding that specialists in wildlife, insects, human health and climate could collaborate to develop early warning systems and environmentally friendly interventions. See Table 6 for some geographical links to emerging viral diseases.

Daszak et al. (2000) discuss the impacts of emerging infectious diseases of wildlife on the wildlife themselves, as well as on domestic animals and human beings.

Dounias (personal communication, 2005) describes how the forest can drastically reduce the action of pathogens and control the emergence and spread of infectious disease. Genetic and species biodiversity provide alternative hosts for disease organisms, and some stability comes from the interactions among functional groups of species—recyclers, scavengers, predators, competitors and prey (discussed at greater length in Epstein 1997; Chivian and Sullivan 2002; Chivian 2002).

In the remainder of this section, we address HIV/AIDS, malaria, Ebola and mercury poisoning, which give a sense of the variety of ailments (viral, vector-borne, poison) and are prominent in the literature.¹⁷ We then turn to 20 other diseases, mostly vector-borne, that afflict people living in forests. We then sum up what we have found from our skimming of the medical literature.

3.1 HIV/AIDS

This disease, believed to have originated in forests, spans both of our concerns—the state of health of forest dwellers and the forest-human health link. Sharp et al. (2001) report that in western Africa, the sooty mangabey (*Cercocebus atys*) is the only species naturally infected with viruses closely related to HIV-2

Table 6. Geography of Selected Emerging Viral Diseases (in Grifo 1997)

Virus family	Virus	Signs, symptoms	Natural host	Geographic range
Orthomyxoviridae	Influenza	Respiratory	Fowl, pigs	Worldwide
Bunyaviridae	Hantaan, Seoul and other hantaviruses	Hemorrhagic fever, renal syndrome, respiratory stress Fever, hemorrhage	Rodents (e.g., <i>Apodemus</i>)	Asia, Europe, United States
	Rift Valley fever		Mosquitoes, ungulates	Africa
Flaviviridae	Yellow fever	Fever, jaundice	Mosquitoes, monkeys	Africa, South America
	Dengue	Fever, hemorrhage	Mosquitoes, humans, monkeys	Asia, Africa, Caribbean
Arenaviridae	Junin (Argentine HF)	Fever, hemorrhage	Rodents (<i>Calomys calossus</i>)	South America
	Machupo (Bolivian MF)	Fever, hemorrhage	Rodents (<i>Calomys calossus</i>)	South America
	Lassa fever	Fever, hemorrhage	Rodents (<i>Mastomys natalensis</i>)	Africa
Filoviridae	Marburg, Ebola	Fever, hemorrhage	Unknown; possibly primates	Africa
Retroviridae	HIV	AIDS	Possibly primates	Worldwide
	HTLV	Adult T-cell leukaemia, neurological disease	Human virus (perhaps originally primate virus)	Worldwide, with endemic foci

Source: Morse (1994, 326, Table 1).

HF= hemorrhagic fever; HIV=human immunodeficiency virus; HTLV=human T-cell leukaemia/lymphoma virus.

(which is endemic in that area). Chimpanzees (*Pan troglodytes*) in western equatorial Africa play a similar role for HIV-1, which also appears to have emerged in that region. HIV-1 is composed of three groups (M, N and O), resulting from independent cross-species transmission events. There is evidence that for the M group, the jump from chimpanzees to humans occurred before 1940. These three HIV-1 strains are closely related to the SIV/cpz lineage that affects only the chimpanzee subspecies *P. t. troglodytes* and not *P. t. schweinfurthii* (Gao et al. 1999).

Apetrei et al. (2004) report descriptions of 40 simian immunodeficiency viruses (SIVs) in Africa. These authors conclude that despite

the wide agreement about the simian origin of the two HIV types, there is no evidence that AIDS is acquired like a zoonosis.

Statistics on HIV/AIDS, like those for any sexually transmitted disease must be taken with a grain of salt. Elbe (2002) estimates that in several sub-Saharan countries between a fifth and a third of the adult population is infected with HIV/AIDS (he provides country-by-country estimates as well). He identifies a 5% adult infection rate as a threshold that portends a more widespread and devastating epidemic. USAID (2004) provides a harrowing description of the HIV/AIDS conditions in East and Central Africa—in countries with important forest resources.¹⁸ The agency reports the

overall HIV prevalence rate as 5.7%, though in Kenya it is 13.9%. The USAID report emphasizes the close interconnections among HIV/AIDS, conflict and nutrition and issues a particular warning about the implications for women's status, noting, for instance, that young girls have rates of HIV infection that are five times those of young boys. FAO (2001) presents global data, emphasizing the downward spiral that occurs at a household level: gender inequities, nutritional impacts, breakdown in informal institutions and culture, and higher incidence of poverty and disease (see also Thaxton 2005). Butler (2004) suggests a Malthusian 'check' in Rwanda and relates the spread of HIV/AIDS there to conditions brought about by population pressure (both quantity and speed of increase).

Road and transport networks play an important role in the spread of HIV/AIDS (Helman 1994). Orubuloye et al. (1993) describe the frightening level of sexual activity (and thus exposure to AIDS) in Nigeria among truck drivers and female hawkers. This study, though focused on major roads, is pertinent for forest-dwelling populations because of the transport of logs by truck. Higher HIV infection rates among loggers in Côte d'Ivoire have in fact been observed by Colfer in 1995 and also reported by van Haaften (1995). Tsey and Short (1995) describe a parallel situation when the railroad was introduced in Ghana: Syphilis followed the railway in the early 1900s. In his wider African study, Hunt (1993) found that AIDS was most likely to occur among migrant laborers, suggesting a similar social dynamic. Michael Whyte (personal communication, 19 September 2005) sees the main HIV/AIDS-forest intersection to be "... about armed conflict—in Sierra Leone and Liberia and, above all, eastern DRC and Rwanda. It is about weapons, sexual and other violence, fear and drugs/drink." Elbe (2002) supports this view, maintaining that prevalence rates in the military tend to be two to five times the rates among the general populace (parts of the Zimbabwean army have 80% infection rates). Besides directly affecting the functioning of Africa's military forces, HIV/AIDS has provided them with a tactical weapon: Rape has been used as a systematic tool of warfare in Liberia, Mozambique, Rwanda and Sierra Leone—all countries with significant forest areas, some of which have been both sites and partial causes of their wars (cf. Richards 1992 on Sierra Leone and Liberia). In Rwanda, where 200

000 to 500 000 women are reported to have been raped, there is evidence for a deliberate strategy of infecting women from enemy groups; similarly in the Democratic Republic of Congo, where Ugandan troops are reported to have behaved in similar fashion. Less direct but also important health-related side effects of war include reduced effectiveness of health services, lessened security (and increasing incidence of rape) in refugee contexts, increased intermingling of urban people (with higher incidence of HIV/AIDS) and rural populations, and—because death from HIV/AIDS is more remote than the bullet around the corner—lack of concern about the future both for individuals and for countries.

Anyonge (2005) provides statistics for HIV/AIDS prevalence in the miombo woodlands of southern Africa in 2001: 33.7% in Zimbabwe, 21.5% in Zambia, 15% in Malawi, 13% in Mozambique, 7.8% in Tanzania and 5.5% in Angola. She identifies gender and other inequalities, exclusion from resources, seasonal migration and separation of families as factors that increase vulnerability to AIDS. And she explicitly notes the roles of medicinal plants and forest foods in patient care, with suggestions for increasing access to firewood (to reduce the harvesting labour requirement), developing woodland-based income-generating activities, and sharing forest revenues to support community initiatives to deal with HIV/AIDS in local households.

Gillespie and Kadiyala (2005) document the nutritional implications of HIV/AIDS, observing that people who are undernourished are more affected by the deprivations of HIV/AIDS and may be more susceptible to contracting it. And HIV/AIDS leads to undernourishment—in some cases directly, but more often indirectly, through general destitution because of loss of labor, reduction in agricultural outputs, loss of parents and other caretakers (particularly mothers), etc. Their study suggests specific policies to address the HIV/AIDS problem; they provide practical tips for 'scaling up, mainstreaming and capacity building' and recommend using an 'HIV/AIDS lens' to look at problems¹⁹ and greater cooperation among disciplines.

Lengkeek's (2005) tragic account of HIV/AIDS in sub-Saharan Africa emphasizes agrobiodiversity and indigenous knowledge as important internal and underrecognized strengths of Africa's communities. He calls them potent coping mechanisms for dealing

with the weakened labour force, which is already relying more on forest gathering for daily subsistence.

One interesting finding is that SIV infection is present in numerous African primate species without inducing disease symptoms. Courgnaud et al. (2004) attribute this to host-virus adaptations that have evolved over time in naturally infected primates. In another, earlier study of 788 monkeys in the forests and households of Cameroon, Peeters et al. (2002) report that humans who hunt and handle bushmeat are exposed to many viruses that are genetically highly divergent.

3.2 Malaria

Currently an estimated 500,000,000 people are infected with malaria and infection rates are increasing in many parts of the world. Epidemics have even affected traditionally endemic zones where transmission had been eliminated. These outbreaks are generally associated with deteriorating social and economic conditions, and the main victims are underserved rural populations, particularly pregnant women since the disease is responsible

for a substantial number of miscarriages and low birth weight babies (<http://www-micro.msb.le.ac.uk/224/Malaria.html>). There is currently no vaccine to prevent this disease, and about 200 million people suffer from malaria each year. In fact, malaria causes 2 million deaths each year, mostly children in sub-Saharan Africa.

Working in tropical forests, one becomes inured to the prevalence of malaria, and yet it is in fact a major killer. A recent report indicates that there are nearly 50% more clinical cases of malaria worldwide than previous estimates suggested. Whereas WHO had estimated 273 million cases of malaria worldwide in 1998, with 90% of them in Africa, a recent report raises the estimate of active cases in 2002 to 515 million, with only 70% in Africa. Snow et al. (2005) make a strong case for obtaining better data on malaria, in the effort to attain the United Nation's Millennium Development Goals. Table 7 provides a longitudinal global overview.

Plasmodium, the malaria parasite, is a single-celled protozoan, living as a parasite in human beings (and a few other hosts) and the Anopheles genus of mosquitoes. There are

Table 7. Global Population at Risk from Malaria, ~1900 to 2010

	Global population	Malarious land area (km ²)	Percentage of total area	Countries at risk	Population exposed	Percentage of total population
1900	1,158,409,472	77,594,480	53.16	140	892,373,056	77.03
1946	2,391,400,960	58,565,752	40.12	130	1,635,815,808	68.40
1965	3,363,417,344	53,492,988	36.65	103	1,924,360,320	57.21
1975	4,085,759,488	48,075,780	32.93	91	2,121,086,592	51.91
1992	5,419,255,808	43,650,812	29.90	88	2,565,702,144	47.34
1994	5,582,432,256	39,537,020	27.08	87	2,570,555,136	46.05
2002	6,204,095,488	39,758,172	27.24	88	2,996,419,584	48.30
2010	6,807,085,056	39,758,172	27.24	88	3,410,862,080	50.11

Source: Hay et al. (2004, 17).

Area totals were generated using the maps of all-cause malaria risk distribution through time (Figure 1). The percentage of malarious land area was calculated from a total global land surface area of 145,975,899 km². To estimate countries at risk, territorial designations for 2002 were used throughout (Environmental Systems Research Institute, Inc., Redlands, CA, USA). Country-specific "medium variant" population growth rates from the World Population Prospects database (<http://esa.un.org/unpp>) between 1950 and 2010 were applied to the Gridded Population of the World (GPW) v2.0 to generate population distribution maps for 1900, 1946, 1965, 1975, 1992, 1994 and 2002 to match the malaria risk distribution maps and were also projected to 2010 to enable evaluation of potential future changes in global malaria risk. Global summary counts of these population distribution maps give the accuracy to within 5% of the UNDP global population estimate (<http://esa.un.org/unpp>) for all calculated years. All area and population summaries from these polygons were processed in Idrisi Kilimanjaro (Clark Labs, Clark University, Worcester, MA, USA).

four types of malaria parasite: *Plasmodium falciparum*, the most widespread and dangerous (leading sometimes to the fatal cerebral malaria), and *P. vivax*, *P. ovale* and *P. malariae*, which are less aggressive, but still a danger for weakened people. A number of lesser known malaria species are also implicated in occasional human disease (possibly *P. simiovale*, *P. brasilianum*, *P. tenue*, *P. knowlesi*, http://www.tulane.edu/%7Ewisner/protozoology/notes/pl_sp.html).

The *Plasmodia* develop inside red blood cells, which eventually burst, releasing their parasites, infecting other red blood cells, and continuing to develop. The *Plasmodia* quickly become synchronous, so that all the infected red blood cells burst at the same time, leading to the periodicity of the fever.

Malaria parasites are transmitted only by the female anopheline mosquito, with males feeding only on plants. Though there are about 380 species of anopheline mosquito, only 60 or so are able to transmit the parasite. Like all other mosquitos, the anophelines breed in water, each species having its preferred breeding grounds, feeding patterns and resting place. Their sensitivity to insecticides is also highly variable, see <http://www-micro.msb.le.ac.uk/224/Malaria.html>. A mosquito becomes infected by biting a carrier and then a few weeks later transmits infective forms of the parasite when the mosquito takes another meal. Interestingly the parasites kill mosquitoes. Human victims normally become ill 10 to 15 days after being bitten. Symptoms include fever rising and falling over a period of several hours, often accompanied by diarrhea, nausea and vomiting. The symptoms usually recur following a 2-3 day cycle.

Aron et al. (2001) noted the much greater danger of death from malaria for Africans than for sufferers in other parts of the world. Yet the crisis of HIV/AIDS has to some extent further removed this killer from the limelight. Molyneux (1998) reports that 500 million children under 5 die each year from malaria. WHO, he writes, '... calculates that the economic burden of malaria in Africa [would] be some US \$2 billion in 1997, whilst at the household level it is calculated that 32% of family incomes of the poorest are expended on malaria control' (932).

Malaria is a major cause of morbidity and mortality in Ghana, especially among children and infants who account for 40% of the cases, and its treatment is a major drain

on household finances (Asenso-Okyere and Dzator 1997). Some of the malaria is related to land-use change: Hunter (2003) reports an increase in malaria in Ghana after many dams were built in the 1950s,²⁰ and Brinkman (1994, drawing on work by Khatibu n.d.) found a rise in prevalence of malaria after the introduction of irrigation for paddy rice in Zanzibar.

Patz et al. (2000) provide a thorough review of the recent history of malaria, linking it closely to processes of deforestation (briefly addressed also in Petney 2001, and Aron et al. 2001; see also Norris 2004), though there is contradictory evidence on this link. In parts of Southeast Asia, rural malaria deaths are correlated with forest cover (see Figures 1 and 2, taken from the *Southeast Asian Journal of Tropical Medicine and Public Health*, Anonymous 1999, on the Mekong Delta). Klinkenberg et al. (2003), in a longitudinal study, linked high malaria risk in Sri Lanka to greater-than-average rainfall, large forest coverage, swidden cultivation and poverty. Hay et al. (2002b) refer to their previous work (Hay et al. 1998; Hay et al. 2000) showing a positive correlation between the normalized difference vegetation index (NDVI) and malaria incidence.

Patz et al. (2000) discuss the adverse health impacts when people unfamiliar with malaria migrate into malarial areas. Migrants often do not understand how their own behaviour can increase the incidence of the disease, and they tend to be less resistant to new strains (also discussed for the Brazilian Amazon by Moran and Fleming-Moran 1996²¹ and De Bartolome and Vosti 1995, who confirm the prevalence of malaria among newly arrived colonists in the Brazilian state of Rondonia; see also Molyneux 1998, 2002). Most of the new inhabitants of Machadinho settlement immediately contracted malaria. Moran and Fleming-Moran (1996, quoting Sabroza et al. 1995) found that malaria had increased by 24% per year during the period of Transamazon colonization in the 1970s. Maurice-Bourgoin et al. (2000) mention the high incidence of malaria among gold miners in Amazonian Bolivia. Service (1989) linked it to the war in Nicaragua.

Patz et al. (2000) also outline the preferences of different kinds of mosquitoes for different kinds of water sources²² and note how climatic conditions, temperature, altitude, humidity, rainfall, flooding, wind and El Niños all contribute to an increase in malaria infection (also discussed in Patz and Wolfe 2002).

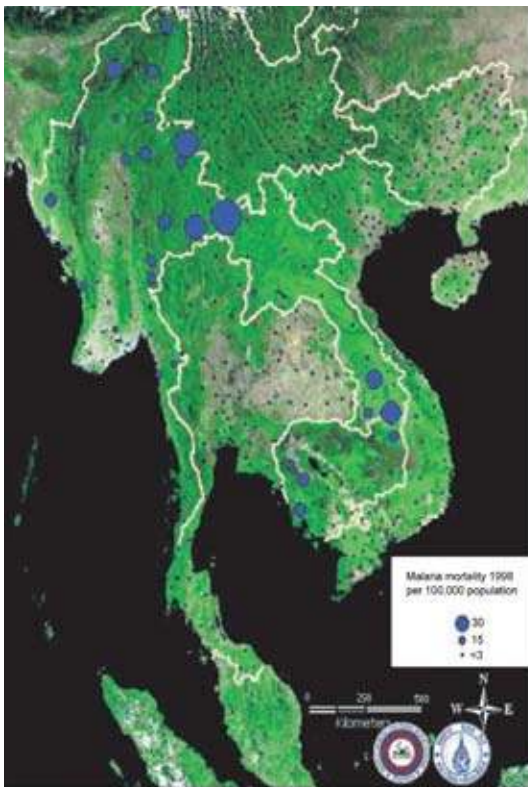


Figure 1. Malaria Mortality and Forest Cover, 1998 (Anonymous 1999)

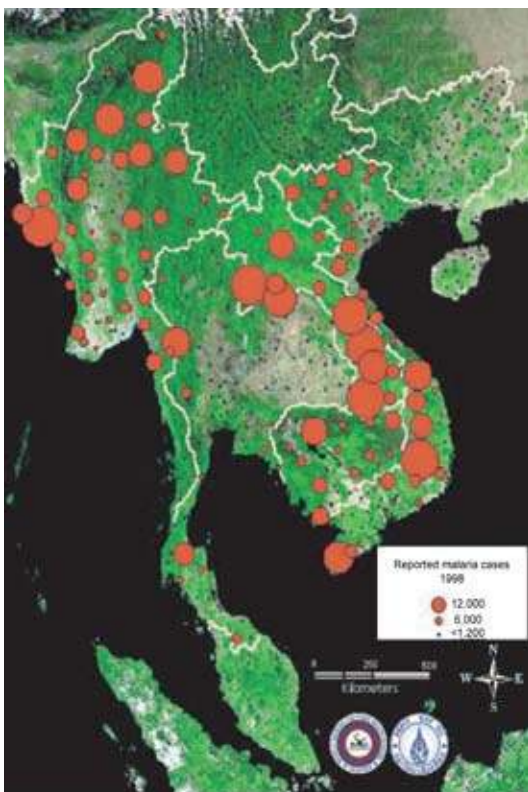


Figure 2. Malaria Cases and Forest Cover, 1998 (Anonymous 1999)

Apicomplexan parasites, of which the malaria-causing *Plasmodium* species are one type, pursue diverse life-history strategies, infecting virtually all animals, from mollusks to mammals (Roos 2005). Some Apicomplexan parasite life cycles are relatively simple, involving only a single host, whereas others require sexual recombination in a vector species for transmission. Some parasites are specialists, restricted to particular species and tissues, whereas others are generalists. For example, *Plasmodium falciparum*, which causes the most lethal form of human malaria, infects only great apes (including humans, the only great ape that is not purely associated with tropical forests) and is transmitted only by anopheline mosquitoes. In contrast, *Toxoplasma Gondii*, another type of apicomplexan parasites, can infect almost any tissue of warm-blooded animals, causing disease in immunodeficient hosts (including AIDS patients and human and animal fetuses). For *Theileria* the sexual stage occurs in ticks, for *Plasmodium* in mosquitoes and for *Toxoplasma* in cats (including domestic).

Understanding these complex life cycles and their dependencies would help us understand how these parasites survive in the environment and what affects transmission to and between humans. The nature of the landscape, how it is used and other details of local ecology and of human behaviour can all prove vitally important.

Walsh et al. (1993) provide a very thorough (though now rather dated) global survey of the relationship between deforestation and malaria and see a positive link. The diversity and adaptive characteristics of mosquitoes and their interactions with the human and nonhuman environment are their most striking findings. A popular view is that diseases have sometimes served to inhibit human intrusion (e.g., to Panama, to the Amazon); these authors discuss the *terai* of Nepal as one example of this, noting also that, unlike most cases, the result of malaria control was immediate deforestation and the development of a prosperous agricultural belt. Globally, they also emphasize the economic consequences of malaria, in days of work lost, often at critical periods in the agricultural cycle (see also Pattanayak et al. 2005b, for a critique of the narrow methodological approaches generally taken in studies of the causes of malaria).

Specific cases can demonstrate some of the interactions between human health and

forests. Nakazawa et al. (1994) examined people in four villages in the Gidra of lowland Papua New Guinea and found rates of malarial infection from 35.3% to 100% in males and 31.6% to 100% in females. Men who hunt in mangrove swamps and collect coconuts in the bush and men who dive in rivers were the most frequently bitten: Cumulative prevalence was higher in males than in females in a coastal village for *Plasmodium falciparum* and in a riverine village for the less virulent *P. vivax*.

Bustos et al. (1997) report on low levels of malaria in Morong, Bataam, Philippines. Saul et al. (1997) confirm low but stable levels of malaria in the same locale, with a fair amount of asymptomatic malaria. They note also that local people do not believe mosquitoes are vectors. Colfer has observed the same belief among educated Indonesian community workers in Sumatra, where both community members and community workers regularly suffer from malaria. These authors all note that the severity of malaria attacks in Asia seems much lower than in many African countries.

Pattanayak et al. (2005a, b) conducted careful studies of deforestation, poverty and malaria in two protected areas in Indonesia: Ruteng, Flores, and Siberut Island. They found inverse correlations between primary forest and malarial infection in both places (for children in Ruteng and for household heads in

Siberut). In Ruteng, on the other hand, they found positive correlations between secondary forest regrowth and malarial incidence among children.

Brinkman (1994), summarizing the work of others, links an increase in malaria to the introduction of coffee cultivation in southern Thailand in 1986. Malaria was endemic in the area, and adults tended to have acquired immunity. But forest clearing to establish the coffee plantations resulted in an excellent habitat for *Anopheles minimus*. The immigrants, working with local people who were asymptomatic carriers, were provided inadequate housing, which increased their vulnerability to mosquito bites. Brinkman notes a similar pattern of increasing malaria incidence with the mixing of populations in Ethiopia, Somalia and the Amazon. In another area of Thailand, malaria had disappeared with the introduction of cassava cultivation but reemerged when cassava fields became rubber gardens and orchards. Colfer, who spent a year in a village in central East Kalimantan in 1979 and has returned repeatedly, has anecdotal evidence of an increase in the incidence of malaria, concomitant with overall deforestation through logging, large-scale conversion to oil palm and industrial tree crop plantations, government resettlement schemes and fire. Others have noted links among logging, standing water and malarial infection.

An increasing number of studies consider the relationship between climate change and malaria. Some (e.g., Matola et al. 1987) have proposed that malaria creeps up mountains as they become deforested and hotter. Hay et al. (2002a), on examining the available data, questioned this link, arguing that the hotter climate has no effect on malaria incidence, but Sheil questions that conclusion, noting the differences in temperature between urban-based recording stations and rural conditions. Zhou et al. 2004 consider the use by Matola et al. (1987) of spatially interpolated climate data to be inappropriate for trend analysis in areas known to have high spatial temperature heterogeneity (see below). Haggett (1994) proposes some possible health implications for climate change, mostly linked to expansion of tropical organisms into temperate zones, as do Patz and Wolfe (2002).²³ Mayer (2000) discusses various possible health implications of warmer temperatures, including an estimate that the population at risk of developing malaria



Typical housing
in central Gabon
(Photo by
Carol J. P. Colfer)

could rise to 2.5 billion people under some temperature scenarios.²⁴

In another article, Hay et al. (2002b) acknowledge that forecast climate changes “may cause some modification to the present global distribution of malaria close to its present boundaries,” but they think that attributing recent malaria outbreaks in East African highlands to climate change is “at best equivocal, at worst unfounded.”

Zhou et al. (2004) acknowledge the difficulty of sorting out the variables and use a nonlinear mixed-regression analysis to look at autoregression (number of malaria outpatients in the previous period), seasonality and climate variability, and the number of monthly malaria outpatients in the past 10-20 years in seven highland sites in East Africa. Nonlinear and synergistic effects of temperature and rainfall on the number of malaria outpatients were found in all seven sites. These authors conclude that the number of malaria outpatients was highly sensitive to climate fluctuations and that climate variability was important in the initiation of malaria epidemics there.

They also hypothesized the mechanisms that might explain the reemergence of *Plasmodium falciparum* epidemic malaria in East African highlands: 1) increased travel from malaria-endemic Lake Victoria, 2) degradation of the health care infrastructure, 3) resistance to antimalarial drugs, 4) land-use changes and 5) global warming. They reject the first three hypotheses and focus on human population increase and movement (including the presence of people without functional immunity to local strains), land-use change and temperature variability. They note that human mortality is increased by drug resistance, inadequate access to drugs, failure to seek treatment in a timely manner and HIV infection.

Hay et al. (2004) used geographic information systems and historical maps to quantify human impacts on the distribution of malaria in the 20th century (see Figure 2). Among their conclusions: During the past century, despite a halving of the land area supporting malaria (due to human activities), 2 billion more people are currently exposed to malaria because of demographic changes.

Using remotely sensed data on waterways, elevation, amount of forest between houses and selected waterways, and presence of humans, Roberts and Rodriguez (1994) predict malarial vector abundance in several locations. They argue for greater use of

such tools in managing and targeting vector and disease control measures. Ginwalla et al. (2004) also used remote sensing imagery to study the effects of deforestation on the incidence of malaria among household heads in the Indonesian island of Siberut. They found the relative abundance of primary forest associated with a lower incidence of malaria. Patz et al. (1998) demonstrated the value of using soil moisture (rather than rainfall data) in predicting changes in malaria transmission intensity, based on data from Kisian, Kenya.

Malaria incidence rose sixfold between 1987 and 1998 in the northern region of the Peruvian Amazon. Using Landsat Thematic Mapper and field surveys, a team from the Johns Hopkins School of Public Health examined the relationship between the extent of deforestation and entomological risk factors associated with malaria. Their findings support the idea that deforestation may contribute to the increase in malaria in the Amazon (<http://www.jhsph.edu/globalchange/deforestation.html>).

3.3 Ebola and Marburg Viruses

Sommerfield (1994, 277) stresses the importance of ecological degradation in ‘the epidemic emergence of Lassa, Marburg, Ebola and many other viruses’. Schou and Hansen (2000), by reviewing the literature on Marburg and Ebola viruses, discovered 23 outbreaks since the first outbreak of Marburg in Germany in 1967. They found that nearly 800 of the 1,100 deaths in Africa followed direct, intimate contact with infected patients (and very few from contact with nonhuman primates used for scientific purposes). These ailments belong to a larger group of illnesses called viral hemorrhagic fevers, many of which are life-threatening. All depend on vertebrate hosts and arthropod vectors, commonly rodents and insects, and are therefore restricted to the host’s habitat. Humans are not the natural reservoir, though once infected, people can sometimes transmit the disease; <http://www.health.state.nd.us/EPR/public/viral/VHFeverFacts.htm>.

Ebola and Marburg are quintessential forest diseases in the Filoviridae family, with high fatality rates for humans and other primates. Although found in and around tropical rainforests, these viruses have been linked to forest degradation and other processes that put people in contact with previously inaccessible forest-based pathogens (Borchert

et al. 2000). The disease outbreaks occur during transitional periods between wet and dry seasons (Pourut et al. 2005).

Three distinct genotypes, Ebola-Zaire, Ebola-Sudan and Ebola-Côte d'Ivoire, affect humans, and a fourth, Ebola-Reston affects only nonhuman primates (Cohen 2004). But there is little genetic variability, so this factor does not seem to be important in the emergence of filoviruses, as it is with other RNA viruses (Feldmann et al. 2002; Pourut et al. 2005). Ebola-Reston virus was first isolated in nonhuman primates in *Cynomolgus* monkeys (*Macaca fascicularis*) imported to the United States from the Philippines in 1989-90 (Feldmann et al. 2002). Suzuki and Gojobori (1997) used genetic sequencing data to show that the Marburg and Ebola viruses originated from a common ancestor 7000 to 8000 years ago.

Cohen (2004) describes the illness:

Ebola is transmitted person to person by direct contact with infected body fluids, or by direct inoculation via contaminated instruments such as needles or razors. The incubation period of Ebola haemorrhagic fever is usually between four and 21 days. The illness is characterised by an acute onset of fever, malaise, myalgia, severe frontal headache, and pharyngitis.

These symptoms are common to many other acute infections in Ebola-endemic areas, rendering diagnosis difficult. After about a week, patients develop a maculopapular rash, followed by vomiting and bloody diarrhea and uncontrollable haemorrhaging from body orifices and needle sites. Death is from blood loss and shock. Treatment is largely supportive (Borchert et al. 2000; Cohen 2004). Pourut et al. (2005) report case fatality rates in the literature between 50% (Sudan) and 80% (Zaire). Good hygiene is effective in controlling the spread of the virus (Feldmann et al. 2002).

Borchert et al. (2000) provide a thorough discussion of Ebola and Marburg viruses (summarized in the subsequent paragraphs). They note that since 1967, when Ebola and Marburg were discovered, 1209 cases and 873 deaths have been diagnosed (see also Figure 3), slightly more than Schou and Hansen (2000). Borchert et al. compare their own statistics to the 1998 UN estimate of 13.9

million deaths from HIV since the beginning of the AIDS epidemic in the 1980s (UNAIDS 1999). They note that even if the cases and fatalities from Ebola and Marburg were multiplied by 100 to account for underreporting, these filoviral diseases would make only a marginal contribution to the global burden of infectious disease. These authors do not, however, underestimate the seriousness of the diseases, both at the local level (where damage is serious) and potentially nationally or globally. Impacts on those providing health services, which have been found often to be at the epicenter of the outbreak, have been devastating.

The worst outbreaks have occurred where the health system is dysfunctional, whether from economic crisis, public sector breakdown or war. An August 1976 epidemic, for instance, killed 318 people in 55 villages around the Catholic mission in Yambuku, Democratic Republic of Congo; 88% of the cases were fatal, and both sexes and all ages were affected. Hygiene was deplorable, with five needles per day being shared among outpatient, prenatal and inpatient wards, with (at best) a rinse in warm water between injections, and occasional boiling at the end of the day. An injection at the hospital was the only plausible mode of transmission for 26% of the cases, and 13 of the 17 hospital staff were infected, with 11 dying. In some cases outbreaks have not been detected or reported in a timely manner, or higher levels of the health system did not respond adequately or appropriately. Sometimes national governments have not recognized the seriousness of outbreaks or have tried to hide them from the international community.

Filovirus diseases can be transmitted to distant places: infected Philippine monkeys appeared in a lab in Reston, Virginia, U.S., for example, and an infected Yambuku staff member who went to Kinshasa, 1000 km away, infected three more people there. Although transmission is normally via direct contact with the bodily fluids of diseased individuals, rendering caregivers the most vulnerable, there is some evidence of air-borne transmission (e.g., the Reston strain). Should these viruses mutate to become transmissible to humans by air, the consequences would be dreadful.

The reservoir of the filoviruses remains a mystery (Feldmann et al. 2002; Pourut et al. 2005). Initially, nonhuman primates were considered likely suspects, but the death rate for these animals is so high that this seems

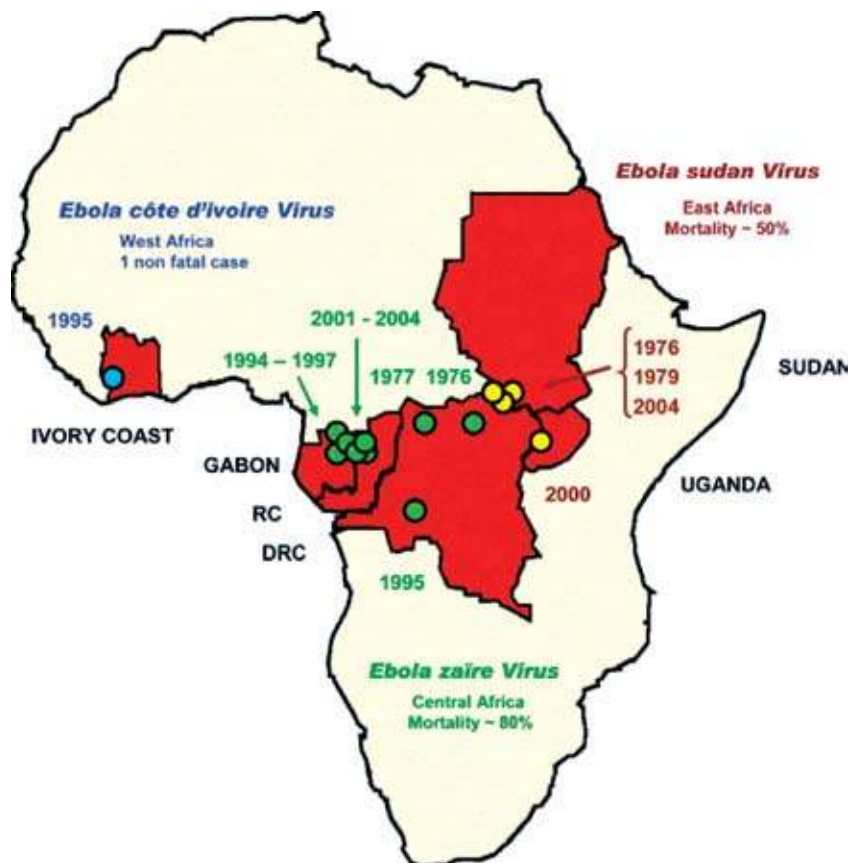


Figure 3. Human Ebola Outbreaks in Africa

RC: Republic of Congo; DRC: Democratic Republic of Congo

Source: Pourrut et al. (2005).

unlikely. Fruit and insectivorous bats have been shown experimentally to be infected without symptoms. Such a persistently infected host is almost a requirement for a zoonotic disease.

Central Africa (between the 10th parallels north and south of the Equator) and perhaps the Philippines appear to be an endemic focus for filoviruses. The relative infrequency of transmission to humans suggests that people do not normally come into contact with the reservoir, reinforcing the idea that human 'invasion' of remote forested areas may play a role. This hypothesis is also supported by the outbreaks in Kikwit, Democratic Republic of Congo, in 1995 and multiple outbreaks in extremely remote areas of Gabon.

Pourrut et al. (2005) thoroughly examine each of the known occurrences of Ebola and Marburg in an effort to sort out the 'natural history' (summarized below). In many of the cases the human index case is unknown; in others a known animal carcass (chimpanzee,

gorilla, vervet monkey, duiker) is involved. In several well-known cases, the victims had been in close contact with bats in the days preceding their illness, and bats are implicated in the transmission of related families of viruses (*Rhabdoviridae* and *Paramyxoviridae*²⁵). Dobson (2005) reports additional evidence of links between bats and various emerging diseases. Arthropods, including *Aedes* mosquitoes, are also possibilities, though the evidence is minimal.

Between 2001 and 2003, in Gabon and RC (when there were also significant human Ebola outbreaks), 50 gorilla, 15 chimpanzee and 14 duiker carcasses were found in the outbreak areas—this in a climate wherein bodies decompose within 3 weeks. Fourteen of the 34 dead animals tested positive for Ebola infection. This evidence, combined with other observational data, suggest very high mortality rates among these animals. In 2002 and 2003, gorilla and duiker populations are estimated

to have fallen by 50% in the Lossi sanctuary in RC; chimpanzee populations fell by 88%. Analysis of animal carcasses in Central Africa confirm that the great apes particularly are at serious risk from Ebola. Antibodies were also found in a number of monkey species (drills, a baboon, a mandrill and a *Cercopithecus* monkey), suggesting that the transmission of the virus may be complex, going beyond direct passage from the reservoir to the great apes. John Wolfe, of Johns Hopkins School of Public Health, found that chimpanzees that hunted were more likely to become infected with Ebola than chimpanzees with other risk factors, including direct physical contact with dead Ebola victims.

Pourut et al. (2005) conclude that all three main subtypes occur in a homogeneous ecological area (African equatorial forest). Great apes and other species are naturally infected by the virus, probably directly from the reservoir. These intermediate animal species become ill, usually fatally. Their carcasses are infectious for humans who in turn infect their neighbours. Better understanding of the reservoir and natural life cycle of the virus would be helpful in preventing human outbreaks and reducing the impacts on seriously endangered species like the great apes.

3.4 Mercury Poisoning (*Minamata Disease*)

Mercury has adverse neurological and other effects on humans and is particularly damaging to fetuses, causing mental retardation. Mercury poisoning is the subject of a significant body of health-related literature on people living in forests. Mercury levels have been particularly well studied in the Amazon area, though we also reviewed studies in the Philippines, Zimbabwe and Tanzania. Moran and Fleming-Moran (1996) describe the multiple sources of mercury related to gold mining in the Amazon; they also discuss how significant amounts of organic mercury are emitted into the atmosphere when forests are cleared by burning.

In the Amazon, gold mining has been assumed to be a primary culprit. Leino and Lodenius (1995) estimated that between 1980 and 1986, mercury emissions totalled around 590 tons in the Serra Pelada goldfields of eastern Amazonia. This study took place in Tukurui on the Tocantins River, downriver from the goldfields. These authors found that predatory fish were particularly badly contaminated, and the mercury in people's hair was positively correlated with the number of predatory fish meals consumed. Although this study did not find symptoms of mercury poisoning, the authors expressed concern about the likely impacts on fetuses.



Gorilla hunting in Cameroon (Photo by Edmond Dounias)

Boischio and Henshel (2000), besides providing an excellent review of studies of mercury and fish consumption in the Amazon and elsewhere, report the levels of mercury based on fish consumption levels and human hair samples in the Upper Madeira River in Rondonia, Brazil. In 1991 and 1993 fish was one of the most common foods consumed, and many fish species had dangerous levels of mercury. Harada et al. (2001) also conducted a study of mercury poisoning in the Tapajos River area of eastern Amazonian Brazil, in the communities of Barreiras, Rainha, and Sao Luis do Tapajos, between 1994 and 1998 (see also Lebel et al. 1998). Harada et al. also found high levels of mercury in the people's hair and evidence of clinical symptoms of mercury poisoning.

De Oliveria-Santos et al. (2002b) interviewed and examined volunteers in two communities located downriver from artisanal gold mining in Pará State in the eastern Amazon. Mercury levels in the exposed communities were higher than in Santana do Ituqui, outside the area. Although levels of mercury in the fish were below the limits set in Brazilian health guidelines, the high rates of fish consumption were cause for concern. De Oliveria-Santos et al. (2002a) did a similar study among Mundurucu Indians in the community of Sai Cinza, also on the Tapajos River (with gold mining upstream) in Pará, with similar results. Dorea (in press) provides a very thorough summary of studies done on mercury in the Amazon, and basically concludes that the nutritional benefits of fish consumption outweigh the mercury-related dangers.

De Oliveria-Santos et al. (2002b) conducted a subsequent, comparative study of mercury in four areas in the Amazon considered not exposed to gold mining. They found lower levels of mercury in the water, the fish and hair samples than in the areas exposed to gold mining, but the levels were still considerably higher than those found in northern latitudes. The authors postulate that it may be necessary to develop new standards for 'normal' levels in tropical areas.

Mergler (2002), who also provides a survey of the literature on mercury contamination in the Amazon, compares findings from three sites along the Tapajos River (two in Brasilia Legal and one in Cametá) with those from the population around the St. Lawrence River in Canada (which is more polluted than the Tapajos). This study included various tests of

neuromotor and cognitive functioning and found adverse effects from fish consumption in both populations. Blood mercury concentrations were 25 times higher along the Tapajos than in the St. Lawrence river population, probably because the Amazonian population consumed more fish.²⁶

Mergler and her interdisciplinary team (Mergler 2003), having worked in the Amazon, particularly Brasilia Real, for nearly a decade, have come to the surprising conclusion that much of the mercury comes naturally from the soil, rather than from gold mining (which does exacerbate the problem). Forest clearance and soil erosion, and consequent leaching into the water, are central causes. On the encouraging side, the team has worked closely with local women, who have changed local eating habits (reducing consumption of piscivorous fish), with the predicted reductions in mercury levels in people's hair.

Maurice-Bourgoin et al. (2000) did similar studies in the Madeira River watershed of Bolivia, in the upper Amazon basin, between 1995 and 1998, including water, fish and hair sampling. Piscivorous fish in the Beni River showed mercury concentration levels four times WHO safety limits. The Essejas indigenous communities living along the banks of the river showed the highest concentrations of mercury, related to the amount of fish in their diet; the gold miners themselves were more dramatically affected by malaria (which could reflect lowered immune systems because of exposure to mercury).

Akagi et al. (2000) examined water, fish and children to study mercury connected with gold mining in the Philippines. Apokon, Tagum, Davao del Norte, is home to 29 gold processing and refining plants. Levels of total mercury in water and in three fish species were elevated. Of 163 children tested, 6% had elevated T-hg blood levels, and 3% had elevated total mercury in their hair samples; all the children had abnormalities (underheight, gingival discoloration, underweight, adenopathy and dermatologic abnormalities).

Drasch et al. (2001) report more worrying results from the Philippines, where his team examined gold miners and others living in Diwalwal (near Mount Diwata on Mindanao), people in the downstream area of Monkayo and a control group from Davao. Among the gold miners themselves, evidence of mercury intoxication was obvious: 'They reported fatigue, tremor, memory problems,

restlessness, loss of weight, metallic taste and sleeping disturbances. We found intentional tremor, mainly fine tremor of eyelids, lips and fingers, ataxia, hyperreflexia and sensory disturbances as well as a bluish discoloration of the gums' (160).

Members of the downstream community showed fewer overt symptoms, and the control group appeared healthy (though lab tests also showed elevated levels of mercury). A third of the people living in Diwalwal are children, many of whom are actively involved in gold mining and receive direct daily exposure to mercury.

Van Straaten (2000) looked at mercury related to gold mining in the Lake Victoria gold fields in northern Tanzania and the Tafuna Hill area near Shamva, Zimbabwe. This study focused on mercury in the water and in the soil and concluded that it was very localized. About 70% to 80% of the high level of mercury was lost to the atmosphere, but its fate and pathways were unknown.

In some parts of the world, particularly areas with high concentrations of toxic elements (usually metals), land remains forested because of its unsuitability for growing crops. Well known examples include the commercially important ore deposits in the nickel-rich ultramafic soils of Cuba and New Caledonia and the cobalt- and copper-rich soils of Congo. Localized enrichment has been reported also for arsenic, selenium, zinc, lead and cadmium. Such soils (usually raised sea beds) have rarely been assessed but are geologically widespread, and various plants and animals accumulate these elements either passively, or actively as defenses, leading to a genuine but uncertain possibility that these toxic elements may accumulate in local diets (Boyd 2004; Coleman et al. 2005).

3.5 Other Forest Health Problems

The selected health problems described below, most of which have direct forest links, reflect the range of important health problems that afflict local people. Our emphasis is on tropical rainforest areas, but we include some health issues in drier forests as well. Table 4 indicates the causal links between specific diseases and forests. Vector-borne diseases predominate—unlike health problems in temperate and nonforested areas.

3.5.1 Trypanosomiasis, Sleeping Sickness, and Chagas Disease

Trypanosomes are single-celled parasites, implicated in Chagas disease, African sleeping sickness, and Leishmaniasis. See Cross (2005) on the importance of these parasites for the very poor in developing countries. He focuses on their role in sleeping sickness, Chagas' disease, and *Leishmaniasis*. Patz et al. (2000) describe trypanosomiasis, which is caused by *Trypanosoma* spp. The African version of trypanosomiasis (sleeping sickness) is caused by *Trypanosoma brucei*, transmitted by the tsetse fly (*Glossina* spp.). In the open savannahs of eastern Africa, the most important trypanosoma species is *T. b. rhodesiense*; *T. b. gambiense* is the main vector in western and central African riverine areas. Wild game mammals (bushbuck) serve as reservoirs of *T. rhodesiense*, the more virulent of the two species; *T. gambiense* is primarily found in domestic stock (pigs, cattle, dogs).

The fly's bite leaves a red sore that is followed weeks later by flulike symptoms that progress to slurred speech, confusion, difficulty walking and seizures. If untreated, the infection often kills. Figure 4 shows the cycles of transmission in forest and savannah.

Trypanosomiasis has precluded cattle raising in many parts of Africa (see White 1995 for an interesting historical version of white and African views of tsetse fly and sleeping sickness problems). Molyneux (1998), who links this disease clearly with the presence of forest and shrubs, mentions its importance in Uganda and Côte d'Ivoire and discusses the difficulties of controlling the disease under the conditions of civil unrest and war that prevail in the Central African Republic, Sudan, Zaire and Angola.

The Latin American version, Chagas disease, is caused by *Trypanosoma cruzi* and transmitted by the Triatoma (cone-nosed) bug. Chagas disease, which takes decades to manifest itself, attacks the heart and is carried by so-called kissing bugs. Briceno-Leon (1993) estimated that 7.6% of the Latin American population—around 24 million people—was infected. Other, more recent global health estimates have put the total at more than 16 million, including about 500 000 in the United States. There is no cure, though not everyone infected develops the disease. Animal reservoirs include opossums, armadillos, rodents, dogs and cats; outbreaks are associated with mud, thatched or dirt-

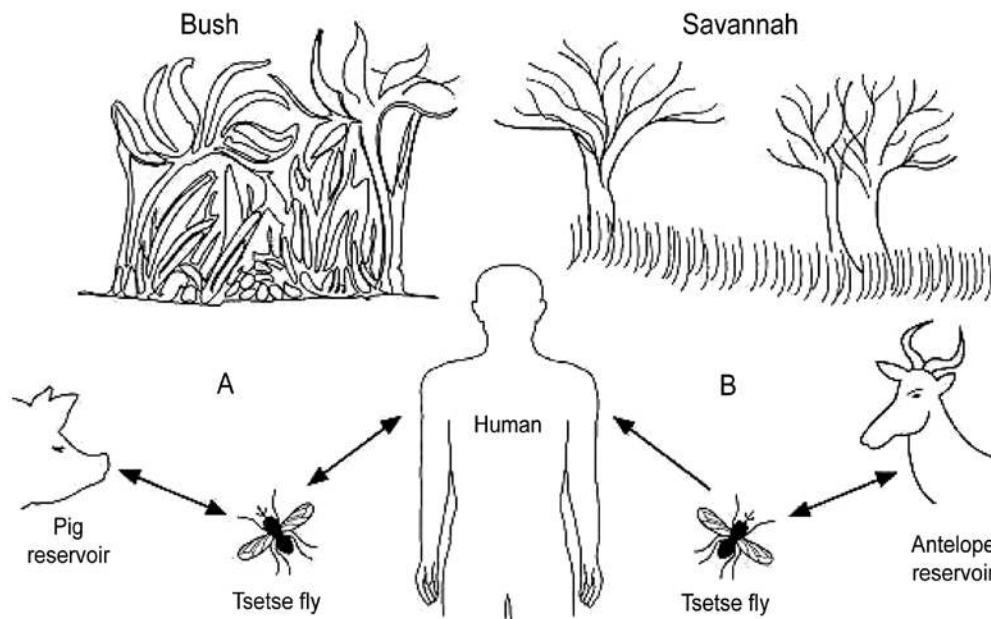


Figure 4. Domestic and Wild Cycles of Gambian and Rhodesian Types of African Sleeping Sickness

(A) In West Africa, riverine tsetse flies (*palpalis* group) living in the bush transmit the Gambian forms to humans (man-fly cycle) and sometimes to domestic animals, particularly pigs. (B) In East Africa, *morsitans* group tsetse flies of the open savannah transmit the Rhodesian form to various mammals, mainly antelopes, and to humans. The Gambian cycle can result in an epidemic. Source: <http://gsbs.utmb.edu/microbook/ch082.htm>.

floored dwellings (<http://gsbs.utmb.edu/microbook/ch082.htm>). See Figure 5.

Coura et al. (2002) recount a recent increase in Chagas disease in the Amazon, related to human migration and deforestation. *T. cruzi* infection derives from a variety of wild mammals and several triatomine insect vector species. Moran and Fleming-Moran (1996) summarize studies showing frightening levels of morbidity and mortality linked to this disease. They estimate that the disease costs \$5 billion annually in work-related losses in Brazil, second only to malaria among the endemic diseases. But Molyneux (1998) reports considerable reduction in the incidence of this disease since 1980 in Argentina, Bolivia, Brazil, Chile, Uruguay and Paraguay, due to long-term house spraying.

Briceno-Leon (1993), studying Venezuela, attributes the difficulties in treatment to the decades-long interval between infection and onset of the disease. Medical personnel had not told sufferers of their disease because of its incurability, so there was a lack of local knowledge about it. A few families received

subsidies to improve their housing, which helped reduce exposure to *T. cruzi*.

3.5.2 Onchocerciasis (River Blindness) and Loa Loa

Onchocerciasis is the world's second leading infectious cause of blindness, causing much chronic suffering and severe disability. It is often called river blindness because the *Simulium* blackflies that transmit the disease breed and thrive in fast-flowing rivers. Fear of the disease even leads people to abandon these fertile areas; <http://www.who.int/tdr/diseases/oncho/default.htm>.

In eastern Africa the principle variety of *Onchocerciasis* transmitting *Simulium* is not free living in the streams but is dependent on the presence of fresh water crabs. The use of insecticides dripped into streams and rivers eliminated crabs and flies in many forested catchments. However, the vector is not so vulnerable in other regions.

Patz et al. (2000) link onchocerciasis in Ecuador, Guatemala, Mexico, and West,

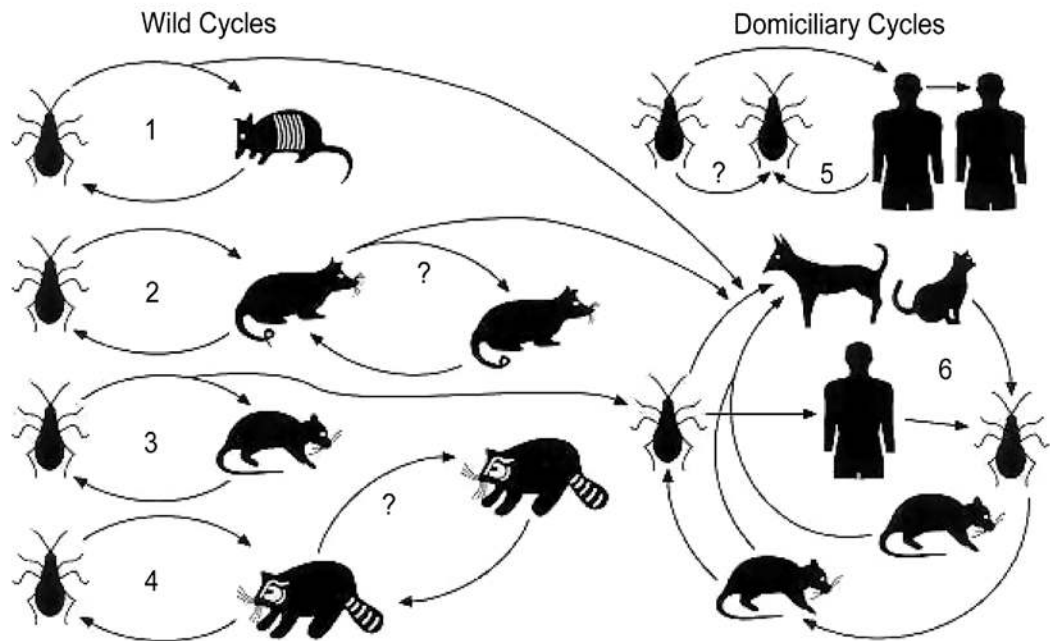


Figure 5. Wild and Domiciliary Life Cycles of Chagas Disease

Some triatomine bugs transmit *T. cruzi* to various wild animals (cycles 1–4). Other bugs are adapted to houses and transmit the parasite among humans and domestic animals (cycles 5 and 6). Modified from Zeledón (1974); see also <http://gsbs.utmb.edu/microbook/ch082.htm>.

Central and East Africa to deforestation. Walsh et al. (1993) provide examples of how onchocerciasis interacts with humans, flies and the environment in Africa and Central and South America, with varying relationships to deforestation. Thomson et al. (2000, reported in Ostfield et al. 2005) explained ~50% of the variation in onchocerciasis incidence in West African villages by a nonlinear and multifactor function of variation in measures of forest cover and land cover class.

Petney (2001) refers to the work of Katarwa et al. (2000), which documented a successful program of dealing with onchocerciasis in Uganda. These authors attributed their success to the way in which the drug distributors were chosen and the involvement of the participants in the choice of the method of drug distribution.

Thomson et al. (2000) address a problem with use of the drug ivermectin in community-based efforts to control onchocerciasis in Central and West Africa. Severe and sometimes fatal encephalopathic reactions to ivermectin were reported in patients with high blood concentrations of loa loa (studied in more

clinical depth by Boussinesq et al. 2003). By overlaying maps from rapid epidemiological mapping of onchocerciasis (REMO) and maps showing risks of high concentrations of loa loa, Cameroon and the Democratic Republic of Congo were identified as potentially problematic for the use of ivermectin. Walsh et al. (1993) describe loiasis as being caused by the filarial worm loa loa, and occurring only in West and Equatorial Africa, transmitted by horse flies (*Chrysops*). Thomson et al. (2000, 1077) report these horse flies to be 'associated with forest and forest-fringe habitats with the larval stages restricted to wet, organically rich, and muddy low-lying habitats within the forest'. The worm does not appear to survive in deforested areas, though the presence of *Chrysops* seems to increase in areas being degraded (Molyneux 2002; Patz et al. 2000). Thomson et al. (2004), following up on initial work on loa loa in Cameroon, find that infection rates increase with increasing age, in elevations between 0 and 1000 (decreasing above that), and male gender. Rates also increased with increasing standard deviation of NDVI and maximum normalized difference



Gabonese man with signs of elephantiasis on his legs, Loa Loa, Gabon (Photo by Carol J. P. Colfer)

fraction index (NDFI), but decreased with maximum NDVI itself (indicating a nonlinear relationship to maximum NDVI).

3.5.3 Yellow Fever

Yellow fever is an acute hemorrhagic fever caused by an arbovirus (arthropod-borne virus), transmitted by mosquitoes (usually *Aedes aegypti*, a daytime biter), that affects around 200 000 people per year in 33 countries; 90% of the cases occur in Africa (<http://www-micro.msb.le.ac.uk/3035/Flaviviruses.html> Cooper and Kiple 1993). Monath (1999, 2003) considers the disease grossly underreported and says that 15% of those infected develop the hepatitis syndrome, and 20% to 50% die—evidence that yellow fever is a much more serious problem than other viral hemorrhagic fevers.

The virus originates in Africa but was brought to other regions very early, probably via mosquitoes in ships' bilge water. This virus is unusual in that it can be transmitted from adult to juvenile mosquitoes without needing to pass through a host. The virus is believed to have had a very severe impact on susceptible neotropical primates, and may also have joined the many other western diseases that depleted indigenous populations soon after

the Spanish landfall. The equatorial areas of Africa and South America are now considered the 'endemic areas', including wide ranges of tropical rain and dry forest.

Galat and Galat-Luong (1997) stress the role of environmental change in yellow fever transmission. In primary forest, mosquitoes infect monkeys (which do not become ill), high in the canopy. But in modified forest-savanna contact zones or forest mosaics, where monkey populations have been decimated, mosquitoes turn to human beings. Digoutte (1999) expands on this information, reporting 1970s conclusions from Senegal and Côte d'Ivoire that the males of several mosquito species (*Aedes furcifer*, *A. taylori*, *A. luteocephalus*) were infecting monkeys in the canopy. Recent epidemics have struck West Africa. In Haddow, East Africa, the virus circulates in the canopy between monkeys and *A. africanus*. These mosquitoes, visiting banana plantations to feed, in turn infect *A. bromeliae*—a cycle that does not occur in West Africa but caused an outbreak in Kenya in the late 1990s. Digoutte concludes that the virulence for human beings of the wild yellow fever virus is quite low, in contrast to urban yellow fever, where humans are the only vertebrate host for the virus (with the vector being *A. aegypti*).

Cordellier (1991) identified three types of yellow fever epidemic, based on differences in vectors: urban, with strictly interhuman transmission; intermediate, with transmission among humans and with *A. aegypti*; and sylvatic, with occurrence in villages, almost always involving *A. furcifer* and no strictly interhuman transmission.

Mondet (2001) studied yellow fever in Amazonian Brazil (all of which was sylvatic) from 1954 to 1999. S/he followed the disease incidence (along river systems) and noted the significance of a) human and monkey populations that were only partially immunized against yellow fever, and b) locations where contact with mosquitoes was intense (in the narrow strip of trees along watercourses). Mondet concludes that forest clearing will inevitably increase human contact with vectors, and that the easily transmitted urban variety could emerge.

3.5.4 Leishmaniasis

Leishmaniasis is a zoonotic disease that occurs in two forms. Cutaneous leishmaniasis (CL) can vary from a minor skin infection in the form of sores and boils to a severe form that rots away the nose and mouth (muco-cutaneous leishmaniasis). Visceral leishmaniasis (VL) attacks internal organs, particularly the liver and spleen, causing anemia and eventually killing the sufferer. The epidemiology of the disease is extremely diverse, with 20 *Leishmania* species pathogenic for humans. Two million new cases occur worldwide every year, with about 350 million people currently at risk (Campos-Neto et al. 2001; <http://www.targethealth.com/ontarget/2005/03282005.htm>).

The parasite is carried by bloodsucking female sand flies of the genus *Phlebotomus* in the Old World and *Lutzomyia* in the New World. The sand fly larvae need organic matter, heat and humidity for growth and inhabit household rubbish, tree holes, animal burrows and cracks in walls of human dwellings. Only about 30 of the 500-plus species of *Phlebotomus* sand flies are known to transmit *Leishmania* parasites. A 1997 WHO report notes that *Lutzomyia logipalpis* is the only known vector of *L. d. chagasi* (WHO website, 1997; <http://homepages.uel.ac.uk/D.P.Humber/akhter/trans.htm>). All New World sand fly species except *L. peruviana* are zoonotic and mainly sylvatic. The main reservoir for *L. panamensis* is arboreal, as are

the various vectors, whereas rodents serve as reservoir species for *L. mexicana*, with transmission accomplished primarily by forest floor sand flies (<http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=mmed.section.4376>). See Box 2.

WHO has recently declared leishmaniasis to be one of the world's most serious parasitic diseases. It affects 88 countries, including 72 in the developing world. Ninety percent of VL cases occur in five countries: Brazil, Bangladesh, India, Nepal and Sudan (all but Sudan having significant tropical and subtropical forest areas). Ninety percent of CL cases occur in Afghanistan, Algeria, Brazil, Iran, Peru, Saudi Arabia and Syria (with only Brazil and Peru having significant tropical forest cover). Overall prevalence is 12 million people, and 350 million are at risk. The burden, calculated in disability-adjusted life years, is 860 000 DALYs for men and 1.2 million DALYs for women. Recently, Leishmaniasis-HIV co-infections have become a problem in Europe, East Africa and India (<http://www.who.int/tdr/diseases/leish/direction.htm>).

CL, which WHO considers an occupational disease of forest workers, has been increasing dramatically in Brazil—from 21 800 cases in 1998 to 35 000 cases in 2000—because of behavioural and environmental changes that increase exposure to sand flies. The changes include new settlements, intrusion into primary forest, deforestation, dam and irrigation construction, as well as more urban-oriented factors. Walsh et al. (1993) report worldwide increases in VL as well, in Neotropical outer city zones and war- and drought-stricken regions of Africa.

Andrade-Narvaez et al. (2003) studied localized cutaneous leishmaniasis in the Yucatan Peninsula in Mexico. Covering 1993–1995, they found *chicleros* (gum collectors) and agricultural workers to be the main victims, with a seasonal transmission pattern restricted to November through March. In the Yucatan Peninsula, the disease is a typical wild zoonosis restricted to the forests, and the population at risk is men between 14 and 45 years who overnight in the forest.

Walsh et al. (1993) provide an excellent overview of the incidence and behaviour of leishmaniasis in South and Central America, where it is typically spread from opossums (*Didelphis marsupialis*), rats (*Proechimys*) and foxes (*Cerdocyon thous*) via sand flies to humans. Continuing deforestation and the

human colonization of new areas, combined with the biodiversity and adaptability of the *Leishmania* parasites and sand flies, suggest that leishmaniasis will remain with us as a health problem; their assessment is reinforced by Cross (2005).

Patz et al. (2000) link increases in leishmaniasis to deforestation, migration and agricultural development in parts of Latin America, the Amazon and the Nile (also discussed, linked to afforestation efforts, in Molyneux 2002). Ostfield et al. (2005), however, identify forests and pastures rather than peridomestic habitats as particularly risky, implying wildlife rather than domestic reservoirs for leishmaniasis in northern Brazil (based partially on work by Werneck et al. 2002).

Peterson and Shaw (2003) used ecological niche modeling to identify the geographic and ecological distributions of three *Lutzomyia* sand flies that are CL vectors in South America. Using climate change scenarios, these researchers predict that *Lutzomyia whitmani* will thrive, given dramatic improvements in conditions that favor this species in southeastern Brazil, where CL is reemerging. Climatic conditions for *L. intermedia* and *L. migonei* are improving more subtly, with unclear implications. All three are forest species that appear to be adapting to other habitats. There are indications of higher transmission rates in Pernambuco State, Brazil, where forests are being degraded extensively, and in peridomestic habitats in deforested regions of Brazil. Surprisingly, Teodoro et al. (1999) found that despite tree removals and applications of low-volume insecticide along the forest edge, *L. whitmani* populations continued to increase (originally reported in Brandão-Filho et al. 1999).

3.5.5 Lymphatic Filariasis

Often called elephantiasis from the grotesquely swollen limbs that afflict sufferers, lymphatic filariasis is rarely life threatening but causes widespread suffering, disability and social stigma. It is endemic in 80 countries, with 40% of infected people living in India and 33% in Africa. The parasites responsible are nematode worms of the family Filariidae, of which three species are particularly important: *Wuchereria bancrofti*, *Brugia malayi* and *B. timori*. Female mosquitoes transmit the immature larvae from person to person (<http://www.who.int/tdr/diseases/lymphfil/default.htm>).

Ahorlu et al. (1999) describe the dreaded conditions, including adenolymphangitis (ADL), lymphoedema, elephantiasis and hydrocele, in the coastal, once-forested areas of western Ghana, where these authors estimate that 50 million people suffer from this ailment. In the study sites, the people generally did not accept the mosquito's role in transmission, attributing their sickness to physical, spiritual or hereditary causes (see also Patz et al. 2000; Hunter 2003). Walsh et al. (1993) discuss several manifestations in Malaysia and Indonesia, concluding that deforestation, though inadequately documented, has probably been effective in reducing the incidence of this disease.

3.5.6 Schistosomiasis (Bilharzia)

Schistosomiasis is by no means restricted to forested areas; it is a problem in many parts of the world. The examples presented here come—to the best of our knowledge—from forested or recently forested areas. Brouwer et al. (2003) document the frightening levels of kidney and bladder problems in children in a roughly 200 km² section of Chikwaka Communal Land in Zimbabwe, where 60% were infected with *Schistosoma haematobium*, and half of those had bladder damage. Boys were at significantly greater risk than girls. Ndekha et al. (2003) worked with communities to control schistosomiasis in the community of Guruve, where the prevalence rate was 37.5%, by encouraging the use of the molluscicidal plant *Phytolacca dodecandra*. They had some success and also accomplished other development-related goals by being responsive to community needs and capabilities.

Hunter's (2003) findings document dramatic increases in genito-urinary schistosomiasis immediately following Ghana's program of building 164 dams in the late 1950s. Regionwide, prevalence of the disease rose immediately from 17% to 51%.²⁷ A 1997 study in Ghana showed an overall average of 54% of the children tested infected with schistosomes—with some areas strikingly higher, again with boys much more affected than girls. See also Lerer and Scudder (1999) or Mayer (2000) for more on the adverse impacts of dams.

Brinkman (1994) notes similar patterns in Mali, where prevalence rates for schistosomiasis exceed 50% in areas of irrigated agriculture and 20% in other parts of the country; he reports prevalence rising after the introduction of

Box 2. The Dangers of Contact with Sloths

Forests are full of creatures large and small with varying capacity to harbor disease. The two- and three-toed sloths (*Choloepus hoffmanni* and *Bradypus variegatus*, respectively), for instance, are possible hosts to a wide variety of arthropod-borne viruses (arboviruses). Sloths in Panama and Brazil are remarkable for their long viremias, perhaps due to their low metabolic rate.

Antibodies to the mosquito-borne **Venezuela encephalitis virus** (sometimes fatal to horses) have been found in both Panamanian sloth species, with *Bradypus* likely a more significant potential source of infection, given the higher concentrations and longer time the virus is detectable in this sloth's blood.

The **Mayaro virus**, also carried by mosquitoes, causes occasional outbreaks of human febrile illness in forested areas of South America and Trinidad. Although sloths can be infected in the laboratory, this only occasionally occurs in the wild. Although susceptible to inoculation by **yellow fever virus**, sloths show no signs of illness.

In Panama, a high prevalence of **St. Louis encephalitis virus** has been found in sloths, particularly *Choloepus*, though their role is probably simply as hosts. They appear to be infrequently infected and gradually build up antibodies over a long period of time; even infected individuals show no signs of illness. Whether sloths play an important role in the transmission of this disease to humans remains uncertain. Sloths were also tested for the closely related Ilheus virus, which can cause human febrile illness and encephalitis, but antibodies were found in only a tiny percentage of sloths tested in Panama, suggesting they are not important vectors for the disease.

Culicoides midges transmit the **Oropouche virus**, which has been found in a small number of Brazilian *Bradypus tridactylus*. This ailment causes periodic epidemic febrile illness in humans in Pará State. The same midge carries **Utinga virus** (as do Anopheles mosquitoes), also isolated in *B. tridactylus* in Brazil, as well as *B. variegatus* and *Choloepus hoffmanni* from Panama. Antibodies to the **Utiva virus** have also been found in both two- and three-toed sloths in Panama. Utinga, Utive and **Pintupo viruses** are all members of the Simbu serogroup and are sloth-specific; Utive, Utinga and **Changuinola viruses** are all sloth-specific.

Sloths are proven or suspected reservoirs of at least five species belonging to the *Leishmania braziliensis* complex of the subgenus *Viannia* (*L. b. colombiensis*, *L. b. equatoriensis*, *L. b. guyanensis*, *L. b. panamensis*, and *L. b. shawi*) all responsible for human cutaneous and/or mucosal **leishmaniasis**, via the phlebotomine sand fly vector. In Panama, *Choloepus hoffmanni* had the highest infection rate with *Leishmania b. guyanensis* among all forest mammals with natural leishmania infections. Researchers believe that *C. hoffmanni* is the principal reservoir for *Leishmania b. guyanensis* in Panama. The fact that the animals survive infection without evidence of pathology indicates a long association that has evolved into a commensal relationship. Similar evidence exists from French Guiana, where dermal leishmaniasis is frequent among humans.

Other studies in Amazonian Brazil (near Manaus) found the overwhelming majority of sand flies feeding on *Choloepus didactylus*, implying that these two-toed sloths are the major reservoirs of *Leishmania braziliensis* in the northern Amazon regions (and probably from Nicaragua to Central Brazil). *Leishmania herreri* was isolated from both *C. hoffmanni* and *Bradypus variegatus* in Costa Rica. Scientists note many striking similarities between leishmania and parasites of the genus *Endotrypanum*. Flagellates of the genera *Trypanosoma*, *Toxoplasmosis*, and *Pneumocystis carinii* have also been found in sloths.

Source: Gilmore, Da Costa, and Duarte (2001).

irrigation in Africa, South America and Asia. Walsh et al. (1993), however, identify only *S. intercalatum* as being found in forested areas (apparently not considering areas like the miombo woodlands of Zimbabwe to be forested), in West and Equatorial Africa. They link most increases in the disease to deforestation, describing a number of vectors and habitats (many in deforested areas) around the world.

Uchoa et al. (2000) examined schistosomiasis (*Schistosoma mansoni*) in Minas Gerais (southeastern Brazil), where a program based on molluscicides and chemotherapy was supplemented with a community education program. People in two communities with roughly 35% prevalence rates were not convinced of the dangers of contact with contaminated water; they associated mild infections with water contact (and considered them easily treatable) and attributed severe ones to inadequate health care. On a broader scale, in Bahia, Brazil, Bavia et al. (2001) found that the satellite-determined NDVI (a good proxy for forest cover) was a strong predictor of schistosomiasis distribution.

Patz et al. (2000) describe *S. mekongi* and the disease in the Mekong river area. Curiously, in Indonesia, schistosomiasis has been found in only one part of Central Sulawesi. Izhar et al. (2002) describe the incidence going from 57% in the Lake Lindu area in 1940 (under Dutch rule) to less than 2% in nearby Napu, in 1999. Efforts to maintain the currently much lower incidence are a small part of an integrated program to improve living conditions and protect a national park in the area. To date, incidence is being maintained at a low rate.

3.5.7 Dracunculiasis (Guinea Worm Disease)

By 1997, the incidence of dracunculiasis (relevant in dry forest areas) had been dealt a death blow in Ghana by the introduction of bore holes (Hunter 1997) and the resulting Cyclops flea-free water. Molyneux (1998) reports that dracunculiasis was dramatically reduced in Mali, Niger, Mauritania, Burkina Faso, Uganda, Nigeria and Ghana through an effective program of control. But civil unrest in Ghana and Sudan, and a competing meningitis epidemic in Burkina Faso slowed progress in those countries.

3.5.8 Nipah Virus

Several studies have looked at the interaction between pigs, bats, flying-fox bats (*Pteropus mariannus*) and forests in the Malaysian outbreak of Nipah virus in 1998-1999 (CDC 1999; Chua et al. 2000; Chua et al. 2001; Eby 1991; Johara et al. 2001). This strain was isolated from the urine of *Pteropus hyomelanus*. In Malaysia alone, 105 of the 257 reported and attributed human cases died between September 1998 and May 1999, and 10 others died in other countries (http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/AC449E/ac449e04.htm).

3.5.9 Chamorro Disease

The Chamorro people in Guam suffer from a progressive, fatal brain disease. At its peak in the 1960s, around one-third of the population was affected. Similar diseases have been noted in parts of Melanesia and Japan. Cycads had long been seen as one suspect, but not everyone affected had eaten them, and the topic inspired a vast literature. Recent research in Guam appears to have identified flying-fox bats (*Pteropus mariannus*) as the missing link. The bats commonly eat the seeds of cycad trees (*Cycas micronesia*), which contain beta-methylamino L-alanine (BMAA). This compound, consumed by humans who eat flying-foxes in ceremonial feasts, kills motor neurons, causing the disease. BMAA is now known to be generated by an unidentified species of cyanobacteria that lives in the cycad's roots and furnishes nitrogen. BMAA accumulates: A gram of bacteria contains about 0.3 micrograms of BMAA; bats contain 10 000 times more but, unlike humans, probably do not live long enough to suffer the consequences (Cox et al. 2003). In other locations, cycad seeds and sago are eaten, and BMAA or related dangerous compounds accumulate in those who consume them.

3.5.10 Rabies

A natural reservoir for rabies in South America is the vampire bat (Baer 1991). *Demodius rotundus* prefers mammals and *D. youngi* ('white-winged bat') prefers birds, avoiding people and cattle except in conditions of little choice (Emmons and Fear 1997). When driven from forests by habitat loss, they benefit from cattle ranching, and populations soar, potentially encouraging the spread of rabies.

People living in places where bats are common generally take necessary precautions, but other animals—such as dogs—are bitten, infected, and pose the threat that people see and fear.

3.5.11 Q Fever

'Query fever' (<http://www.emedicine.com/EMERG/topic589.htm>) is an acute infectious disease most commonly spread by inhalation or ingestion but also by ticks. Mammals, birds and ticks all serve as reservoirs, but ticks are the most common vector for humans. Gardon et al. (2001) report on the annual incidence of Q fever in French Guiana, with 37 per 100 000 population being affected during the last four years of the 1990s. A case control study revealed that residence near a forest was a major risk factor, and the authors identified the wild reservoir of bacteria responsible.

3.5.12 *Taenia solium* Cysticercosis (Tapeworm)

A study by Carrique-Mas et al. (2001) in a village in the Chaco region of Bolivia (an area characterized by scrubby forest) revealed a serious problem of *Taenia solium* cysticercosis, with a seroprevalence of 22% in humans and 37% in pigs. People become infected by ingesting cysticerci in undercooked pork. In endemic areas, tapeworm is responsible for a high percentage of neurological disorders and epilepsy.

3.5.13 Dengue

Though not specifically a forest-related disease, dengue has affected many tropical forest peoples. Globally, Gratz and Knudsen (1997) report about 20 million cases annually, with 500 000 people (90% of whom are under age 15) requiring hospitalization and around 24 000 deaths. Though previously considered a primarily urban problem, it now significantly affects rural areas in China, India, Thailand, Malaysia, Indonesia and other Southeast Asian countries. Spread by mosquitoes (*A. aegypti*), the disease is now the most common of all the arboviral diseases and causes massive epidemics in nonimmune populations in Asia, the Pacific Islands, Africa and the Americas. In Southeast Asia, the attack rate increased from 15 per 100 000 in 1979 to 170 per 100 000 in 1987. Problems with control include lack of resources, lack of understanding

among the populace of the transmission cycle, and creation of domestic and peridomestic breeding sites for mosquitoes.

3.5.14 Kyasanur Forest Disease

Haggett (1994) explicitly links India's Kyasanur forest disease to forests, noting that this problem emerged when the tick vector increased as sheep pasture replaced forests (also stressed by Sommerfield 1994, drawing on Nichter 1987).²⁸ Walsh et al. (1993) give a thorough description of the interactions among forest clearance, an ensuing thick undergrowth of *Lantana camara*, ticks (*Haemaphysalis* spp.) and their larval and nymph stages, forest and domestic animals, and human population increase in this Indian outbreak. Haggett also discusses the recent phenomenal growth in recognized viruses, which he attributes both to improvements in our ability to recognize and identify viruses, and to the increasing attention viruses receive when they impinge on temperate, as opposed to tropical, settings—a point made by other authors as well.

3.5.15 Giardiasis

Patz et al. (2000) describe the spread of giardiasis from human hosts visiting the mountain gorillas of Uganda to the animals. Wolfe et al. (2001) studied antibodies to dengue-2, Japanese encephalitis, Zika, Langat, Tembusu, Sindbis, Chikungunya and Batai viruses in orangutans in Sabah, concluding that the animals are also susceptible to arboviral infections in the wild (cf. John Wolfe's observations on chimpanzees and Ebola in Cameroon).

3.5.16 Genetic Predispositions

Differing genetic predispositions represent another, increasingly researchable issue, with controversial implications. The intolerance of many Asians for milk and the malaria-protective effects of sickle cell anemia are well-known examples of genetic predispositions with health-related effects. From an ecological perspective, we know that people are often relatively well adapted to diseases and conditions to which they and/or their ancestors have long been exposed. Similarly, they may be poorly adapted to new diseases and conditions. Balter (2005) discusses genetic differences that affect humans' differing capacity to coexist with malaria.

3.5.17 Haze and Smoke

The emissions that result from forest fires can be a serious health problem for people both in and outside the forest. Harwell (2000) and Colfer (2001) document the adverse effects of the 1997-1998 Borneo fires on the people living there, as do Radojevic and Hassan (1999), who report pollution levels during the 1998 fire periods in Brunei, a place not typically characterized by air pollution. The adverse health effects of indoor smoke pollution from cooking fires (with greater impacts on women and children than on men) have already been mentioned (Section 2.4.4).

3.5.18 Emerging Vector-Borne Diseases

One worrying trend probably related to landscape change and population growth is the appearance of apparently new vector-borne diseases (see, e.g., Wilson et al. 1994). Tesh (1994) notes the ephemeral nature of some of these emerging diseases, along with the probable factors leading to their emergence. Between 1989 and 1992, for instance, Venezuelan hemorrhagic fever (which causes fever, chills, headache, myalgia, sore throat, weakness, anorexia, nausea and vomiting) fairly suddenly appeared in the municipality of Guanarito in Venezuela, killing 33% of the people who contracted it. Guanarito is surrounded by a patchwork of cultivated lands, savannah and gallery forest. Population increase, both natural and in-migrating, has meant continuing forest clearance. Rodents coming in from surrounding grasslands are the likely source of infection. The disease arrives and departs suddenly, and it is highly localized. This same author also documents 26 epidemics of the less deadly Oropouche (ORO) fever in the Brazilian and Peruvian Amazon region and the Isthmus of Panama. The two largest recorded epidemics (Belém and Manaus in 1980-1981) involved about 100 000 people each. Tesh (1994) describes how the disease is thought to appear:

It has been postulated that ORO virus is maintained in two distinct cycles: a) an epidemic urban cycle in which humans are the primary host, and the biting midge *Culicoides paraensis* is the vector; and b) a silent maintenance cycle in which forest animals (probably sloths) are the vertebrate



hosts, and a yet unidentified arthropod serves as the vector. It is assumed that humans entering the jungle occasionally become infected with the virus; when they return to their village or town, if conditions are right, temporary urban transmission occurs and an epidemic ensues. (133)

Air pollution in a field being burned for swidden cultivation, Lao PDR (Photo by Koen Kusters)

Daszak et al. (2001) also provide an analysis of the real and potential impacts of Nipah virus, West Nile virus, and other emerging zoonotic diseases on human health and biodiversity. Gratz (1999) stresses the resurgence of plague (as well as malaria, leishmaniasis and dengue) and links these to ecological changes that have favored increased vector densities, such as dam construction, irrigation and other development projects, urbanization, human travel and deforestation. Graczyk (2002) emphasizes the likely climate-related changes in zoonotic diseases, anticipating an increase in vector-borne diseases generally, with global warming.

We quote another passage from Tesh (1994) at length because it encapsulates the kinds of complex linkages among human behaviour, urbanization, landscape change, ecology, and animal vectors that relate to our exploration of the causal links between forests and human health:

Other factors which have probably contributed to the emergence of ORO fever as a human pathogen are deforestation, urbanization and agricultural development. This has to do with the breeding habits of the presumed peri-domestic vector, *Culicoides paraensis*. Two of the favorite larval habitats of this biting midge are rotting cacao husks and banana stumps. Such decomposing plant material remains moist even during dry periods and serves as an excellent medium for the microorganisms on which the *Culicoides* larvae feed. As a consequence, very dense populations of *Culicoides paraensis* are often found in rural communities near cacao or banana plantations. Furthermore, since these and other ceratopogonids serve as pollinators of the cacao flowers, farmers often place rotting plant material among the cacao plants to intentionally increase the ceratopogonid population in order to enhance pollination and improve fruit yield. Even in urban areas of the neotropics, many people have banana trees in their gardens, which can serve as breeding places for insects. (135-36)

Given the probable impossibility of predicting the emergence of such diseases, Tesh argues that we can deal better with them when they do arise if we have an active surveillance network and trained epidemiological field teams ready to analyze new occurrences and respond with targeted interventions.

3.6 Major Forest Diseases and Health Problems: Conclusions

The longstanding diseases described above have obvious and adverse impacts on human beings. The capacity of various disease vectors to adapt to new environments is legendary. The variety in manifestations of disease and interactions with environmental and human factors is

striking, as is the difficulty of predicting future disease outbreaks and trends. That indigenous populations have certain immunities—and that mixing populations poses dangers to both immigrants and indigenous groups—is apparent. Several recurring issues in the forest-health relationship are important:

- the usually deleterious effects of deforestation on health via complex and variable means addressed in various sections of this review;
- The widespread tendency to replace forests with crop farming, ranching and small animals;
- the creation in disrupted areas of bodies of water that serve as habitats for dangerous vectors;
- the additional opportunities for contagion that come with increased human movement, particularly as vulnerable populations move into forested areas;
- variation and change in vector behaviour that render control difficult; and
- increases and often adverse effects of water control projects and roads on human health (see Patz et al. 2000 for a thorough, holistic analysis of such factors).

Compounding the fact that forests can be hospitable habitats for disease is the comparative lack of attention in the formal medical establishment to these diseases—disproportionately suffered by those with little money, prestige, or influence (see Section 4 for further discussion of this issue)—a point also made by Coimbra et al. (2002).²⁹

In addition to the dangers these diseases pose to humans living in forests, the transfer of diseases between humans and forest animals has potentially lethal implications for faunal biodiversity. In Gabon, virtually all the gorillas in a recent ethological study were wiped out by a very localized Ebola outbreak (Colfer's discussion with two ethologists who had been studying the population, May 2004).

Summary

Individual characteristics, physical and social contexts, and values and norms affect people's health in any given place. Deforestation, disease, population growth, human movement, economics and power are also intimately interconnected. People's perceptions about disease can influence health status of the population. Several emerging viral diseases pose threats to human (and wildlife) populations.

- 3.1 HIV/AIDS interacts with political conflict, nutrition, and women's low status in East and Central Africa. Globally, we see a downward spiral for affected households involving gender inequities, poor nutrition, cultural breakdown, more poverty and disease. Roads and other transport networks play an important role in the spread of the disease. Gender and other inequities in access to resources, seasonal labour and separation of families all increase people's vulnerability to AIDS. Undernutrition can make people more susceptible to HIV/AIDS infection and interfere with working or finding food. Agrobiodiversity and indigenous knowledge are seen by some as potent coping mechanisms for dealing with the prevalence of HIV/AIDS in Africa. Handling of bushmeat increases one's exposure to many viruses.
- 3.2 Malaria is a major killer and factor in the burden of disease in and near forested areas, particularly in Africa. The causal links between deforestation and incidence of malaria are difficult to sort out and vary with location: In many areas there appears to be a clear link; in others malaria incidence increases with amount of forest cover. The logging process can create standing water and thus mosquito breeding sites. In a few cases, such as the *terai* of Nepal and Panama, forest clearing has allowed populations to enter areas that had previously been uninhabitable because of the prevalence of malaria. Local populations often have some immunity, but the movement of peoples with little or no immunity into malarial areas has increased the number of cases. The enormous variability and adaptability of mosquitoes contribute significantly to the difficulty of sorting out causal factors and developing effective health maintenance strategies. The current and future impact of climate change remains unknown.
- 3.3 Although not necessarily related to forests, mercury poisoning is common in some forested areas. Exposure to mercury can lead to lowered resistance to disease, insanity, mental retardation, and other adverse health impacts. Two decades of study in the Amazon basin have established the dangers of piscivorous fish consumption, particularly in areas downstream from gold mining. Collaborative efforts between researchers and community members have in some places reduced exposure to mercury by altering local diets. Recently, researchers have discovered that much of the mercury found in Amazonian populations comes naturally from the area's old soils, and the situation is exacerbated by forest clearing and other erosion-producing processes. Studies of gold mining areas in the Philippines have found worrisome levels of mercury, particularly in children. Mercury levels in soil and water have been studied in gold mining areas in Tanzania and Zimbabwe as well, without direct links to human health impacts.
- 3.4 A huge variety of diseases and ailments affect forest peoples, most notably vector-borne diseases. These have varying relationships with deforestation, but in most cases deforestation appears to increase the disease load of local people. However, analysis of local conditions will be necessary to assess or predict the impact of land cover change on human health.

Policy Recommendations

A. Policy Implications for Human Health Conditions

Recommendations for health professionals

- Establish facilities along transportation routes to provide education on AIDS and the potential dangers of wildlife-human interactions.
- Conduct site-by-site investigations to understand the unique factors contributing to malaria incidence.
- Work with government agencies planning large-scale movements of people into malarial areas to address the greater vulnerability of such non-immune populations.
- Encourage people to seek alternatives to consumption of piscivorous fishes from rivers contaminated by mercury.
- Expand health care delivery in forested areas.

Recommendations for government agencies

- Ensure the availability of active epidemiological monitoring and trained field teams for use in forested areas.
- Expand efforts to strengthen the status of marginalized groups, including women and girls.

Recommendations for health and natural resource specialists

- Work together closely to ensure continuing (or new) access to forest foods and

medicines for families affected by HIV/AIDS.

- Pressure extractive industries to use best management practices and control the use of mercury in gold processing.
- Monitor soils for mercury levels.

B. Policy Implications for Causal Links between Forests and Health

Recommendation for land-use planners

- Mitigate the adverse health impacts of major land-use changes and provide ameliorative services where needed.

Recommendations for forest managers

- Incorporate into management plans the increased dependence of families afflicted with HIV/AIDS on local forest products, perhaps through collaborative management of woodlands.
- Acknowledge that forestry activities help spread HIV/AIDS (via road networks and separation of families) and contribute to solving the resulting problems.
- Use best management practices for logging and avoid leaving standing water; when pools and ponds are unavoidable, ensure that mosquito larvae do not proliferate and spread malaria.

Recommendation for government agencies

- Encourage techniques for extracting gold that do not pollute local rivers with mercury.

Chapter 4

Forests and Medicine

Six topics emerged as significant in our investigation of forests and medicinal plants:

1. medicinal plants and animals from the forest;
2. local knowledge about forest medicines;
3. the role and costs of these medicines;
4. threats to the sustainability of traditional medicines;
5. health care providers in forests; and
6. financial benefits from forest medicines.

We devote a section to each and conclude in Section 4.7 with a discussion of some recurrent themes in this literature.

4.1 Medicinal Plants and Animals from the Forest

Forests are important repositories of medicinal compounds from wild organisms (Seters 1997; Bryant 2002), including some common foods and drinks. This role is the basis for many arguments for rainforest conservation (Seters 1997; Kate and Laird 1999; Simpson et al. 1996; and many others).³⁰ Wild forest resources include alkaloids, like cocaine, reserpine, quinine, ipecac, ephedrine, caffeine, and nicotine, and antibacterial compounds, as well as antifertility compounds. Rao et al. (2004b, 2) give some examples: "These drugs carry important therapeutic properties including contraceptives, steroids and muscle relaxants for anesthesia and abdominal surgery (all made from the wild yam, *Dioscorea villosa*); quinine and artemisinin against malaria; digitalis derivatives for heart failure; and the anti-cancer drugs vinblastin, etoposide and taxol."

Certain plant ecologies, associated with specific taxonomic groups, encourage chemical defenses in plants. These include toxic seeds in fruits, the skins and bark on high-energy storage organs (e.g., tubers), and the delicate

parts of slow-growing species. Such slow-growing species, which are particularly well defended, may be late-successional and understory plants or plants that grow on poor soils. See Stepp and Moerman (2001) for a thorough discussion of why some of these defenses are more common in weedy secondary growth than in primary forests. For thousands of plant species, a vast arsenal of bitter alkaloids undoubtedly provides a competitive advantage by repelling hungry herbivorous mammals. Some of the defenses involve chemicals that have medicinal, toxic or stimulant properties (see <http://waynesword.palomar.edu/chemid2.htm>, or Raffaaf 1996).

Many of the bioactive compounds found in tropical forest plants are highly toxic if used in high doses. Such toxicity is often associated with medicinal values. Many poisonous medicinal resources from forests are or have been used for hunting, fishing and war.³¹ Raffaaf (1996) has identified more than 10 000 alkaloids in species from more than 300 plant families. We draw heavily on his work in the following examples of poisonous forest plants that are useful medicinally (see <http://waynesword.palomar.edu/chemid2.htm>).

An extract from the South American vine, *Chondodendron tomentosum*, is the source of the isoquinoline alkaloid used in curare. Amazonian Indians coat their poison darts with the gummy extract. D-tubocurarine has been used in the West to relax the heart muscle during open-heart surgery and to treat the spastic paralysis of tetanus toxin.

Another indole alkaloid, bufotenine, occurs in the seeds of yopo or paricá (*Anadenanthera peregrina*) from the Orinoco River basin. Indians of this region use a powder from the ground seeds as a hallucinogenic snuff. Bufotenine (5-hydroxydimethyltryptamine) is a secondary derivative of the amino acid



All parts of the shrub *Calatropis procera* are toxic but used in small doses for various medicinal purposes. (Photo by Daniel Tiveau)

tryptophan, a dietary amino acid essential for humans that scientists have not been able to synthesize.

Raffauf (1996) describes the uses of alkaloids from snakeroot (*Rauvolfia serpentina*) for schizophrenia-like symptoms from LSD and as a brain depressant, and the Madagascar (or rosy) periwinkle (*Catharanthus roseus*) for chemotherapy treatments for leukemia, Hodgkin's disease and other malignant cancers,³² among others. Raffauf concludes his review of poisonous alkaloids by wondering about the cures awaiting discovery in tropical rainforests.

Forest animals also serve as sources of medicines. Grifo et al. (1997) found in their study of the 150 most commonly prescribed drugs in 1993 that 23% of the compounds in prescription drugs dispensed in the United States came from animals (see Table 8).

Some poisonous compounds, including polypeptide toxins and dendrotoxins, are purified from venomous snakes, spiders, insects, scorpions, snails, and other animals; these are often selective toxins, which can

Table 8. Biodiversity and Human Health

Origin of 99 Most-Commonly Prescribed Compounds

Origin	Total compounds	Natural products	Semisynthetics	Synthetics	Percentage
Animal	20	3	17	—	20.5%
Plant	19	6	13	—	19.5%
Fungus	10	2	8	—	10%
Bacteria	4	3	1	—	3%
Marine	1	1	0	—	1%
Synthetic	45	—	—	45	46%
Total (top 99)	99	15	39	45	100%

Origin of 150 Most-Commonly Prescribed Drugs

Origin	Total compounds	Natural products	Semisynthetics	Synthetics	Percentage
Animal	27	6	21	—	23%
Plant	34	9	25	—	18%
Fungus	17	4	13	—	11%
Bacteria	6	5	1	—	4%
Marine	2	2	0	—	1%
Synthetic	64	—	—	64	43%
Total (top 150)	150	26	60	64	100%

Source: Grifo et al. (1997).

be useful for experiments as well as serving as 'a starter compound for highly selective drugs' (Bowman and Harvey 1995, in Laird and Kate 1999). Laird and Kate (1999) note the near-absence of research on insects. The poison from several extremely poisonous frogs in Central and South America was used by local groups in hunting.³³ One of these, *Epipedobates tricolor*, was used in South America to poison arrow tips. The alkaloid (epibatidine) from this frog has been modified and tested by Abbot Laboratories for use as a strong analgesic, apparently with few side effects (Wilson 2002).

Barsh (1997) describes the importance of compound prescriptions that include 'antagonists': In Latin American folk remedies, *Heimia salicifolia*, for example, requires compounding with other herbs to 'turn off' some of the alkaloids. De Silva (1997), while recognizing the important roles of medicinal plants, also warns of some dangers in using these powerful chemicals in unknown quantities and quality, as does Etkin (1992).

The medicinal products described above have been confirmed by testing against western standards of effectiveness. However, forest peoples use many more forest medicinal species whose effectiveness and side effects remain unknown, such as abortifacients (Mugisha 2000) and treatments for venereal disease (Kambizi and Afolayan 2001). Some, such as the African use of ants for stitching wounds, are unlikely to catch on. Others, like the tropical tree latex (e.g., *gutta-percha* and *Sapodilla*) for plugging root canals in dentistry, have been widely used. Many medical uses remain local or are traded in very small volumes. Myers (1992) says that more than 1,400 varieties of plants from tropical forests are thought to be potential cures for cancer. See Section 4.3 for more examples.

In areas with significant Chinese populations, specialist shops continue to sell items said to contain ingredients from tigers, rhinos and leopards (e.g., <http://www.savethetigerfund.org/>), all used traditionally as medicines. Although tiger bones have played a role in Chinese medicine, they do not now occur in any products endorsed by the state (though the ingredient may be dishonestly listed on labels). All Chinese medical textbooks in the 20th century have recommended water buffalo horn (raised for food in China for more than 5000 years) as a substitute for rhino horn, which was traditionally used to



Dental problems are common in forested areas – a man from Bengkulu, Sumatra (Photo by Carol J. P. Colfer)

treat not impotency, as widely stated in the West, but life-threatening fever (Luger 2005). The use of such wildlife for medicines is well described and governments have made serious efforts to address it. Information about the uses of animal parts in traditional medicine is conflicting; many conservationists believe that medicinal uses promote illegal hunting.

The forests also harbour a vast number of popular drugs in daily use. Here we give only a few examples of the many possibilities. Ghana and Nigeria are home to the cola nut, which is rich in caffeine and used in popular cola drinks (including Coca-Cola, which originally also included coca, *Erythroxylum coca*, another forest plant); cola nut is chewed widely in Central and West Africa to inhibit fatigue and hunger, and as an aphrodisiac. Ginger (*Zingiber officinale*), used in the West in cooking and drinks, is widely used in Southeast Asia to treat minor ailments, ranging from intestinal to upper respiratory to arthritic complaints. The chocolate or cacao tree (*Theobroma cacao*), probably originating in the Amazon Basin, grows in the understory of humid tropical forests. Its Latin name means 'food of the gods'. Cacao contains theobromine, a caffeine relative,

with various reputed characteristics, from a mild stimulant to a pleasant aphrodisiac.

4.2 Local Knowledge about Forest Medicines

Indian and Chinese medical traditions are ancient and well established, but even within those countries, local people have their own versions of health care. Forest communities, particularly, usually have experts who may or may not be willing to share their knowledge; their skills are often passed down orally from generation to generation, with people adopting and adapting new knowledge and techniques. Some local healers become famous over larger regions. Healing is often associated with religious and spiritual practices, such as divination and the appeasement of spirits. This complexity can make it hard to assess the wider validity of local practices.

A wealth of indigenous and local knowledge about forest medicines exists. Anyinam (1995) provides an overview of the links between ethnomedicine and the biotic environment, giving many examples of the kinds of cultural perceptions and practices that intertwine with ecology. Farnsworth and Soejarto (1988) maintained NAPRALERT, a database of 33 000 species, of which around 9200 have ethnomedical uses. They believe that roughly 28% of plants on earth have been used medicinally. The studies cited below are representative; both the amount of recorded traditional knowledge and the number of known

plants are much larger than represented here. We organize this information geographically.

Joshi and Joshi (2000) survey studies of indigenous medicinal plant knowledge in Nepal (see Table 9) and express concern about the loss of such knowledge as cultures and landscapes change. Their study demonstrates both the ethnobotanical knowledge of the people of the Kali Gandaki Watershed in central Nepal and its utility in treating local illnesses. Like many other researchers, they find traditional medicines important for primary health care.

Many students of ethnomedicine in Nepal have emphasized the importance of local medicinal knowledge for remote people who have little cash (Satyal et al. 2002; Bhattarai 1997; Shrestha and Dhillion 2003). Ghimire et al. (2005) demonstrated the heterogeneity of knowledge among members of two communities where medicinal plant use was widespread in Shey-Phoksundo National Park, in Nepal. Shankar and Majumdar (1997) explore knowledge and traditions relating to biodiversity and the historical use of medicinal plants in Nepal. De Alwis (1997) describes the importance of ancient Ayurvedic traditions in the medical system of Sri Lanka and estimate that traditional medicinal species number 550 to 700.

Voeks and Sercombe (2000) describe the poverty of ethnomedical knowledge among the Penan of Brunei; similarly, in Malinau, the Punan look to swiddening groups for medicinal products. The authors' explanation is that the Penan, who lived deep within the forest,



Indian medicines for sale, Myanmar (Photo by Brian Belcher)

Table 9. Medicinal Plants of Kali Gandaki Watershed

Disease category	Plants
Cardiovascular complaints and circulatory diseases	<i>Berberis asiatica</i> , <i>Capsella bursa-pastoris</i> , <i>Portulaca oleracea</i>
Cough, fever, headache and respiratory ailments	<i>Artemisia dubia</i> , <i>Datura stramonium</i> , <i>Ficus religiosa</i> , <i>Justicia adhatoda</i> , <i>Justicia procumbens</i> , <i>Taraxacum officinale</i> , <i>Terminalia bellerica</i> , <i>Vitex negundo</i>
Dermatological afflictions	<i>Achyranthes bidentata</i> , <i>Amaranthus spinosus</i> , <i>Artocarpus lakoocha</i> , <i>Cannabis sativa</i> , <i>Cassia tora</i> , <i>Cyperus rotundus</i> , <i>Ficus religiosa</i> , <i>Jatropha curcas</i> , <i>Melia azedarach</i> , <i>Ocimum basilicum</i> , <i>Terminalia chebula</i> , <i>Woodfordia fruticosa</i>
Dental problems	<i>Achyranthes bidentata</i> , <i>Jatropha curcas</i> , <i>Portulaca oleracea</i> , <i>Potentilla fulgens</i> , <i>Trichilia cannoroides</i>
Gastrointestinal disorders	<i>Acacia catechu</i> , <i>Aegle marmelos</i> , <i>Ageratum conyzoides</i> , <i>Bauhinia variegata</i> , <i>Cannabis sativa</i> , <i>Cassia tora</i> , <i>Centella asiatica</i> , <i>Chenopodium album</i> , <i>Cipadessa baccifera</i> , <i>Euphorbia hirta</i> , <i>Mangifera indica</i> , <i>Melia azedarach</i> , <i>Oxalis corniculata</i> , <i>Plantago major</i> , <i>Plumbago zeylanica</i> , <i>Scutellaria repens</i> , <i>Terminalia bellerica</i> , <i>Terminalia chebula</i> , <i>Trichilia connaroides</i> , <i>Urena lobata</i> , <i>Woodfordia fruticosa</i> , <i>Zanthoxylum armatum</i>
Genito-urinary complaints	<i>Asparagus filicinus</i> , <i>Ficus religiosa</i> , <i>Ocimum basilicum</i> , <i>Plantago major</i> , <i>Urtica dioica</i>
Skeleto-muscular affections	<i>Berberis asiatica</i> , <i>Justicia adhatoda</i> , <i>Urena lobata</i> , <i>Urtica dioica</i>
Ophthalmological problems	<i>Colebrookea oppositifolia</i> , <i>Euphorbia hirta</i>
Other uses (cuts, wounds, etc.)	<i>Ageratum conyzoides</i> , <i>Bidens pilosa</i> , <i>Centella asiatica</i> , <i>Eupatorium adenophorum</i> , <i>Mangifera indica</i> , <i>Mimosa rubicaulis</i> , <i>Oxalis corniculata</i> , <i>Rumex nepalensis</i> , <i>Selaginella biformis</i> , <i>Taraxacum officinale</i> , <i>Vernonia cinerea</i> , <i>Woodfordia fruticosa</i> .

Source: Joshi and Joshi (2000).

were less exposed to dangerous disease and therefore had less need of complex medical knowledge (see Section 3, above, and Dounias et al. 2004 on the greater resistance to local forest diseases of some true forest-dwelling populations). However Dounias also points out (personal communication, 2005) that, while the Penan do not have high levels of medical expertise, some African pygmy groups (Aka, Baka, Medjan, Mbuti and probably others) are renowned for their skills as traditional healers, with their expertise widely sought.

Indeed Africa has extensive ethnobotanical knowledge of medicinals. Noumi et al. (1999) examined 26 plants used by traditional practitioners to treat hypertension in Bafia (120 km from Yaoundé, Cameroon) and warned of the possibility of undesired abortions. Etkin and Ross (1994) distinguish between wild and

‘semiwild’—the medicinal plants found among the densely populated Hausa settlements of northern Nigeria)³⁴—and report 374 medicinal plants used in 3,165 distinct remedies. Laird and Wynberg (1997) report 3000 species of higher plants used as medicines in South Africa, with 300 in common use.

Similarly in the Americas, Stepp and Moerman (2001) note the abundance of Mayan medicinal plants in disturbed areas in the highlands in Chiapas, Mexico. They also provide evidence from several studies, including their own, showing that medicinal plants are often weeds (defined in appendix). Voeks (1996) makes the same point for Bahia, Brazil, where he found many medicinal plants---planted, wild, native, and exotic---in secondary regrowth. Of the 99 plant species Milliken (1997) found used to treat malaria in

Roraima, Brazil, only 22 had appeared in the literature as being used for this purpose.

Gender differences in medical knowledge are important. Joshi and Joshi's (2000) study showed Nepali women to be more knowledgeable about medicinal plants than men, as did Leaman et al. (1991) and Gollin (1997) in East Kalimantan, Indonesia.

Considerable controversy surrounds the use of medicinal plants and animals, with several important issues:

- their potential as a sieve for finding compounds of use in western pharmaceuticals;
- the utility of traditional and local health care knowledge for maintaining health locally;
- possible dangers associated with their use; and
- their role where few health care alternatives exist.

4.3 The Role and Costs of Forest Medicines

Forest medicines offer three benefits. First, their continuing use represents a knowledge resource (indicated in Section 4.2) of considerable significance for the world's current and future pharmacopoeia. Second, the plants and animals themselves are the physical reservoir for this future use. Third, and most germane to this section, they represent the only pharmacy for people living in remote areas where 'modern' medicine is not available. Here we focus first on the extensive use that is made of traditional medicine, then on its efficacy and finally on trade. An important question is to what degree widespread use indicates efficacy—a subject of some controversy.

Akerele (1991) notes that since the Alma-Ata Conference in 1979, WHO has urged member states to identify, evaluate, process, cultivate and conserve their plants used in traditional medicine; and to ensure quality control of such drugs by applying suitable standards and modern manufacturing techniques. According to Rao et al. (2004a, 1), 'China, Cuba, India, Sri Lanka, Thailand and a few other countries have endorsed the official use of traditional systems of medicine in their health care programs'.

Balick and Cox (1996) and Balick et al. (1996) provide useful surveys of the literature on medicinal uses of tropical plants, addressing

biodiversity, conservation, ethnomedicine, ethnobotany, pharmacognosy, habitat protection, ethical issues and intellectual property rights. Bhat (1995) used the CAB abstracts, which contain around 50 000 records accumulated between 1973 and 1993, to examine information on five kinds of plants (totaling 8000 species but not classified as forest or nonforest), 52% of which were medicinals and 11% were poisons, giving some indication of the ubiquity of medicinals (see also Bhat 1997). Aflora (<http://130.54.103.36/aflora.nsf>) is another excellent source of ethnobotanical information on medicinal plants, specifically in Africa. It provides information on the cultural context in which the plants are used (see Salas 1994 for a short rationale).

The literature emphasizes the abundance of potentially useful plant species. He and Sheng (1997) report that the official *Pharmacopoeia of the People's Republic of China* lists 709 drugs, with only slightly more than 40 being animal or mineral. Plant material accounts for more than 80% of the drugs sold, and of the 1000 most commonly used medical plants, 80% of the species are wild.

Bhattarai (1997) reports that 85% of the Nepali population uses folk herbal remedies; Shankar and Majumdar (1997) estimate that for 400 million to 500 million people in India, traditional medicines are the only alternative. Mahapatra and Panda (2002) found 215 wild plants used medicinally by forest villagers in Orissa. Anyiman (1995) reports that in all of India, some 2500 plants are used medicinally.

Gollin (1997) reports on the medical system of the Kenyah Dayaks of Borneo, whom she found to use 200 species of plants and 6 species of animals in their medical and poison pharmacopoeia.

Barrett (1995) found 154 plant species used medicinally in his surveys in the city of Bluefields and surrounding countryside in Nicaragua, with more than 200 medicinal plants for the wider region.

The economic value of traditional medicines is considerable (see also the distribution of benefits, described in Section 4.6) but difficult to pin down. At the most disaggregated level, Kaimowitz (2005) reports that US \$75 billion of pharmaceuticals of natural origin are sold each year. Rao et al. (2004a) found that the annual reported international importation of medicinal and aromatic plants for pharmaceutical use averaged 350 000 mg, with

a value of over US\$ one billion annually during the 1990s. Akerle (1991) reports results from WHO (1987) and values the production of traditional plant remedies in China at US \$571 million annually. In Sri Lanka, for instance, the number of Ayurvedic hospitals using these medicinal plants increased from fewer than 15 to 42 over a 10-year period (de Alwis 1997). Medicinal uses of wild forest herbs may be unsustainable: *Munronia pumila* is a common ingredient in local prescriptions in Sri Lanka, but 200 plants must be uprooted to produce 1 kg of material. This, compounded with very low prices to collectors, exacerbates sustainability problems (de Alwis 1997).

Cunningham (1993) estimates that 70% to 80% of Africans consult traditional medical practitioners for health care and expects the demand to rise. More than 400 indigenous species of medicinal plants are sold in Nalta, South Africa (Cunningham 1993). Achieng (1999) reports that the bark of *Prunus africana* (used for prostate cancer in the West) is worth US \$220 million to the pharmaceutical industry, based on an average annual harvest of 3,500 tons and prices up to US \$60 per kg. Cunningham and Mbenkum (1995) consider increased domestication of this species, for which demand is likely to rise (see also Cunningham et al. 2002).

Sales of medicinals in African local markets are often handled by women. Cunningham noted large numbers of women in the regional markets of Abidjan, Côte d'Ivoire, and in South Africa. He also presents a case from Ethiopia where 95% of the sellers are women from a marginalized ethnic group, with low social status. Ndoye et al. (1997) and Perez et al. (2003) found that women dominated the collection and sale of nontimber forest products, including medicinals, in Cameroon: 94% of the traders were females who specialized in small-scale (and less profitable) trade.

Cunningham's (1993) dental stick data focus on urban sales but reflect wider usage. In Mozambique, *Euclea divinorum* and *E. natalensis* and in Côte d'Ivoire, *Garcinia afzelii* and *G. kola*, are the most commonly sold species; in Cameroon, *G. mannii* and *Randia acuminata* formed a chewing stick 'cottage industry.' In Ghana the favorites were *G. afzelii* and *G. epunctata*.

Satyal et al. (2002) studied medicinal plants among the Bhotia tribes of Nepal's Kumaun Higher Himalaya area and found that in three valleys of the region, the sale of

five medicinal plant species were the major contributors to household incomes. Olsen and Bhattarai (2005), who have conducted studies in the Himalayas (including forested areas), developed a typology of 13 kinds of 'economic actors' involved in medicinal plant trade, from collectors to wholesalers. A quarter of the collectors were female specializing in small-scale trade (none of the more wide-ranging economic actors were women). Olsen and Larsen (2003), in a systematic study that cross-checked data from local to international levels, found that annual values of the medicinal plant trade (including both forest and nonforest-based species) to rural harvesters ranged from US \$0.7 million to \$3.3 million, with 85% of the value coming from three products. The value in 1997-1998 was US \$2.3 million. The total trade in alpine species in 1997-1998 amounted to approximately 1600 tons, indicating the involvement of an estimated 25 000 to 35 000 harvesters. Official government estimates of medicinal plant trade accounted for only about 20% of the estimates from this study, largely because of the difficulties governments have collecting accurate data on illegal exports (see also Olsen 2005).

Medicinal plants are common and profitable, but what about their efficacy? Many have been found to be efficacious from a western perspective, many not. Some medicinal plants are useful universally, some are useful locally, and some are harmful. Research on differentiation should take into account placebo effects, cultural and psychological uses, and preventive effects, as well as chemically confirmed efficacy from a western point of view.

Barsh's (1997) study is unusual in its care and thoroughness. He studied 100 research reports, published between 1990 and 1994 from the MedLine CD-ROM database, to determine the efficacy of traditional remedies based on lab tests or clinical data. He reports on traditional medicines that were found to be effective for 23 medical uses, from both literate and indigenous-folk traditions all over the world, including in forested areas. He also provides numerous examples of studies showing high levels of efficacy for the total pharmacopoeia in individual traditions. He warns of the importance of getting accurate information about collection, preparation and dosage from knowledgeable practitioners, rather than from the general public.

Shanley and Luz (2003) argue that market sales, which they demonstrate in Brazil for all socio-economic groups, are evidence for the efficacy of many medicinal plants. Sheil disagrees, citing as counterexamples the widespread use of nutmeg and clove as a cure for the bubonic plague in Europe in the 16th and 17th centuries, and the use of tiger bone, seahorse and rhino horn today. This question remains open.

Handa (1996), building on the Ayurvedic tradition, examines spices and their potential roles in health promotion. In clinical trials, *Piper longum*, *P. nigrum* and *Zingiber officinale*, for example, were effective in the treatment of tuberculosis (TB), by enhancing the bioavailability of a drug (rifampicin).

That quinine and quindine, derived from Andean forest trees of the genus *Cinchona*, have for many decades been the world's main defense against malaria and the saviour of countless lives underlines just how important plants can be. The latest malaria treatment is also based on a plant, *Artemesia*, from the traditional Chinese pharmacopia (though American companies have tried to patent it). ICRAF and others are gearing up to grow it in East Africa (Clifford Mutero, personal communication, 2005; see also Dalrymple 2005). Brandão et al. (1992) conducted a study of herbal medicines in use in Pará and Rondonia, in the Amazon. They found that the plants used to treat malaria symptoms were all from the local flora, and 4 of the 22 plants tested, or 18%, showed activity against *Plasmodium berghei* in mice. They also tested 273 species based on random selection, finding only 2, or 0.7%, that were active (see similar experimental evidence of nonrandomness in activity in Bornean ethnomedicine, Leaman 1996).

Cunningham (1993) highlights the importance of chewing sticks, which have been proven effective in maintaining dental hygiene by effectively removing food particles that cause decay, in African contexts where dentists are in short supply.

Heinrich et al. (1998), in an attempt to get beyond lists of species, report on a comparative study of four Mexican communities to determine to what degree the same plants are used for the same diseases (locally defined), both within communities and between them. These authors found a fair amount of agreement about medications for gastrointestinal disturbances, but less for

respiratory and dermatological diseases and other ailments.

Elisabetsky and Siqueira (1996) examined the psychopharmacologic basis for 'nerve tonics' used in the Amazon, made from the roots of *Ptychopetalum olacoides*. They concluded that such tonics do affect the central nervous system, with desired effects on the symptoms for which they are commonly used.

Traditional treatment of wounds, a very important health risk in tropical forested areas, is addressed in Bodeker and Hughes (1996). They argue for the utility of indigenous knowledge about wound treatment, detail the laboratory and tests they have done at Oxford Wound Healing Institute to assess efficacy, and describe their own plans to use the local remedy, *Aloe* spp., to treat the sores associated with HIV/AIDS in Tanzania. Kambizi and Afolayan (2001) conducted an ethnobotanical study of herbal medicines used to treat venereal diseases in rural southern Zimbabwe and subjected six common medicines to antibacterial screening. Most of the plants were found to have broad-spectrum antibacterial effects, and these authors stressed the importance of such traditional knowledge in people's daily lives—and the danger of losing it.

Etkin (1992) raises the question of how western pharmaceuticals are used and perceived in nonwestern settings—an important health issue in the developing world, including forested areas. She focuses specifically on the idea of 'side effects' so prominent in western biomedicine, explaining some of the different possible interpretations of these phenomena in nonwestern practice: Side effects can be seen as part of the process, as differential appropriateness for different patients, as dosage markers, and as indicators of the need for additional medications. Her point is consistent with the widely held view in the field of system dynamics that there are no side effects, just effects. Such a holistic view recognizes interactions among parts—an approach that the evidence in this review suggests is very important for forests and human health.

4.4 Threats to the Sustainability of Medicinal Plants

The World Conservation Union (IUCN) concludes that more than 20 000 species are used as medicine worldwide, and half of these are

under threat of extinction (<http://www.iucn.org/themes/ssc/sgs/mpsg/main/Why.html>).³⁵ Many authors have recounted the threats to medicinal plants from habitat destruction, overharvesting, increasing commercialization, and loss of indigenous knowledge, as well as population increase, forest fires, shifting cultivation, and overgrazing (Anyinam 1995; Bhattarai 1997; Chivian and Sullivan 2002; de Alwis 1997; Elisabetsky and Shanley 1994; Shanley and Luz 2003; Rao et al. 2004a; and others).

Use and sale of medicinal plants are intimately connected with the threats to their survival. The example of *Prunus africana* (also called *Pygeum* in older texts) can serve to introduce issues that continually surface about effective traditional medicines. The bark of this tree, a ‘traditional medicine’ that is now commonly used to treat prostate problems all over the world (and listed in Appendix II of the Convention on International Trade in Endangered Species), was once distributed widely in sub-Saharan Africa. Achieng (1999) reports that most remaining trees are in Kenya, Uganda and the Democratic Republic of Congo; a few trees also remain in Cameroon and Madagascar. Asanga (quoted in Achieng 1999) reports that on Mount Cameroon, for instance, up to 8000 trees were stripped and left dead but standing; in Kenya the threats are from its utility as timber and fuel.

Cunningham (1993) emphasizes the adverse effects of the increasing popularity and commercialization of natural medicinal products from Africa. He notes, for instance, that with commercialization, medicinal plants that were formerly harvested only by specialists become an open-access resource to be harvested by all, and many of the traditional restrictions that limited harvesting in the past are ignored. Cunningham (1997a, 117-18) provides an illustration from Africa:

Firstly, there has been a decline in the area of distribution of natural vegetation that was, or would have been the sources of supply of traditional medicines. An extreme example of this is *Monanthotaxis capea*, which formerly was harvested for its aromatic leaves for a trade from Côte d’Ivoire to Ghana but is now extinct in the wild after the forest reserve in which it occurred was declassified and cleared for agriculture. In addition, supplies of herbal medicines to [traditional medical practitioners] are



Extracting medicinal bark from the Amazonian tree, anuera (Photo by Patricia Shanley)

affected by competing uses such as timber logging (e.g., *Pericopsis elata* in Côte d’Ivoire, *Pterocarpus angolensis* in Zambia and Malawi), commercial harvesting for export and extraction of pharmaceuticals (e.g., *Griffonia simplicifolia* and *Prunus africana*), and use for building materials and fuel.

Commercialization is often a vital part of the medicinal plant problem—though domestication and sustainable management are potential alternatives. Anyiman (1995) discusses the overharvesting of wild-growing *Rauvolfia serpentina* and *Coptis teeta* in India, and gaharu (*Aquilaria* spp.), reportedly used for ailments associated with pregnancy and childbirth,³⁶ in Indonesia. The same author notes how the widespread interest and market for various animal parts has led to the overexploitation of rhinos, tigers, musk deer, bears, monkeys and pangolins. He and Sheng (1997) briefly discuss the threats in China; Bhattarai (1997) covers Nepal.

An important issue raised by Cunningham as well as Shanley and Luz is the slow growth rate of many threatened species. *Warburgia salutaris*, the bark of which is used medicinally,



Traditional
medicine market,
Myanmar
(Photo
by Brian Belcher)

is one such example from southern Africa (Cunningham 1993; see also Botha et al. 2004 on the impacts of harvesting this bark under two types of management—private land and protected areas). *Tabebuia impetiginosa*, used to treat gastric ulcers, internal inflammation and tumors, and *Hymenaea courbaril* are similar examples from Brazil (Shanley and Luz 2003). Kuipers (1997) mentions the difficulty of sustainably harvesting roots, commonly used medicinally, though Dounias (2000) describes a method that is used by pygmies for sustainably managing wild yams and might be transferable. Rao et al. (2004a) argue for cultivating medicinal and aromatic plants in agroforestry systems, as do Satyal et al. (2002) for Nepali tribal groups.

Cunningham (1993) describes how medicinal plants have been protected in the past, through taboos, seasonal and social restrictions on gathering, the nature of plant-gathering equipment, lack of access to markets, and perceived inordinate toxicity of plants. In some cases, plants were intentionally managed because of their medicinal value (e.g., in West Africa, *Irvingia gabonensis* and *Ricinodendron heudelotii*, whose bark was used for diarrhea and dysentery) or for religious and spiritual

reasons (e.g., grave sites, sacred groves). By restricting the number of apprentices, traditional practitioners also safeguard medicinal resources (see Section 4.5 on healers); such mechanisms work in developed countries as well, though the forest implications are fewer. Governmental regulations designed to restrict the use of medicinal plants have been largely ineffective.

One initiative that holds promise for helping people achieve sustainable management is certification of medicinal plants (Leaman and Salvador 2005; see also Shanley et al. 2002). Although an encouraging trend, certification is not a panacea. Barriers include expense, consumer awareness and discrimination against small producers (Hamilton 2004). Peters (1994) has some valuable tips for increasing the sustainability of nontimber forest products more generally, many of which would be relevant to medicinals.

4.5 Health Care Providers in Forests

Traditional healers are the dominant providers of medical care in forested areas. Their importance was first formally suggested at the World Health Assembly in 1976, with subsequent stronger formal support for better recognition of their expertise (Akerle 1991). Traditional healers are said (by numerous sources, with slightly varying estimates) to provide between 70% and 95% of the primary health care in Africa. Anyinam (1995) lists some of the most common kinds of specialists one finds in communities: spiritual or magicoreligious healers, herbalists, technical specialists like bonesetters, and traditional birth attendants. He suggests that such practitioners (as well as the remote groups they serve) may be more 'endangered' than the medicinal plants themselves. Leonard (2003) notes the preference, in many parts of Africa, for traditional healers over 'modern' ones, reflected in the higher fees paid to traditional practitioners in both Cameroon and Kenya. In many areas, the belief that healers can also poison or curse their patients creates a strong willingness to pay (Leonard 2003). In Central Africa, powerful leaders are said to be able to transform themselves into leopards, elephants or hyenas.

People in some societies, such as the Tabwa of Zaire (Roberts 1997), make conceptual links between healers (sorcerers) and leaders (see Nguyen and Peschard 2003 for a more general

discussion of healing and politics). Among the Kongo of Zaire, Janzen (1978, 24) writes, ‘The antithesis of ideal governance is witchcraft, *kindoki*; the contrast between competent authority and the disastrous consequences of unbridled envy, anger and injustice is a recurring theme in the exploration of causality of illness. The chief partakes of the same power as the witch...’

Based on data from Cameroon, Tanzania and Ethiopia, Leonard hypothesizes that many people prefer traditional healers because payments are contingent on outcomes. Examining traditional healers, mission hospitals and clinics, and government hospitals and clinics, he finds that traditional healers put more effort into healing than do the other health care providers and motivate greater effort on the part of patients to contribute to their own healing. See Box 3.

Barsh (1997, 28-29), who sees traditional healers as empiricists, identifies four characteristics that would render the content of traditional ‘folk’ pharmacopoeia empirical:

- Most remedies contain bioactive compounds that have at least some of the medical properties claimed for them.

Box 3. Patients as Active Participants in Health Care

Considering African traditional healers and the people in their care, Leonard (2003, 20) writes,

This paper advances an image of patients that are active in the production and pursuit of their own health. This has important implications for health policy, where there is currently a strong bias towards the ‘passive patient’. The definition of the word patient includes ‘one that is acted upon’. Indeed Sen (1995, 11) used this definition in a different context as a contrast to agents: ‘To see (them) as patients rather than as agents can undermine the exercise ... Not to focus on the fact that they think, choose, act, and respond is to miss something terribly crucial.’ The patients interviewed for this paper are not passive in either treatment or choice of practitioner. Healers are successful because they understand this.



A local healer diagnosing a disease, Jambi, Indonesia (Photo by Carol J. P. Colfer)

- The proportion of bioactive compounds found in the pharmacopoeia is significantly greater than in nature.³⁷
- ‘Folk’ healers prepare traditional remedies in ways that isolate their most bioactive compounds or remove toxic ones.
- Healers combine plants in ways that create medically significant synergistic effects.

He also suggests that traditional healers may rely more on the process of learning than on the content, thereby erecting barriers to access to their knowledge. He likens the process of learning to be a healer to that of learning to hunt. Hunters, through long observational experience under a wide variety of conditions, are able to develop complex analog models of prey psychology, which they may be unwilling or unable to verbalize.

Gollin’s (2001) thorough study in East Kalimantan examined the sensory characteristics—particularly taste and smell—of medicinal plants used by the Leppo’ Ke Kenyah; the conclusions support Barsh’s finding of an empirical approach among traditional healers and other medicinal plant users.

The ever-presence of traditional medical practitioners in remote areas of the world is well documented (cf. Airhihenbuwa and Harrison 1993). Cunningham (1993) quotes

statistics from others: 30 000 to 40 000 traditional practitioners in Tanzania (compared with 600 medical doctors), and in Malawi, 17 000 traditional medical practitioners and 35 medical doctors. In the same work, he looks at the ratios of traditional practitioners and medical doctors to total population in 7 African countries. For traditional practitioners, ratios range from 1:100 in Swaziland to 1:1200 in Venda, South Africa; for medical doctors, the ratios range from 1:987 in urban Kenya to 1:70,000 in rural Kenya. His own interviews with sellers of traditional medicines in 20 markets in 13 African cities show how common traditional medicines are, as well as the variation in health-related gender roles. In Durban, South Africa, he found 270 female sellers and 22 male sellers, and in two cities in Côte d'Ivoire, 144 women and 30 men. In Malawi, where he found 16 sellers, they were all men.

Courtright (1995) found 117 healers, 46% of them women, in 71 villages in Chikwawa District in Malawi and interviewed 107 in a study of eye health. In the population, there was an average of 334 people per healer.

Laird and Wynberg (1997) report about 200 000 traditional healers in South Africa, with 200 to 300 healers' organizations, 10 of which were quite large. This is particularly striking since until recently, being a traditional healer was strictly illegal under the Suppression of Witchcraft Act (despite WHO recognition of the value of traditional medicine globally). Varga and Veale (1997) interviewed 45 traditional healers (as well as 218 nonhealer women) in South Africa, examining their use of *isihlambezo*, a tonic widely used by pregnant women but distrusted by the medical establishment because of fears about variation in dosage, among other things. They found a readiness among respondents to combine traditional and 'modern' medicine, particularly among their urban sample. Their conclusions about the tonic's efficacy were mixed. It potentially has both therapeutic and harmful consequences.

Rukangira (2005) emphasizes the holistic approach of traditional healers, adding,

...prominent features of traditional healers are a deep personal involvement in the healing process, the protection of therapeutic knowledge by keeping it secret, and the fact that they are rewarded for their services. The social context of the

therapeutic process requires reciprocity and this payment contributes to the effectiveness of the treatment. (18)

Joshi and Joshi (2000) stress the important roles of traditional healers (*jankhri*) in Nepal. Shrestha and Dhillon (2003) report reluctance of Nepali healers to share their knowledge, for fear that the efficacy of their treatments would be adversely affected. On Borneo, young Penan hunter-gatherers of Brunei Darussalam prefer free medical services and medicines provided by the local government health clinics. However, older Penan prefer traditional systems and are afraid of unknown side effects of clinic medicines (Voeks and Sercombe 2000).

Jackson (1995) tells the story of a group that is trying to resuscitate the indigenous medical practices of the Tukanoan Indians of Amazonian Colombia, whose health has reportedly deteriorated in the past 25 years as TB and hepatitis B have been introduced, along with more malnutrition.

Although the emphasis in this section has been on traditional healers, there are also studies showing the effectiveness (or lack thereof) of conventional medical systems in forested areas in developing countries. Stebbins (1993), for instance, describes the multiplicity of factors that prevent a well-planned health care program, *Coordinación General del Plan Nacional de Zonas Deprimidas y Grupos Marginados* (COPLAMAR), from effectively serving the health needs in a Mexican forest community.

In sum, traditional practitioners play important roles in the world's forests, contributing to health care in a meaningful and valued way. Linking traditional medical practice and 'modern' medicine—both to maximize the utility of both systems and to reduce the incidence of dangerous practices—is given only lip service in many countries;³⁸ more attention and resources probably need to be devoted to this idea.

4.6 The Economic Value of Forest Medicines

A vast literature, some quite polemical, considers the distribution of profits coming from forest medicines. The subject is addressed from the perspectives of law and intellectual property rights, botany, ecology, anthropology, medicine and public health, but one central issue is the balance between

benefits to pharmaceutical companies and benefits to forest communities.

Shanley and Luz (2003) have argued convincingly that global pharmaceutical development receives much greater attention than the needs of local communities, particularly in the tropics—needs that should be clear by now. Yet WHO estimates that 80% of people in the developing world rely on traditional medicines,³⁹ particularly plants, for their primary health care (Farnsworth et al. 1985; Walter 2001). The wide use of traditional medicines is attributed to their accessibility, affordability and compatibility with cultural norms (WHO 2002). Medicinal products gathered from forests are often the only remedies available to people in the developing world (Elisabetsky and Wannamacher 1993, for Amazonia; FAO 1991). The degree of reliance on and preference for medicinal forest resources differs across communities and generations. When alternatives are available and affordable, some people may reduce their dependence on traditional medicines; then again, they may not.

People who collect and sell plants also receive some benefits. In many traditional societies, women are the primary herb gatherers and herbalists (FAO 1997; Pérez et al. 2003; see Box 4 and Section 4.3).

But others benefit far more from the large and growing market for pharmaceuticals in the developed world. Walsh and Goodman (1999) provide a fascinating analysis of the conflicts in the United States, combining concerns for the long-term viability of the Pacific yew tree (*Taxus brevifolia*, the natural source of the effective anticancer drug taxol), breast cancer victims, government-granted pharmaceutical monopolies, and the public's role in health and environmental decisionmaking. Pharmaceutical companies make extensive use of forest plants in their products (see Table 10)⁴⁰ but guard access to information on their activities and profits as they seek competitive advantage in global markets.

In the United States, for instance, Grifo et al. (1997) report that 57% of the 150 drugs most commonly prescribed between January and September 1993 contained at least one major active compound derived from or patterned after compounds found in nature. Additionally, in recent years alternative medicinal products, many of which have their roots in tropical forests, have become increasingly popular in the developed world.

Box 4. An Indigenous Healer on Deforestation

Writing about traditional knowledge and biodiversity in Asia-Pacific, GRAIN and Kalpavriksh (2002, no page numbers) interviewed a traditional healer:

Angela Bautista, a faith healer and herbal doctor in Pila, Laguna, Philippines does not charge for her services and is surprised to hear of the huge profits pharmaceutical companies make from their sales. Putting a price tag on what is freely available in nature is incomprehensible to Angela. Firmly believing that there is a spirit in every living being, she warns that if you clear the forest you invite trouble from its uprooted spirit.

See McCaleb (1997) for a discussion of some popular natural medicinal products and rationales for encouraging their use; or Laird (1999), who provides an exhaustive discussion of all aspects of the botanical medicine industry. Johnson and Cabarle (1993) quote an undocumented source (Miller and Tangle 1991) who estimated the value of plant-derived over-the-counter pharmaceuticals to exceed US \$40 billion per year (in contrast to US \$7 billion worldwide from trade in tropical hardwoods). Kate and Laird (1999) report that global sales of botanical medicines topped US \$20 billion in 1997; global sales of pharmaceuticals were US \$300 billion that year, with those of natural origin estimated at US \$75 billion. Kuipers (1997) provides extensive information on pharmaceuticals and phytopharmaceuticals in Germany, where they are very popular. The above figures show enormous consumer interest. People in the developed world have a clear stake in forest-based medicinal compounds, yet little benefit accrues to those living in or near the forests.

Pharmaceutical companies incur significant expenses in discovery, laboratory research, processing, distribution and legal requirements.⁴¹ But many who have looked at this issue are troubled by the divergence in wealth between the companies and the forest communities in and around medicinal plant collection areas. See Mendelsohn and Balick (1995) for various calculations on how

Table 10. Major Patents on African Biodiversity

Species	Patent number and owner	Use and benefit-sharing
Forskolin (<i>Coleus forskohlii</i>)	US 4,724,238; EP 0265,810; IN 162,171; IN 147,030; IN 143,875 held by Hoechst (DE)	Traditionally used in medicine throughout Africa, India and Brazil. Patent applies to the use of Forskolin's anti-inflammatory and analgesic properties.
Yellow yam (<i>Dioscorea dumetorum</i>)	US 5,019,580 held by Shaman Pharmaceuticals and M. Iwu	Used in West African traditional medicine to treat diabetes. Patent applies to the use of dioscoretine to treat diabetes
Monellin from serendipity berries (<i>Dioscoreophyllum cumminisii</i>)	US 3,998,798; JP 5,070,494 held by University of Pennsylvania (USA) and Kirin Brewery Ltd (Japan)	Used for centuries by West Africans to sweeten food and drink
<i>Harungana vismia</i>	US 5,837,255 held by Shaman Pharmaceuticals Inc. (USA)	History of traditional medicinal use in a variety of African countries. Product targeted towards the treatment of hypoglycemia and diabetes.
Mesembryanthemaceae family, including <i>Sceletium tortuosum</i>	WO 9,746,234 held by Farmac Nederland B V (NL) and South African nationals	Traditionally used by communities in Southern Africa as an inebriant and sedative. Patent grants a monopoly on the use of mesembrin and related compounds in the treatment of mental disorders.
Brazzein ("J'oublie") (<i>Pentadiplandra brazzeana</i>)	US 5,527,555; US 5,326,580; US 5,346,998; US 5,741,537 held by the University of Wisconsin (USA)	Plant originates from Gabon, where it has long been used as a sweetener. Patent applies to the protein compound providing the sweetness, the Brazzein gene and transgenic organisms expressing the gene. This will eliminate the need for it to be collected or grown commercially in West Africa. Prodigene is introducing the gene in maize. There are plans for benefit sharing with West African people who discovered and nurtured the resource.
Pygeum (<i>Prunus Africana</i>)	US 3,856,946; FR 2,605,886 held by Debat Lab (France)	The tree is native to African montane forests, with a broad range of distribution. Traditionally used for carving and to some extent for medicinal purposes. Its use for the treatment of prostate disorders has resulted in sales of some US \$150 million per year, but also serious overexploitation in many areas.
Thaumatococin from (<i>Thaumatococcus daniellii</i>)	US 4,011,206 US 5,464,770 held by Tate & Lyle (UK) and Xoma Corp (USA)	Plant originates in West Africa, and researchers at the University of Ife in Nigeria first identified its potential as a sweetener. The gene has since been cloned and used as a sweetener for confectionery. People from whose lands the plant was obtained received no compensation.
Fungus (<i>Eupenicillium shearii</i>)	US 5,492,902 held by the U.S. Dept of Agriculture; the University of Iowa Research Foundation; and Biotechnology Research and Development (USA)	Fungus is derived from soils of Côte d'Ivoire. Intended use is as an insecticide.

See www.grain.org/docs/africanbiodiversity.pdf ; thanks to Chuck Peters and Louis Putzel at the New York Botanical Gardens for their help in confirming the forest-based status of some of these products.

many millions of dollars drug companies can potentially make from undiscovered tropical forest drugs. Laird and Wynberg (1997), for instance, quote research showing that the price of *Aloe ferox* crystal after crushing and packaging is 1700% of what is paid to aloe tappers in South Africa, with pharmacies adding another 30% to 50%. Laird (2002) has edited an excellent collection on equitable partnerships between traditional groups and the pharmaceutical industry, considered from many perspectives. She and Wynberg (1997) provide a careful case study of bioprospecting in South Africa, with practical suggestions for ways forward. Moran (1997) also describes some practical attempts to address this issue, including long-term compensation mechanisms through trust funds, pilot projects, an ethnobiomedical plant reserve in Belize, and training in ethnobotany. Mays et al. (1997), working with the U.S. National Cancer Institute, have used 'letters of collection' that guarantee compensation and transfer of technology to source countries in the form of royalties and scientific exchange. Such letters do not, however, promise intellectual property rights (IPR).

UNEP (1996, 11) notes,

Generally, researchers whose inventions qualified for IPR protection resided in developed countries, while the communities that lived near genetic resources and associated biological resources used in such inventions resided in developing countries and did not generally participate in the 'advanced' research that led to IPR-protected inventions. Such indigenous and local communities generally did not receive significant compensation if traditional knowledge or practices helped identify a naturally occurring compound that led to the development of a commercially valuable pharmaceutical or other product. Generally, traditional knowledge has not qualified for IPR protection under current laws.

Although determining how profits should be divided and who should receive them is difficult, the current state of affairs is considered by many authors to be inequitable. Contributing to the sense of injustice is the oft-cited utility of using indigenous medical knowledge as a sieve to narrow down the pool of plants to investigate (Balick 1990; UNEP

1996; Leaman 1996). Plants recognized by local people as medicinally useful have greater bioactivity (Section 4.5), and many traditional remedies are efficacious (Section 4.3). The number of recognized forest plants that have not been tested suggests that many more useful compounds remain unknown to science. Cox and Balick (1994) argue that working with local people is more effective than random collection methods. Soejarto (1996) concludes that since more than half of all plant species are found in tropical forests, which cover only 7% of the earth's surface, the search for new plant-derived medicines should begin in tropical forests. Both Soejarto (1996) and Artuso (1997) suggest ways to better manage bioprospecting and subsequent testing.

Shaman Pharmaceuticals is the best-known proponent of a partnership approach. See King et al. (1996) for a description of its activities and approach. This firm made serious efforts to involve local people in the search and to ensure that some of the benefits were returned to the communities from which medicines were obtained (Bryant 2002). Dorsey (2003) reports that Shaman used more than 15% of expedition costs to fund projects or programs based on the expressed needs of the communities with which they worked, yet he found "ambivalent and even antagonistic reactions to Shaman" in the Ecuadorian *Oriente*. King (1996) describes his own efforts to work with local communities in the Ecuadorian Amazon in the search for new drugs with Shaman Pharmaceuticals. However,

In February 1999, Shaman Pharmaceuticals ceased its pharmaceutical operations, laying off 65 percent of its work force, and moving its assets into operations of the privately-held Shaman Botanicals (Pollack 1999) ... Some interpreted Shaman's closure as a failure of the ethnobotanical approach to drug discovery (*Economist* 1999); however, others identified Shaman's problems as indicative of issues typical to small biotechnology companies: 'Shaman is just one of many biotechnology companies that have virtually collapsed after their first product hit setbacks. It is also one of many that are running out of money and unable to raise new capital because of depressed stock prices' (Pollack 1999). (Laird and Kate 1999, p.61)

Karasov (2001) is optimistic that provisions in the Convention on Biodiversity will improve matters.⁴² See Swiderska (2001) for the provisions relating to indigenous knowledge and benefit sharing, including case studies of participatory processes in Peru, India, Philippines and South Africa. Karasov describes programs of Costa Rica's Instituto Nacional de Biodiversidad (INBio), which worked with the pharmaceutical company, Merck, and the International Cooperative Biodiversity Groups Program; both have sought benign bioprospecting (as opposed to biopiracy). See Dutfield (1997) for a critique of the INBio example, focusing on the near-total exclusion of indigenous peoples from direct benefits; but the company did pay US \$1 million for research rights in Costa Rica and agreed to contribute 25% of profits made from Costa Rican plants to rainforest conservation in the country (Sittenfeld and Gamez 1993, quoted in Seters 1997). Soejarto (1996) focuses on national rights vis-à-vis "biotechnologically developed countries" but mentions the traditional knowledge available from local communities. Other companies that use traditional knowledge to guide them to drug discovery include Pfizer and Monsanto (Laird and Kate 1999), but large-scale, random screening remains the dominant approach in the pharmaceutical industry. The companies

may be avoiding controversy about intellectual property rights, but their proprietary interests preclude an objective evaluation of the extent to which they use random screening versus local knowledge.

4.7 Forest Medicines: Conclusions

This chapter has marshaled evidence relating to the medicines that come from forests and their probable effects on human health. Regarding the health of people living in forests, three issues dominate: traditional versus western health care systems, interdisciplinary versus monodisciplinary efforts, and participatory versus nonparticipatory approaches. Improving people's health in remote forested areas is likely to require greater attention to traditional health care systems, approached in an interdisciplinary and participatory fashion. Our reason for thinking this derives from the inaccessibility of forest communities, their low priority status in formal health care systems⁴³ and the diversity of forests and their human communities, which makes standardized solutions typically ineffective. Regarding the causal links between forests and human health, we see a larger role for single-discipline and nonparticipatory research in cooperation with the formal health establishment.

Summary

- 4.1 Forest ecosystems encourage the evolutionary development of poisons as defense mechanisms for plants and animals. Many of these poisons also have medicinal uses—some known by local people and used traditionally, some used in western medicine. Forests also produce commonly used compounds, such as cola, caffeine, chocolate and chili peppers, as well as cocaine.
- 4.2 Local people in tropical Asia, Africa and Latin America have considerable knowledge of medicinal plants. Their traditional health care systems are widely considered important, especially given the absence of more formal health care services.
- 4.3 Medicinal plants are used widely across the world, and the market for traditional medicines is large and expanding. The less valuable medicinal plants are often collected and sold by women. Evidence of the efficacy of some traditional remedies is growing.
- 4.4 Medicinal plants, particularly those with slow growth patterns, are threatened globally. Some of the threats include commercialization and global markets, loss of traditional mechanisms that contributed to sustainable use, and competing uses of the same species. Certification and better management techniques offer two possible partial solutions.
- 4.5 Traditional practitioners are dominant providers of health care and greatly outnumber personnel from formal health care systems in many forested areas. These practitioners, with varying specialties, tend to take an empirical and often holistic approach to health care. Local people often use both traditional and ‘modern’ health care systems and sometimes prefer traditional practitioners.
- 4.6 The distribution of benefits from forests is a controversial issue, rendered emotional by a widespread sense of injustice. Forest peoples are considered by many to be inadequately compensated for their knowledge of forest medicinal plants, and many believe that pharmaceutical companies reap unacceptably large profits, given the poverty of forest peoples. The issues are complex and include intellectual property rights, as well as amounts and recipients of benefits. Attempts to work collaboratively with local communities in bioprospecting have yielded mixed results.

Policy Recommendations

A. Policy Implications for Human Health Conditions

Recommendation for pharmaceutical industry managers

- Explore equitable distribution of the profits and benefits from forest-related knowledge.

Recommendation for natural resource managers

- Acknowledge the importance of medicinal plants and include their protection in management plans.

Recommendation for health care professionals

- Exert greater efforts to marry traditional and ‘modern’ health care systems in and around forested areas by working with traditional healers, assessing traditional medications, and understanding traditional health-related worldviews.

B. Policy Implications for Causal Links between Forests and Health

Recommendation for health personnel

- Assess the healing qualities of forest-based medicinal plants and incorporate effective ones in the repertoire of medicines.

Recommendation for government agencies

- Make greater efforts to maintain forest ecosystems, keeping in mind the current and potential value of medicinal plants and animals.

Chapter 5

Role of Culture in Linking Health and Forests

... the health and illness views of every people are a part of their innermost being, not to be cast aside lightly until overwhelming evidence indicates that there are better explanations.

—Foster and Anderson (1978, 226)

Culture, or way of life, is vitally important to all peoples' well-being, and in fact encompasses the other issues addressed in this review. Foster and Anderson (1978), in a classic work, delineate the multiple links between culture and health. Participation in a cultural system is a defining characteristic of human beings. The links between forests and food, health and medicine are closely related to cultural integrity, since each culture has its mechanisms for providing these human needs. Peoples whose cultural systems are under attack—as are many in forested areas—manifest social problems, such as increases in alcoholism, prostitution, domestic violence, child abuse, stress and even war.⁴⁴ Researchers in the field of forestry tend to see such issues as interfering with human well-being. Health professionals tend to phrase them as mental health problems. Anthropologists

have traditionally talked about cultural disintegration and adverse culture change.

Many cultural systems are intimately interconnected with forested environments, whether the people live within the forest or on the forest fringe (including city dwellers and researchers studying culture). Forest-based cultures have evolved within the forest environment, and their survival requires that that environment be sustained. Cultural links to the forest include subsistence, income generation, medicinal plants, gender roles, knowledge and symbolic systems, and spiritual links. Fundamentally, this kind of intertwining between culture and forests creates important elements in the meaning of people's lives.⁴⁵ Without the forest, such people can be set adrift. As the forest is destroyed, the related aspects of their culture are adversely affected. This in turn leads to both mental health



The hemispheric hut of the Baka is exclusively made of vegetal materials and is built by women in just a few hours. This ephemeral construction offers protection against night cold and mosquitoes (Photo by Edmond Dounias)

problems and loss of forest-related knowledge systems. The effects are even more likely when forest loss is unplanned, uncontrolled, and/or initiated externally—leading to feelings of disempowerment, inferiority and impotence among local people. Mental illness can destroy both motivation and capacity to manage remaining resources effectively. Loss of environmental knowledge can have a similar effect. A vicious downward cycle ensues, further adversely affecting the environment.

One general caveat: Culture is mutable, and people change. The points we stress here are a) all human beings are enmeshed in and dependent on their own cultures for mental and social well-being; b) rapid, uncontrolled, and/or forced cultural changes are harmful to people's health and may be harmful to their environment; and c) voluntary and typically gradual changes can be beneficial.

The dependence of forest-dwelling peoples' cultures on the environment in which those cultures evolved fully captures this review's two central concerns—the health conditions of people living in and around forests and the causal links between human health and forests. People's mental health has been closely tied to the idea of cultural integrity: They live and die within a particular cultural and ecological context, and they derive meaning in their lives—a central component of human well being (and therefore, health)—from these contexts. When such contexts change—whether through accelerated rates of deforestation or exposure to alien cultures or other forces—people tend to suffer adverse emotional and stress-related physical effects.

Here we highlight some examples of cultural differences to illustrate the variety of approaches to health and illness among forest peoples. Such cultural differences can explain forest dwellers' sometimes-negative responses to medical and public health approaches based on assumptions of the universality of human health care preferences, needs and beliefs. Although the examples may seem alien to many readers, we are convinced of their importance in dealing with the health (and other) problems of forest peoples.

Forest peoples' conceptual models and values are critical to understanding their health problems and behaviour and developing solutions. Such features are as important to study as specific diseases, forest species, landscape changes and other more 'concrete' topics. Concluding with cultural issues is

also a useful reminder of how food, disease and medicine are integrated in functioning, complex and changing human systems. People interpret and interact with their environment through a cultural lens.

5.1 Culture, Cultural Integrity and Mental Health

Much anthropological and sociological literature in the mid-20th century focused on the adverse effects of 'modernization' or 'development' on the integrity of people's cultures, persuasively showing the deleterious effects of rapid changes to cultural and environmental contexts.⁴⁶ Van Haaften (1996, 2002) has shown the mental health impacts of the changes wrought by environmental devastation in West Africa, including increased depression, hopelessness and anomie. Clark (1993), studying the people working in a gold mine in Mount Kare, Papua New Guinea, discusses the potent symbolic intersection of a kind of gold fever, concepts of pollution connected with women, and the interplay of the local culture with the colonial experience in people's interpretations of their frequent illnesses. Local people say that 'men have been ... polluted by development' (747). Trying to cure illnesses without understanding local interpretations of causation often results in ineffective treatment, lack of follow-through by patients, and misuse of medications. De Boeck (1994) examines symbolic meanings of hunger in the context of what might be termed cultural breakdown among the aLuunde of Zaire in an area affected by the diamond trade with Angola. Attempts to address hunger may be ineffective if local concepts of hunger are not understood; a common error is providing culturally unacceptable foods. Redford (1995) notes the links between hunting and the male gender role in some societies, urging attention to women's sometimes subsidiary roles connected with the hunt (see also Siskind 1975; Murphy and Murphy 1985; or Tiani et al. 2005 for a recent Cameroonian example). Attention to gender roles is important for addressing nutritional problems in forest communities, as well as differences in knowledge about medicines and health care in general.

Barrett (1995), based on data from Nicaragua where 'cultural syncretisms abound in a labyrinth of ethnomedical interaction' (1613),⁴⁷ argues against the use of positivist science⁴⁸ to understand people's health

behaviour. He also considers emphasis on culture as a determinant simplistic. He recommends instead a focus on the individual's identity, comprising the various imagined cultural groups to which he/she belongs:

In the case of health behavior on Nicaragua's Atlantic Coast, individuals choose from among the available cultural landscapes, usually unconsciously, as they form the self-identifications which will form the basis for everyday behavior. A self-identified indigenous person will most often choose from among ideologies associated with ethnomedical tradition—respect for the natural world, belief in spirits, knowledge of plants, etc.—and will more often than not act in accordance with these beliefs and identifications. Healing ceremonies and medicinal plant use will likely become part of that person's health-related behaviour. (1619)

The implication of Barrett's observation is that different individuals will interpret their illnesses differently, and that will affect how they can and should be treated: treatments need to be tailored to the individuals, taking into account their different health-related conceptual models.

Conklin (1995) describes the worldview of a Brazilian group. The Wari' of the western Amazon consume their own dead in the belief that they are maintaining a complex system of exchange with the animals they hunt. Their newly dead and eaten relatives are believed to turn into spirit animals who will send them peccaries to hunt. The newly dead also symbolically provide food for these spirit animals. This system of belief includes the conviction that humans and animals came from a common ancestor. One can easily imagine the horror with which their worldview would be met by outsiders and the adverse mental health implications for the Wari' if contact continued over the long term.

Roseman (1991), who writes a thoroughly qualitative ethnography of the Temiar people of the Malaysian rainforest, focuses on their system of healing and its links to music. The ethnography also provides numerous links among people, their health and their environment—links that differ materially and conceptually from those of most people in the medical profession. Understanding Temiar concepts would, for instance, be helpful for

western-trained doctors trying to establish trust with the people—trust being a basic foundation on which successful treatment normally depends.

Richards (1992, 1996) provides an ethnographic analysis of the links between the Mende people and the Gola Forest on the border between Sierra Leone and Liberia. Besides documenting their many practical uses of the forest (including secondary forest), he describes the rich symbolic significance of elephants and a secondary regrowth tree, *Musanga cecropioides*. The elephant conceptually links the forest to settled life; and musanga serves as a conceptual bridge between the forest and the town. Richards (1992) also notes the intergenerational implications of forests for these people: 'The power locked up in the forest, and the energy released through the secondary succession, are still thought of as ancestral blessing. The recovery of the bush from a period of cultivation (and the abundance of useful products found therein) is a sign that ancestral blessing has not been withheld' (151). Such belief systems are integral parts of the system of meaning (and therefore the mental health) of the Mende people.⁴⁹

Janzen's (1978) thorough medical ethnography of the BaKongo of Zaire includes discussion of the jural status of therapy and pluralistic 'therapy management' among this forest-dwelling people. Illness is often seen as linked to social relations, and an individual's suffering may be evidence of broader problems within his/her clan. Whenever illness strikes, close kin gather and make decisions about its causes, the appropriate therapy and the best healers, and they retain this decisionmaking authority throughout (including after a specialist has been called in). A clan council may be called to resolve such problems and function in a manner rather akin to a group therapy session, moderated by clan leaders or by a specialist. There are also interclan councils that perform similar functions when members of two or more clans are involved. In such cases, ceremony, litigation and therapy are intertwined. The forest is implicated symbolically throughout the diagnosis and treatment in the conceptual parallels between inside and outside, the dead and the living, and forest and savannah.

This smattering of the rich literature available on forest peoples' worldviews related to health is sufficient to demonstrate

centrality of the forest-people-health links. Other important issues include the degree to which health beliefs and practices are integrated with other parts of cultural systems (their ‘embeddedness’), the differing theoretical orientations and philosophical assumptions about health and health care, and the variety of approaches to health and illness among the world’s forest peoples. Maintaining human health requires attention to the holistic nature of culture and the interconnections among forest peoples, their cultures, and their forests.

5.2 Traditional Knowledge and Beliefs

Traditional knowledge can be straightforward, as in systems of classification; or it can be complex, as in total worldviews (see Ellen et al. 2000 for an excellent critique of some of the more extractive approaches to looking at indigenous or traditional knowledge; see also Section 4.2). Some indigenous knowledge is so much a part of the culture that it becomes less meaningful and helpful or even meaningless outside that context. ‘Knowledge’ implies truth or accuracy, but what one group believes to be true may be seen as false by another, and universal agreement may be elusive. This is particularly true of issues pertaining to health.

Numerous studies have tried to tap widely useful indigenous knowledge. Martin et al. (2002), for instance, describe their efforts to train indigenous ethnobotanists in Sabah, Malaysia. Leaman (1996; Leaman et al. 1991) and Gollin (1997, 2001) have done thorough studies of the uses of medicinal plants among the Kenyah Dayaks of East Kalimantan. Madge’s (1994) study of Gambian women’s knowledge and practice of collecting and processing collected foods is unusual in its emphasis on women’s work.

Jackson (1995) writes of a group in Colombia that in 1983 brought shamans together to study ‘ecological medicine’ (which addresses the cosmos and the community as well as individuals) in the town of Acaricuara on the Papuri River. This effort was part of a broader Colombian policy of ‘ethnoeducation,’ which strove, according to the Ministry of Education, to be ‘flexible, participative, bilingual, intercultural and systematic’ (308). But Jackson’s article highlighted a set of related dilemmas and problems: shamanic secrecy,

interest in personal gain, use of *yaje* and coca in healing, differences in pedagogical traditions, and the integration and possible inextricability of medical issues within culture.

Gittelsohn et al. (1997, 1742) briefly summarize a widespread set of beliefs about foods, based on their experience in western Nepal:

A version of the hot-cold food classification system is common throughout Nepal. Almost all foods can be assigned to one of three ‘valence’ categories: hot, cold, or neutral. In Nepal, it is perceived that when an individual consumes a lot of food of a particular valence, illness can result, which can be corrected by consuming foods of the opposite valence.

Messer (1997) expands on this issue in relation to women’s lesser nutritional status in many areas, suggesting that in some cases women’s inadequate diets are related not to purposeful discrimination but rather to cultural notions like the hot-cold differentiation of food types. Aumeeruddy (1994) found the same classification into hot and cold in Kerinci Seblat (Sumatra, Indonesia), encompassing medicines as well as soil, water and foods. She finds that many groups do not differentiate clearly between foods and medicines (cf. the current fascination with ‘health foods’,

Participatory approaches can tap the knowledge of the elderly, a community meeting in Muluy, Pasir, East Kalimantan, Indonesia (Photo by Carol J. P. Colfer)



including sale of medicinals as health foods; also noted in Balick and Cox 1996; or the collection by Prendergast et al. 1996).

A central cultural element related to food from forests is the traditional knowledge local people have about forest foods (see Section 2.3). Local knowledge of foods can contribute to our global understanding and better use of forest resources, as well as being a source of self-confidence and pride for forest peoples in the wider world—something that is important for improving their mental health and strengthening their capacity to act collectively to obtain better treatment by the wider society.

No centralized database on indigenous knowledge about forest foods exists, but a vast literature documents individual cases. Among the Kenyah Dayaks in Indonesia, for instance, Soedjito identified 59 species of forest foods (TAD 1981), and in a subsequent study among the same group, Tamen Uyang found an additional 38 forest foods (Colfer et al. 1997). Some of the literature focuses on people's food preferences and uses: wild plants in Amazonia (Dufour and Wilson 1994), insects in Mexico (Ramos-Elorduy 1993),⁵⁰ game and hunting in the Neotropics (Redford 1993) and Kalimantan (Wadley et al. 1997) and food taboos in Zaire (Aunger 1994). One popular topic is food practices relating to children and pregnant and nursing women, with their different immune status (e.g., de Garine 1982).

Different groups attach different meanings to foods, which can in turn lead to different health outcomes. The physical presence of a food resource does not mean that it is available and utilized in the manner outsiders might assume. In Kalimantan, for instance, Colfer found that some people literally could not imagine subsisting without rice. Milton (1991) compares four forest-dwelling Amazonian groups (the Arara, Parakana, Arawete and Mayoruna) with very different dietary patterns and concludes that these differences serve as mechanisms for distinguishing each group from others. Colfer et al. (1989) found a similar result for the Minang, Javanese and Sundanese in a transmigration location in central Sumatra. Such differentiation also serves to reduce conflict over resources. De Boek (1994) found that the aLuunde of Zaire considered the crops that women cultivated (especially manioc, but also maize and beans) and the animals that men hunted to be the

kinds of food that could assuage hunger; these food exchanges symbolically reproduced the human systems of exchange of men and women in marriage in the village. The aLuunde would not cultivate new crops and were less interested in domestic animals, since these foods did not carry the symbolism of the traditional ones. De Garine and Pagezy (1990) write of the 'meat hunger' in Central Africa that is less a physiological than a psychological problem. A conservation biologist who was unaware of the importance of meat to these people might well make elaborate and well-meaning plans to reduce local hunting, which might have little chance of success. Or a nutritionist could develop protein substitutes that would be unacceptable to people whose hunger for meat is psychological. Examples abound of plans that came to naught because of ignorance of local people's way of life, beliefs, knowledge and culture. Successful development and conservation efforts will require institutionalizing mechanisms to strengthen mutual understanding, through discussion and negotiation.

Many anthropologists have studied the cultural aspects of food (e.g., Douglas 1966; de Garine 2001; Bahuchet 1988). Grivetti (1981), though dated, provides an overview of different theoretical approaches pertaining to food and culture. A central concern in some of the literature is varying values. Bowman (2001), for instance, conducted research in Cameroon on attitudes about gorillas and chimpanzees (reporting similar attitudes in Botswana). Based on in-depth interviews with those involved in hunting primates, he found the following common ideas that justify hunting, in local perceptions:

Religion/providence: Animals are provided for human beings by God

Infinity of resource: There is no end to the forest and its products

Inevitability: Eating any animals is a logical, natural and necessary process for people

Magical thinking: The fate of the animals is in God's hands or in a magical realm (81)

A more holistic approach is taken by Grenand and Grenand (1996), who describe the way the Wayampi of French Guiana see and interact with their world—using indigenous knowledge, sustainable practices, human-nature interactions and socialization—to ensure a continuing supply of such forest products as

food. Ellen (2002) also recommends a holistic view that recognizes the embeddedness (or integration) of indigenous knowledge in its cultural context (see Ellen et al. 2000). Ellen (2002) concludes that those less involved in regular agriculture are likely to have greater substantive knowledge of uncultivated resources, even if this knowledge may not be verbalized. Coimbra et al. (2002) examine the health experience of the Xavante of Central Brazil from both a holistic, cultural viewpoint and a historical perspective. They emphasize the importance of looking at context, from a particularistic point of view,⁵¹ in trying to understand people's health status and experience.

Barrett and Lucas (1993) provide a quintessentially anthropological analysis of 'depth' and 'shallowness' of meaning and 'heat' and 'cold' among the Iban of Sarawak in Malaysia. They trace these ideas through various components of the Iban way of life, including birth, death, illness, and the actions of shamans. Voeks and Sercombe (2000) contrast the medical views of the hunter-gatherer Penan of Brunei with the more elaborate and complex medical systems of other settled inhabitants of Borneo, such as the Kenyah (also discussed in Section 4.2). The Penan often attribute illness to offended spirits. Their system of belief includes some food taboos (e.g., pregnant women must not eat reticulated python), gift-giving to offended spirits, bird augury and dream reading, and they recognize and use perhaps 20 medicinal plants. The authors conclude: 'With a low population density, lack of domesticated animals, and a nomadic lifestyle, they were never subject to the panoply of diseases that affected settled groups. As a result, the Penan, and perhaps other tropical forest, hunter-gatherer groups were never forced to develop a complex system of etiology and healing' (688-89).

Local attitudes and norms can influence forest land-use choices. Peoples in Central Africa have seldom taken to rearing cattle, not because of low profits, but because of cultural predispositions regarding animal rearing; similar considerations apply to Borneo (Sheil and Wunder 2002). Similarly, the Dayak people in Borneo place a high importance on wild forest pigs and consider them one of the most valuable forest resources, whereas Muslim in-migrants see them as pests (Colfer et al. 1997; Sheil and Wunder 2002).

Cultural norms, habits and economic

situations, among other factors, have created a wide variety of practices and preferences for wildlife species (Ramos-Elorduy 1993; also see Section 6, "Cultural factors in food choices," in Hladik et al. 1993). In Africa and Asia, for instance, increased income generally leads to an increased demand for wild meat. Yet in many parts of Latin America, people prefer domestic protein sources and make a dietary change away from wild sources when they can afford to do so (Bennett and Robinson 2000b). Although some bushmeats are traditionally taboo, shortages can erode these norms (Mainka and Trivedi 2002). Government officials and missionaries also have influence. For example, some Dayak groups that are short on preferred forms of meat will now eat monkey and snake—'because the church says it is OK now'—which the older people still view as taboo (Sheil, personal observation).

Pragmatically, these diverse and evolving norms can undermine the application of standardized solutions from one society to another. Ignoring cultural difference in efforts to improve human health and well being has been hazardous.

5.3 Culture: Conclusions

This section has raised the issue of the importance of culture in the health—particularly mental health—of forest peoples.⁵² We have tried in passing to use culture as a device to demonstrate the interrelationships among health-related issues, like food, disease and medicine. And we have introduced some spheres of health-related indigenous knowledge found among forest peoples.

Cultural perceptions about human health among forest-dwelling peoples represent a treasure trove of diversity, which can be comparable in value to biodiversity. Forest peoples vary in their knowledge of their own health and the health-related features of their surroundings. Some of their understandings about medicinal plants and their preparation may be of use more widely for addressing the health concerns of others; some of their ideas may be effective in treating the health problems only of those with similar worldviews; some of their theories of health may provide insights for health practitioners and students of health more generally—and some of their ideas are in fact dangerous to human health.

These different understandings of health and illness have serious implications for addressing

health problems in the developing world. Rigidly adhering to a western-based view of health may in fact do more harm than good. The overuse and misuse of antibiotics is perhaps the best-known example, but others include the marginalization (or even criminalization) of traditional practitioners, which reduces access to *any* kind of health care; the promotion of western vegetables when more nutritious local vegetables are readily available; and the unwillingness of formal medical practitioners

to acknowledge traditionally defined mental illnesses, resulting in the hiding of such occurrences. New medicines and their uses may be interpreted differently and used inappropriately unless providers construct a bridge to local views about health, illness and treatment. As many authors have suggested, participatory approaches to health care may be necessary to improve health among forest (and other) peoples.

Summary

5.1 The centrality of the forest-people-health links is clear, particularly among hunter-gatherers and many swidden farming groups. Other important issues include the degree to which health beliefs and practices are integrated with other parts of cultural systems (their embeddedness), the differing theoretical orientations and philosophical assumptions about health and health care, and the variety of approaches to health and illness that exist in the world's forests. Maintaining human health requires attention to the holistic nature of culture and the interconnections between forest peoples, their cultures and their forests. On a more global scale, protection of cultural diversity can serve as an insurance policy against overreliance on western cultural models.

5.2 Effective communication with forest peoples requires understanding of their world views and openness to learning about their perceptions. Indigenous knowledge about foods and medicines varies in its wider applicability and should be assessed but is likely to include useful elements for health and forest professionals. Wider recognition of useful indigenous knowledge can contribute to the self-confidence of forest peoples, with positive implications for mental health.

Policy Implications

A. Policy Implications for Human Health Conditions

Recommendations for health care providers, foresters and other policymakers

- Acknowledge the mental health implications of external attack—whether cultural or environmental—on local forest systems.
- Develop institutional mechanisms that encourage beneficial ‘marriages’ between local and formal knowledge systems.
- Using formal studies or participatory approaches, build feedback mechanisms into policy formulation and service delivery to account for different cultures.
- Assess the wider utility of local, indigenous medical and public health knowledge, and use it where appropriate.

B. Policy Implications for Causal Links between Forests and Health

Recommendations for health professionals

- Examine the effectiveness of indigenous health systems (including mental and spiritual health), compared with existing and planned alternative services.
- Use relevant indigenous knowledge to improve health care.

Recommendations for natural resource managers

- Study indigenous forest management mechanisms that have allowed tropical forests to be used sustainably.
- Use relevant indigenous knowledge to improve forest management.
- Protect forest products, services, and other uses that contribute to human health.

Recommendation for government agencies

- Protect forest-based cultures as part of a global effort to maintain cultural diversity.

Chapter 6

Conclusions and Recommendations for Further Study

We discuss three implications of our research, three ways we need to improve our communications, and three ideas for future research.

First, what have we learned about the condition of people's health in and around forests? Tropical forests provide essential foods, medicines, health care and meaning to peoples all over the world—with the benefits generally increasing with proximity to the forest. However, forest communities are not high on the agenda of most governmental health care institutions because the people involved are often few and the logistics of serving them formidable. Although there is some evidence that hunter-gatherers—the most pristine forest-dwellers—*may* have better health than other rural peoples, most people in and around forests suffer from debilitating and fatal ailments, including many of the same problems that beset nonforest dwellers in developing countries. Conversely, there is ample evidence that dams, roads, mines, and other development activities leading to deforestation have in many cases worsened the health of those living nearest to the forest. These two contradictory trends compel us to consider undertaking further research on the forest - human health links, but also suggest that we may need to address these links individually, taking a holistic and case-by-case approach.

The need to fashion solutions to the health care needs of these people is pressing. This urgency, combined with the diversity of factors affecting the health of forest peoples lead us to believe that the most direct and cost-effective way is to use participatory, interdisciplinary approaches that marry traditional with 'modern' health care. Such an approach acknowledges and builds on the cultural and biological diversity that exists where forest

peoples live, it recognizes the holistic nature of their lives, it allows the world to make benign (and appropriately compensated) use of their indigenous knowledge, and it takes into account the impossibility of supplying trained medical doctors and public health personnel to every village.

Having explored the causal links between forests and people, we have seen the usually negative effects of forest loss on the health of peoples living in and around forests; we have seen how diseases originating in forests can spread to neighbouring habitats and even around the world (and vice versa); and we have seen how the diversity in forest types, wildlife, disease vectors, human populations, cultures and interactions among these factors all affect human health. As the climate changes, some project that disease incidence in forested areas and elsewhere will increase.

Here, the pressing needs are more conventionally scientific, but they also require acknowledgement of the diversity in ecosystems and their interaction with divergent human systems, and attention to scale and time. The specific interactions among vectors, populations and the biophysical environment need to be addressed locally—each place and each community is different, though commonalities in disease-forest-human links may emerge. The transmission of particular forest-based diseases involves detective work that can span the globe.

The review has revealed a significant, if dispersed, body of knowledge on what is and is not known about forests and human health. But communication needs to be improved if we seek better health for people living in and around forests and better understanding of the forest-human health link.

First, better communication between local communities and researchers, practitioners

and policymakers is needed. The complexity of health-forest interactions means that the direct involvement of local people is essential. This has been emphasized in many studies, and is consistent with our own experience.

Second, better interdisciplinary communication is required. Forests, cultures and diseases all represent complex systems for which a variety of expertise is needed. Author after author called for improved interdisciplinary communication, and we second that call.

Third, research results must be communicated to policymakers and others who can make direct, practical use of the information. Pattanayak et al. (2005b) makes suggestions on how to do this using a decision analysis framework. Participatory action research with communities and policymakers is another approach—one we are exploring. But more experimentation in conveying results effectively to users is needed. Indeed, this Occasional Paper represents one effort to address this issue.

Much health-related research remains to be done. We suggest here three large-scale studies that involve multiple locations, interdisciplinary cooperation and long-term involvement:

1. gaining a better understanding of the relationships between landscape change and human health;
2. long-term monitoring of climate change and human health, for both improved understanding and for anticipation and timely intervention when problems emerge; and
3. long-term process-oriented, participatory work with local communities to strengthen our capacity at all levels to identify, monitor and solve local human and environmental health problems.

The first recommended multiple-site study would be cross-sectional and look at the relationships between emergent diseases and land-use change, with particular reference to changes in forest cover. This interdisciplinary study would identify forested and previously forested places where significant health problems and land-use changes have occurred. It would assess the health impacts of deforestation more thoroughly and also identify ways to improve land-use planning.

The second recommendation is a prospective study pertaining to health and climate change. Several authors have predicted serious health implications from global warming (Menne et al. 2002 provide a fairly comprehensive summary), though there is no agreement about the specifics. Patz et al. (2000) argue for improved surveillance and monitoring of health and environmental change, adding, 'Multidisciplinary co-operation among workers in public health, ecology, and the social and physical sciences holds out the best hope for developing comprehensive risk assessment to aid local, national and international governments and decisionmakers' (1402).

A program to examine existing longitudinal data while monitoring environmental and health changes over time would increase our understanding of environment and health interactions and provide timely information on mitigating the effects of climate change (see Epstein 1994 for a decade-old but similar suggestion).

The third suggestion builds on adaptive collaborative management approaches. This long-term approach uses participatory action research, bringing community facilitators and community members together with others outside the community to identify local problems, define plans, monitor their progress, reflect on their experience and adjust their plans accordingly.⁵³

The payoff would be in learning how to strengthen the involvement of marginalized groups in collective action (through empowerment), foster greater integration between human and environmental concerns (including better understanding of the interactions), explore ways to link communities to outside sources of expertise and help, respond to community members' own wishes for fertility limitation and improve the health of forest-dwelling communities—within an interdisciplinary context.

The next steps include closer attention to people living in and near tropical forests by government officials—particularly in health, forestry and other environmental agencies, and a renewed commitment by researchers to investigate the topics identified above. We certainly expect to act on our own advice!

Endnotes

¹ The anthropologist believes that true objectivity is impossible because the observer him/herself is a human being and brings his or her own perspectives, biases and opinions to issues relating to human beings; the ecologist believes objectivity is possible.

² Goal 2 is to achieve universal primary education; Goal 3 is to promote gender equality and empower women; Goal 5 is to improve maternal health.

³ Taylor (1997) provides a readable overview of some linkages between changes in forest cover and health, including food security, nutrition and modern medicine. He emphasizes the need for collaboration between ecologists and health specialists. See also the new journal *Ecohealth* (www.ecohealth.net) or Margoluis et al. (n.d.); both documents lay out important connections between health and conservation issues and provide examples of projects that link the two. See also Patz et al. (2000) for an excellent review related to environment and disease.

⁴ We sought common definitions for certain key terms used in this review (see appendix), such as *moist forest*, *rainforest*, *wild* and *domesticated*, but few papers defined these terms. Ogden (1996), in an FAO publication, notes, 'Forest foods or "bush foods" are often associated with wild or non-cultivated plants and animals. The dichotomy between "wild" and "domesticated" is however often artificial as the analysis of local farming systems in forested areas world-wide shows a continuum from subsistence foraging to commercial agriculture' (no page numbers).

⁵ In some places (e.g., Indonesia) the boundary between foods and medicines is not entirely clear (Gollin 1997). Kuhnlein and Receveur (1996) report this tendency more generally.

⁶ In October 2003, Anthony Cunningham, Lisa Gollin and Erin Sills joined about 15 CIFOR staff to present their views of important issues in the field and to share perspectives on how CIFOR might best go forward.

⁷ Bhat (1995) maintained that 'approximately a quarter of the total volume of literature currently being generated on medical and related groups of plants appears in less than ten periodicals. Approximately 50% of the total literature is contained in some 50 titles. However, the remaining 50% of the literature is scattered across some 2,500 periodicals in a wide range of disciplines' (Bhat, quoted in FAO 1997, 61).

⁸ In many areas, shrimp farms replace mangroves, the monoculture shrimp become infected with disease and the farms are abandoned, creating ideal conditions for mosquito larvae and thence malarial infestations in the local populace (an example brought to mind by Robert Bos of WHO, 7 September 2005).

⁹ Although the potential to improve agricultural productivity suggests that the relationship is not 1:1, current rates of population growth nevertheless make it probable that forest conversion will continue.

¹⁰ See also Fairhead and Leach (1996) and the collection by Leach and Mearns (1996), which provide examples showing the fallacies of 'received wisdom' about the African landscape and its management. In many cases, the intentional indigenous management and productivity of landscapes, such as secondary forests, are considered marginal by colonial and postcolonial decisionmakers. The importance of such landscapes in women's livelihood strategies has also been documented by many.

¹¹ Groups traditionally referred to as 'pygmies' in Cameroon, such as the Baka and Bakola, prefer to be known by these latter terms. In this review, we are forced to follow the original authors' usage of the more familiar term, *pygmy*—with no disrespect intended.

¹² In Malinau, East Kalimantan, as hunting becomes more difficult, people are turning to raising chickens and pigs and hunting previously ignored species (Sheil, personal observation, 2005). Dounias notes that hunting pressure is related to proximity to the periurban environment rather than a general decrease in the resource (Dounias, personal communication, 2005). See Box 1.

¹³ See Latham (1997) for an overview of important nutritional problems in developing countries and the 4th *Report on the World Nutrition Situation, January 2000*. Neither document focuses on forested areas per se, however.

¹⁴ Although the aged also have problems of access, demographically, women's and girls' problems are more obvious in the developing world.

¹⁵ We use quotes, as Ferguson (1990) does for 'development', in recognition of both the implied accompanying discourses of 'modernity' and 'development', and the unintended consequence of these wider societal trends.

¹⁶ Lyme disease is a quintessentially forest-related disease that has emerged with the reforestation of former farmland in the northeastern United States. Though well described in the literature, it is a temperate zone problem and thus outside the bounds of this review.

¹⁷ Important poisons that we do not discuss in this review include Agent Orange (used to defoliate huge areas of Vietnam during the U.S.-Vietnam conflict) and poisonous snakebites. But see Section 5.1 for discussion of forest poisons, some of which can be useful medicinally.

¹⁸ Field activities in the Adaptive Collaborative Management Program at the Center for International Forestry Research were routinely and frequently disrupted when community members became incapacitated by HIV/AIDS and died—specifically in the miombo woodlands of Zimbabwe (Matose et al. 2005) and Malawi (Kamoto et al. 2005), less obviously, in Cameroon.

¹⁹ Use of an 'HIV/AIDS lens' refers to being alert to the widespread effects of the

disease in many sectors, including considering the possibility of HIV/AIDS causal links when examining problems in sectors that at first glance appear to be unrelated to disease.

²⁰ A project summary in Peden (2000) argues the reverse, that increases in irrigation and changes in water management have not increased malaria in West Africa, despite an increase in anopheline mosquito populations. His research sites were in Côte d'Ivoire and Mali; another project summary, in Sri Lanka, supports the Ghanaian findings, and addresses other health problems related to irrigation (pesticide poisoning, Japanese encephalitis, schistosomiasis, etc.).

²¹ These same authors report WHO statistics that 90% of the malaria cases in the Americas occur in Brazil.

²² See also Spielman and d'Antonio (2001) for a thorough discussion of mosquitoes and their variability.

²³ Russell (1998), although concerned about the implications of global warming for certain arbo-viruses, also does not consider the panic in some quarters about increasing incidence of malaria to be warranted. Specific ailments he anticipates increasing under conditions of global warming, and which he discusses in some detail for northern (tropical) Australia, include Murray Valley encephalitis and Kunjin viruses, with the arthritides Ross River and Barmah Forest viruses causing more infections. He concludes by noting that risk of increased transmission will vary by locality, vector, host and human factors.

²⁴ Robert Bos, of WHO (personal communication, 2005) considers the most important factor to be "the minimum night temperature below which the development of malaria parasites in the mosquito guts stops."

²⁵ *Rhabdoviridae* includes rabies; *Paramyxoviridae* includes Hendra virus, Nipah encephalitis virus, measles virus, and more.

²⁶ Mergler (2002) briefly describes an interdisciplinary network of researchers (COMERN, Collaborative Mercury Research Network), with a 5 year project to study "the sources, transmission and health impact of mercury from an ecosystemic and participatory research perspective" (p. 6). In the Amazon, they are working with a community on the Tapajos River to reduce mercury absorption while maintaining fish consumption. They address three topics: (i) diet (short term), (ii) 'hot spots' or areas that are propitious to methylation in the areas of fish capture

(medium term) and (iii) reforestation to diminish Hg leaching (long term).

²⁷ Malaria, lymphatic filariasis (elephantiasis) and dracunculiasis (Guinea worm disease) also increased.

²⁸ Lyme disease (in the US), in which the tick vector increased when forest lands replaced agricultural fields, presents a reverse example.

²⁹ Kaimowitz (personal communication, 2005) notes, by contrast, the disproportionate attention to ebola, which, though dramatic, affects relatively small numbers of people (almost all, poor forest dwellers).

³⁰ Voeks (1996) and Stepp and Moerman (2001) argue that other landscapes—usually regrowing secondary forest or bush environments—are richer in medicines. These habitats are actually included in our own broad definition of forests.

³¹ See Dounias (2000) for examples of such plants from Central and West Africa.

³² Such treatment has a 99% survival rate for childhood leukemia and 70% chance of remission for Hodgkin's disease.

³³ Iskandar (2004) reports that in East Kalimantan, the fat of the python (*Python reticulatus*) "is used against burns...and as a traditional medicine for skin diseases" (p. 17); and poison from [*Ophiophagus*] Hannah was used in the past on the tips of darts for blowpipes (p. 23).

³⁴ Etkin and Ross (1994:88) define semiwild as "plants neither explicitly cultivated nor actively tended but nevertheless affected by human activities." Cf. Dounias' (2000:135-156) "paracultivation" among Cameroon's pygmies. There is a considerable body of information on the "fuzzy" nature of the distinctions among wild, semi-wild, semi-domesticated, domesticated, etc., which we do not go into here. These discussions reflect the firm differentiation between agriculture and forestry in the west. Such a differentiation does not apply for most tropical forest peoples, who manage and modify their agroforestry environments in various subtle and overt ways.

³⁵ Farnsworth and Soejarto (1988) estimate 9200 plants with ethnomedical uses; Bhat (1995) found 8000, with India alone home to 45 000 plant species, with 15 000 labeled endangered or vulnerable. Such variation is at least partly related to the multiple uses of plants for food, medicine, fiber and timber, and also to differences in interpretation from place to place and group to group.

³⁶ None of the present authors, all of whom have worked in gaharu harvesting areas of Indonesia, have heard of this use. Certainly it is not medicinal uses of gaharu that have threatened its continued availability, but rather export for use as incense.

³⁷ Bioactive compounds are more likely to be found in recognized medicinal plants than in plants that are tested randomly.

³⁸ China and India, and to a lesser extent Indonesia, are large and notable exceptions to this generalization.

³⁹ WHO, which has mostly focused on western medicine, is increasingly looking at other traditional practices. See WHO definition in Appendix.

⁴⁰ A similar table on bioprospecting in Asia-Pacific is available in GRAIN and Kalpavriksh (2002).

⁴¹ Horrobin and Lapinskas (1998) consider the absolute minimum cost of meeting all the regulatory requirements for legalizing biomedicines at US \$100 million. Others who agree include Laird and Wynberg (1997), Chesney (1996), and Mendelsohn and Balick (1995).

⁴² Laird et al. (n.d.) found that 26 companies of the 55 they interviewed had heard of the convention, and of those, 10 thought it might be relevant to their industry.

⁴³ Because forest communities tend to be small compared with urban or intensively managed agricultural systems, health care providers prioritize these larger population centers, as providing more beneficial use of their limited health budgets.

⁴⁴ War is obviously bad for people's health, and it is common in forested areas (see, e.g., Richards 1996; 2003; de Koning 2005). Some consider the forest a refuge for revolution and violence, which adversely affects the health of the innocent. However, we do not deal with war in any systematic way in this review.

⁴⁵ Cultures that are intimately bound up with the forest (such as hunter-gatherers and many swidden farmers) evolved in different ecological niches than the cultures of those who live adjacent to the forest (such as settlers, transmigrants and refugees). Cultural differences of this kind make anthropologists uncomfortable with sweeping terms like 'forest-dependent peoples'.

⁴⁶ See Escobar (1995) or Ferguson (1990) for more recent and more general theoretical discussions of the adverse effects of 'development'.

⁴⁷ That is, individual aspects of the medical systems of various cultures come together in any given individual's mind in complex, interrelated ways that may be difficult to understand.

⁴⁸ Positivist science is sometimes called reductionist science. It is what westerners have in mind when they use the term *science*, and it includes the belief that there exists an objective truth that we can all see in the same way if we use systematic, replicable methods that yield statistically significant results.

⁴⁹ Richards' (1992) chapter includes a fascinating discussion of the conceptual differences in the ways environmentalists and the Mende think about the forest—differences that need attention as we deal with these people and this forest.

⁵⁰ See also Redford (1995) for a discussion of edible caterpillars (*Papilio polytes* and *Conimbrasia belina*) and beetles; or Vantomme et al. (2004) on the value of caterpillars in the diets of the people of Cameroon, Central African Republic, Republic of the Congo (Brazzaville) and the Democratic Republic of Congo.

⁵¹ 'Particularistic', implying an understanding that comes from looking at things contextually and individually, is opposed conceptually to 'universalistic', implying common standards applied everywhere.

⁵² Despite the abundant literature on the adverse effects of 'culture change' on forest

and other rural peoples, comparatively little has been written on mental health 'normalcy', beyond western concepts. Assessing levels of mental illness remains a difficult task in nonwestern cultures. Many forest peoples' behaviour that might be indicative of mental illness in the West may be considered locally normal, and vice versa. Jenkins et al. (1991), for instance, outline the major issues in the cross-cultural study of depression, concluding that any such study should include a major ethnographic component to take into account cultural difference.

⁵³ Participatory approaches have been called for by various authors. See Margoluis et al. (n.d.), Melnyk (2001); and Ribaira (n.d.) for conservation-oriented participatory approaches. Bennett and Robinson (2000a) have called for collaborative approaches in improving wildlife management. Courtright (1995) worked with traditional healers to address eye problems. Ndekha et al. (2003), having worked with the health provider community in addressing schistosomiasis in Zimbabwe, described the difficulties of collaborative work with communities and the importance of viewing community participation as a process of social learning, rather than focusing exclusively on the results of the specific effort. Murray and Sanchez-Choy (2001) describe an approach similar to CIFOR's Adaptive Collaborative Management approach, described in detail in Colfer (2005a, b).

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Appendix

Definitions

- arbovirus** any of a large group of viruses transmitted by arthropods, such as mosquitoes and ticks, that include the causative agents of encephalitis, yellow fever and dengue (<http://www.answers.com/topic/arbovirus>, accessed 27 May 2005). The term comes from *arthropod-borne virus* (Haggett 1994).
- biodiversity** the variability within and between living organisms and the ecological systems of which they are a part, including genetic, species and ecosystem diversity (CBD 2001).
- biopiracy** the stealing of knowledge from traditional and indigenous communities or individuals (GRAIN and Kalpavriksh 2002).
- BMAA** beta-methylamino L-alanine, a substance that kills motor neurons, causing Chamorro disease.
- DALY** ‘disability-adjusted life years’, an estimate that combines losses from premature death and loss of healthy life resulting from disability (Ginwalla et al. 2004).
- ethnomedicine** ‘the totality of health, knowledge, values, beliefs, skills and practices of members of a society including all the clinical and nonclinical activities that relate to their health needs’ (Foster and Anderson 1978).
- ex situ** ‘ex-situ conservation is the conservation of components of biological diversity outside their natural habitats (CBD 1992)’ CBD: convention on biological diversity, www.biodiv.org,
- filovirus** a family of viruses (Filoviridae) responsible for Marburg and Ebola diseases.
- hunting** ‘... all capture by humans of wild mammals, birds, and reptiles, whether dead or alive, irrespective of the techniques used to capture them. This usually involves killing animals for human use, especially meat for eating, for traditional medicines or trophies, but it also can include taking of live animals as pets, or for the biomedical or zoo trades. It also encompasses taking animals both for personal consumption and for commercial sale’ (Bennett and Robinson 2000, 2).
- IPR** intellectual property rights
- in vitro** in an artificial environment outside a living organism (American Heritage® 2000).
- in vivo** within a living organism (American Heritage® 2000).
- in situ** 1. In the original position. 2. Confined to the site of origin (American Heritage® 2000).
- Lp(a)**, a particle of low-density lipoprotein cholesterol (LDL-C). Cholesterol is carried in the human blood stream by two principal classes of particles known as ‘high-density lipoproteins’ and ‘low-density lipoproteins’ (sometimes referred to as ‘good’ and ‘bad’ cholesterol in popular culture). High levels of low-density lipoprotein particles in the blood have been implicated in arterial diseases including atherosclerosis (a very common pathology in western peoples) and are therefore frequently assessed in modern health checks.
- medicinal plants** ‘... all higher plants that have been alleged to have medicinal properties, i.e., effects that relate to health, or which have been proven to be useful as drugs by Western standards, or which contain constituents that are used as drugs’ (Farnsworth and Soejarto 1988, 26).
- NDVI** normalized difference vegetation index, considered a good proxy for forest cover.
- nontimber forest products** ‘... biological resources other than timber which are harvested from either natural or managed forests. Examples include fruits, nuts, oil seeds, latexes, resins, gums, medicinal plants, spices, wildlife and wildlife

products, dyes, ornamental plants, and raw materials such as bamboo and rattan' (Peters 1994, no page numbers).

ORO Oropouche fever, a virus from Brazil, the Peruvian Amazon and the Isthmus of Panama, probably hosted in forested areas by sloths.

phytopharmaceuticals. Herbal remedies. Medicinal products whose active principals consist exclusively of plant materials.

semiwild 'neither explicitly cultivated nor actively tended but nevertheless affected by human activities' (Etkin 1994, 88).

sustainable hunting hunting in which the following conditions obtain: '(a) harvest must not exceed production, (b) the management goals must be clearly specified, and (c) the biological, social and political conditions must be in place that allow an appropriate use and an effective management' (Bennett and Robinson 2000, 8).

sustainable nontimber forest product harvesting 'a sustainable system for exploiting non-timber forest resources is one in which fruits, nuts, latexes, and other products can be harvested indefinitely from a limited area of forest with negligible impact on the structure and dynamics of the plant populations being exploited' (Peters 1994, no page numbers).

traditional healer 'Traditional healer services refers to the application of knowledge, skills, and practices based on the experiences indigenous to different cultures. These services are directed towards the maintenance of health, as well as the prevention, diagnosis, and improvement of physical and mental illness. Examples of traditional health service providers include herbalists, faith

healers, and practitioners of Chinese or Ayurvedic medicine. In contrast, allopathic service providers are those trained in western medicine.' (World Bank 2006, no page numbers)

traditional birth attendant 'the term TBA refers only to traditional, independent (of the health system), nonformally trained and community-based providers of care during pregnancy, childbirth and the postnatal period' (WHO 2004, 8).

traditional medicine '... diverse health practices, approaches, knowledge and beliefs incorporating plant, animal and/or mineral based medicines, spiritual therapies, manual techniques and exercises applied singularly or in combination to maintain well being, as well as to treat, diagnose or prevent illness' (WHO 2002, 7).

tropical rainforest 'an evergreen plant community, at least thirty meters in height, rich in great woody lianas and in arborescent and herbaceous epiphytes, but the woody forms predominate. Mature forests have a closed canopy and contain several more or less distinct strata, thus creating a habitat complexity characteristic of the tropical rain forest' (Farnsworth and Soejarto 1988, 27-28).

vector-borne transmitted indirectly by an agent of infection, or vector, that bites or touches a person (<http://dict.aiedu.com/word/vector-borne%20transmission>).

weed 'a valueless, troublesome, or noxious plant, often exotic, growing wild, especially one growing profusely; a plant growing where it is not wanted' (Helms 1998).

zoonotic disease 'an animal disease that can be transmitted to humans' (<http://dict.aiedu.com/word/vector-borne%20transmission>).

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