

Promoting human health through forests: overview and major challenges

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Abstract This review aims to contribute to the ongoing discussion about human health, global change, and biodiversity by concentrating on the relationships between forests and human health. This review gives a short overview of the most important health benefits that forests provide to humans, and the risks that forests may pose to human health. Furthermore, it discusses the future challenges for the research on the links between forests and human health, and for delivering health through forests in practice. Forests provide enormous possibilities to improve human health conditions. The results of a vast amount of research show that forest visits promote both physical and mental health by reducing stress. Forests represent rich natural pharmacies by virtue of being enormous sources of plant and microbial material with known or potential medicinal or nutritional value. Forest food offers a safety net for the most vulnerable population groups in developing countries, and healthy forest ecosystems may also help in regulation of infectious diseases. Utilizing forests effectively in health promotion could reduce public health care budgets and create new sources of income. Main challenges to delivering health through forests are due to ecosystem and biodiversity degradation, deforestation, and climate change. In addition, major implementation of research results into practice is still lacking. Inadequate implementation is partly caused by insufficient evidence base and partly due to the lack of policy-makers' and

practitioners' awareness of the potential of forests for improving human health. This calls for strong cooperation among researchers, policy-makers, and practitioners as well as between different sectors, especially between health and environmental professionals.

Keywords Forests · Human health · Bioactive compounds · Forest food · Infectious diseases

Introduction

The relationships between human health and well-being, biodiversity, healthy ecosystems, and climate change have in recent years received increasing attention in international discussion and policy processes; for example, the Millennium Ecosystem Assessment has listed ecosystem goods and services that are crucial for human survival and without which life on Earth would not be possible [1]. Forests and trees supply an abundance of ecosystem services that help in creating healthy living environments and in restoring degraded ecosystems. In addition to tangible products, forests for example mitigate floods, droughts, and the effects of noise, purify water, bind toxic substances, maintain water quality and soil fertility, help in erosion control, protect drinking water resources, and can assist with processing wastewater. Forests can mitigate climate change and may help in regulating infectious diseases. Woodlands and trees have a positive impact on air quality through deposition of pollutants to the vegetation canopy, reduction of summertime air temperatures, and decrease of ultraviolet radiation. Forests also provide recreational, cultural, spiritual, and aesthetic services. However, ecosystem services and goods that forests provide are threatened by deforestation, pollution, biodiversity degradation, and climate change.

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Several international initiatives work with issues related to biodiversity, global change, and human health; for example, the Global Environmental Change and Human Health (GEC&HH) project concentrates on studying health risks posed by global environmental change, and on developing adaptation strategies [2]. The Cooperation on Health and Biodiversity (COHAB) initiative aims to respond to the gaps in awareness and policies on linking biodiversity with human health and well-being [3]. This initiative aims to establish a framework to support existing activities on international development, biodiversity conservation, and population health, and to support the United Nation's Millennium Development Goals.

An example of European initiatives is the research network of Forests, Trees, and Human Health and Well-Being (COST action E39), which is underway during the years 2004–2008 [4]. This European network aims to increase knowledge about the contribution of natural places to the health and well-being of people in Europe. It also aims to improve the description and evaluation of pathways linking forests and trees to human health. The International Union of Forest Research Organizations (IUFRO) has initiated a special project (task force) on forests and human health [5]. The particular niche of this task force is to address specifically the relation of forests to human health on a global scale. It aims to facilitate the dialogue between health and forestry professionals, and to introduce forestry professionals into the worldwide discussion on biodiversity, climate change, and health. Moreover, there are numerous permanent international organizations and research institutes which work with linkages between health and environment, e.g., several United Nation's programs and organizations.

The impact of forests on human health is a specific issue which has not been very visible within the larger framework on biodiversity, climate change, poverty, and human well-being. This review aims to contribute to the ongoing discussion about human health, ecosystem services, and biodiversity by concentrating specifically on the relationships between forests and human health. The review gives a short overview of the most important health benefits that forests provide to humans, and the risks that forests may pose to human health. Furthermore, it discusses the future challenges for research on the links between forests and human health, and for delivering health through forests in practice.

Forest visits enhance physiological and psychological health

Incidences of poor health have increased in urbanized societies, partly due to expanding urbanization and modern lifestyles that are related to increasing sedentary work and

mental stress. Growing stress is connected with urban living and contemporary work practices dominated by high technology and virtual worlds [6]. It seems that current health care practices alone cannot solve these problems. Recently, the potential of natural and green spaces in enhancing human health has been recognized [6–19].

Forest environments promote humans' mental and physical health in many ways: forests help in reducing stress and in recovering from attentional fatigue, and generally forests strongly enhance both psychological and physical rehabilitation. Research on the restorative influences of nature has been dominated by two theories, one emphasizing stress reduction [20] and the other focusing on the recovery of the capacity to focus attention [21]. Forests may assist both in preventing illnesses that are mediated by psychological processes such as stress and in curing diseases such as burn-out and depression. Green areas can also help in establishing personal and community identity, social activity, and social participation [22].

Many studies from different parts of the world report that, compared with urban environments, natural environments improve human mood states [8, 14, 23–26], concentration and performance [8, 14, 19, 23], and likewise produce positive changes in human physiology after stressful or attention-demanding situations [8, 14, 25, 26]. These studies show, for example, lower levels of blood pressure, heart rate, skin conductivity, and muscle tension in natural environments than in urban settings [8, 14, 25, 26]. Also, green space near home improves perceived general health and longevity [16, 27]. Some surveys report that performing activities in green settings can reduce the symptoms of attention-deficit/hyperactivity disorder (AD/HD) in children [13, 28].

Forest visits may strengthen the human immune system [15]. Spending time in forest increases natural killer (NK) activity in humans. The increase was observed as long as 30 days later. Since NK cells can kill tumor cells by releasing anticancer proteins, forest visits may have a preventive effect on cancer generation and development [15]. In addition, forest trips significantly reduce salivary cortisol (stress hormone) concentration compared with city visits [17, 18].

Excess weight and lack of physical exercise pose severe threats to public health in urbanized societies. Research findings suggest that attractive green environment may enhance the motivation for physical exercise [10]. Green exercise generates many physical and mental health benefits regardless of the level of intensity, duration or type of green activity undertaken [29]; for example, there are indications that walking in forest can decrease blood glucose levels in diabetic patients [30].

In spite of the existing research base, still more evidence and systematic rigorous research is needed on the mental and physical health effects of forests. Little is known about

the effect of forest type on the positive health benefits, and how forests should be managed to maximize the health benefits. More information is needed on the effect of social and cultural environment and personality on gaining the beneficial health effects. In addition, methodology development as well as rigorous analysis and reporting of those results that do not show positive connections between human health and forests are needed [6]. It has to be noted that not all people perceive natural environments as therapeutic; forests can also be perceived as threatening and alien places which may cause anxiety and uncertainty [31]; for example, childhood nature experiences may influence adulthood relationships with natural environments [31, 32].

Some Western countries have initiated specific programmes encouraging people to exercise in green environments; for example, the British Green Gym programme helps people to become physically active by offering opportunities to exercise in the open air through local environmental or gardening work [33]. Another example comes from Japan where public and private sectors have given designations of “forest therapy base” to forests that have been found through scientific evidence to have relaxing effects [34]. A forest therapy base is usually managed by local governments, and some companies have started to use forest therapy for their employees’ health care.

Despite the growing evidence and knowledge on the beneficial health effects of natural environments, green areas in large cities are threatened by intensive building and other land-use changes. The knowledge on the positive health impacts of green areas needs to be better integrated into land-use policy and planning in order to preserve green areas close to homes.

Forests as a source of bioactive compounds and drugs

Forests provide rich reserve of compounds that can be utilized in pharmaceuticals and nutraceuticals. Tree and plant extracts contain a variety of bioactive compounds such as polyphenols (including flavonoids, phenolic acids, tannins), phytoestrogens (including lignans), stilbenes, carotenoids, sterols, etc. [35, 36], which possess biological activities such as anticancer activity, antiatherogenic, and antioxidant potential [37].

People have utilized trees through the ages for traditional medicine. In recent years many tree species have been found to be a rich source of bioactive compounds with medicinal properties and also a source for functional food. Nowadays several health-promoting or medicinal products from trees are produced and commercialized; for example, xylitol, which can inhibit caries [38], is produced from deciduous hardwood trees. Taxol, a bioactive compound

originally found from *Taxus* bark, is used as drug, for example, for breast and ovarian cancer and has been called one of the best anticancer agents developed from natural products [e.g., 39, 40]. Taxol causes mitotic block, which ultimately results in apoptotic cell death and appears to be the most potent antitumor mechanism of Taxol [41, 42]. Sitostanol, a saturated analogue to sitosterol from a byproduct of the pulp industry, is used for functional food to reduce serum cholesterol [43, 44]. Bark and knots of conifers have been reported lately to contain large variety of bioactive compounds with good antioxidant activities and anti-inflammatory properties [45, 46]. Knots of softwood species contain polyphenols, with lignans as the dominating group [35]. Especially Norway spruce (*Picea abies*) knots are rich in hydroxymatairesinol (HMR), which has strong antioxidative as well as potential antitumor properties [47, 48].

The medicinal use of mushrooms is a worldwide tradition, but especially common in Asian countries. Fungi are nowadays recognized to have great pharmacological potential [49]. Macrofungi have antimicrobial effects: they tend to inhibit the growth of bacteria, fungi, protozoa, and cancerous cells [50]. Several Basidiomycetes fungi have shown to have antitumor activity. Especially high-molecular-weight polysaccharides or polysaccharide–protein complexes exhibit antitumor activities in animals and humans [51]. Objective clinical assessment for anticancer potential in humans is still, however, often needed.

Only a minor part of living plant species have been tested for bioactivity so far. In the past few decades, plant scientists have realized that plants are also a reservoir of untold numbers of microbial endophytes (fungi and bacteria). These organisms have been proved to be a novel, but relatively unstudied, source of potential medicinal compounds [52]. Only a handful of plants have been studied relative to their endophytes, and forests are enormous source of novel natural products produced by endophytic microbes. It should be noted that in the last few years there has been a significant series of findings where well-known antitumor agents have been produced by fermentation of endophytic fungi isolated from plants [53].

One of the major problems facing this use in the future is the rapidly diminishing rainforests, which hold the greatest resource of novel bioactive compounds. There is also a risk that a growing market for pharmaceutical products can lead to overharvesting of some species. This may cause extinction of endangered species and the destruction of natural habitats. Modern tissue culture and bioreactor techniques for production of plant tissues and microorganisms should be further developed and used in cases where overharvesting might become a problem.

In many parts of the world, especially in developing countries, medicinal plants derived from forests and

woodlands are the most important source of medication because of the lack of synthetic medicines and formal health care services. In addition, people may not have enough money to buy medicines. Local people often use both traditional and modern health care systems, the traditional health care systems being especially important in tropical Asia, Africa, and Latin America. The market for traditional medicines is large and expanding worldwide. In Western countries, forest herbs are intensively used among some groups who consider natural products healthier than synthetic drugs. However, many medicinal plants are threatened by habitat loss, climate change, overharvesting, and logging. When exploiting medicinal plants and pharmaceuticals, the rights and livelihoods of indigenous people and local communities should be paid more attention to [54, 55].

Forest food provides a safety net

Forest biodiversity helps to combat malnutrition and diseases of the most vulnerable populations in developing countries. Forest food provides a safety net in case of food shortage and mitigates food insecurity and malnutrition. Forest food may add nutrients that people might not get otherwise and may help people to survive in times of famine, war or drought. In some cases, forest food is the most important source of nutrition, e.g., for people who are suffering human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS) and are not able to work any more [54, 56, 57].

Typical forest foods are fruits and nuts, wild leaves, palms, wild roots and tubers, mushrooms, and insects. Forest foods include proteins and fat, carbohydrates, vitamins, and minerals. They also include phytochemicals such as phenolics and carotenoids [57]. However, excessive use of forest food may not lead to balanced diets in developing countries, and forest food can also sometimes contain toxic compounds.

Forest food, e.g., berries and mushrooms, are used in Western countries as well, usually because of their good taste or nutritional and health-promoting values. In European countries, wild forest and cultivated garden berries are a part of traditional food diet, being a good source of essential nutrients. Berries contain phenolic compounds, such as flavonoids, phenolic acids, lignans, and stilbenes [58]. Among edible plant materials, remarkable high antioxidant activity has been found in berries [59]. The risk of some chronic diseases, such as heart disease, lung cancer, prostate cancer, asthma, and type 2 diabetes, may be lower at higher dietary flavonoid intakes [60]. However, better knowledge of the consumption and bioavailability of dietary bioactive

compounds is needed in order to properly evaluate the role of these compounds in the prevention of diseases and to make science-based dietary recommendations.

Preservation of forests and woodlands is extremely important for the supply of forest food. If rural populations in developing countries lose their access to forest food and medicine, e.g., due to deforestation or ecosystem degradation, this may lead to food insecurity, malnutrition, and disease. Forests also serve as important genetic reservoirs for plants and animals that have potential use for food and medicine. In order to use forest food to complement diets in balanced ways, more knowledge is needed on the nutritional values of different types of forest food. The traditional knowledge of indigenous people and local communities in gathering and hunting of forest foods and medicinal forest plant species should be paid more attention to. In local communities the approach is holistic, for example, there is no clear distinction between medicine and healthy food. In addition, forest management practices that can preserve the valuable species and their nutritional value need to be developed and studied [54, 56, 57].

Forest-related diseases and hazards

As discussed in previous sections, the natural environment and compounds derived from woodlands have an abundance of positive effects on human physical and mental health [7–19, 22–30, 35–53, 61–63]. Forest environments may, however, also pose risks to human health. People living in forests or otherwise having frequent contact with forests may be exposed to forest-related infectious diseases. The lifecycle of many infectious diseases involve the pathogen, the vector, and the human [70]. The vectors are often insects, but can also be mammals. Many infectious diseases such as Puumala virus (PUUV), Lyme borreliosis, Hantavirus cardiopulmonary syndrome (HCPS), and malaria, are associated with forests, which are the preferred habitat for vector and host populations [64–69]. Infectious diseases are severe, especially in tropical regions, but for example tick-borne diseases, such as Lyme disease and tick-borne encephalitis, occur outside tropical regions [70].

Emergence of infectious diseases is linked among other things to deforestation, loss of biodiversity, habitat alteration, and human migration [71, 72]. Human-induced land-use changes are often considered as the primary drivers of infectious disease outbreaks [73, 74]; for example, the increased risk for Lyme disease in northeastern USA is connected with forest fragmentation, urban sprawl, and biodiversity loss [73]. Ecosystem alterations affect the emergence of the diseases by changing the ecological system as well as the habitats of hosts or vectors and parasites. Modification of forest ecosystems—for example,

deforestation, forest fragmentation, and biodiversity degradation—beyond a certain threshold may increase the risk of disease transmission [70, 73]. Increased edge effect can promote interaction among pathogens, vectors, and hosts as well as the population growth of vectors and hosts [73, 75]. Also reforestation may increase the risk for zoonoses in some areas, for example, in Europe.

There is clear evidence that forest clearance affects the emergence of infectious diseases [76, 77]. Deforestation has coincided with an increase of malaria and/or its vectors in Africa, Asia, and Latin America [73, 78]; for example, in South America, deforestation or activities associated with it have produced new habitats for *Anopheles darlingi* mosquitoes and have caused malaria epidemics [79]. The destruction of forest habitat can also result in the replacement of the most common vector species with a more effective vector; for example, when overall mosquito diversity decreases, the surviving dominant species are usually more effective vectors for malaria [75].

The relationships between forest ecosystem and disease transmission are complicated. Modification of forest ecosystems may be necessary, but is rarely sufficient to increase disease transmission or to generate an epidemic [70]. Still more research efforts are needed to clarify how forests can be used in regulating the emergence of infectious diseases. Climate change may enlarge the occurrence area of infectious diseases. Several models suggest that global warming may lead to increasing risk of vector-borne disease [72, 76, 80], but caution is needed when interpreting these results [71, 81].

Forests also include other risks to human health; for example, forests expose people to physical hazards such as forest fires, floods, drought, soil slides, and haze. Forests also include dangerous wildlife and toxic fruits, foliage, and fungi. Forests include flora and fauna that can provoke allergic or irritant reactions, for example, bites of insects and snakes may cause simple localized reactions or serious systemic reactions in sensitive people. The pollen from trees, shrubs, weeds, and grasses is one of the main causes of allergy, and there is a clear need to identify nonallergenic or low-allergenic trees and other plants when designing parks or managing urban forests [82].

Future challenges and possibilities for delivering health through forests

Table 1 lists the main strengths, weaknesses, possibilities, and threats for promoting human health through forests. In recent years, the fundamental effect of forests on human health and well-being has been acknowledged to a greater extent. There are currently numerous cross-sectoral initiatives that promote the work in the field of forests and

Table 1 Main strengths, weaknesses, possibilities, and threats for promoting human health through forests

<i>Strengths</i>	<i>Weaknesses</i>
Partly existing research base	Insufficiently rigorous evidence base
Growing awareness	Weak integration of research and practice
New cross-sectoral initiatives	Lack of dialogue between disciplines and different professionals
Good examples of integration of research results into practice	
<i>Possibilities</i>	<i>Threats</i>
Improved health conditions	Climate change
Combating hunger and poverty	Ecosystem and biodiversity degradation
Reduced health care budgets	Deforestation
New sources of income	Loss of green spaces in urban areas
	Reluctance of policy-makers and practitioners

human health [2–5] and the integration of the research results into the practice [33, 34]. There is also an abundance of existing research on the relationships between human health and forests [e.g., 7–9, 11–19, 22–32, 38–50, 64–70, 76–78].

Forests help in controlling infectious diseases [75] and provide food as well as new pharmaceuticals and nutraceuticals [35, 57]. Forests may advance the achievement of the UN Millennium Development Goals, especially combating hunger, poverty, and poor health. Forests provide numerous ecosystem services that help in maintaining and improving healthy living environments. Forest visits enhance mental and physical health of humans [e.g., 7–19, 22–30]. New innovations as well as new businesses and services, such as forest-derived health-related products and services, have enormous potential. In addition, wide application of forest therapy and green exercise could significantly reduce public health care budgets.

However, the research on human health and forests still faces major challenges. Insufficient dialogue between different disciplines has led to the lack of multidisciplinary frameworks and methodologies. Methodologies are still under development in some fields of research, such as restorative and therapeutic effects of forests. A still greater evidence base and more rigorous research is needed on physiological and psychological health benefits, as well as the relationships between forests and infectious diseases; for example, the influence of forest type or other environmental qualities on the therapeutic and restorative qualities of forests is poorly known. More information is needed on cultural, individual, and social differences in adopting the health benefits of green environments.

We do not know how forests should be managed in order to minimize the dispersion of forest-related diseases, maximize the beneficial effects to mental health, and preserve the medicinal plants as well as valuable species used for food and their nutritional value. The traditional knowledge of local communities in gathering forest foods and medicinal forest plant species is not recorded to a sufficient extent. There is a need to find balance between commercial exploitation of medicinal forest species for pharmaceuticals and maintaining local livelihoods. Development in biotechnology may provide solutions for preserving valuable plant species from overharvesting. Rights of source countries and people need to be secured, and adequate compensation systems need to be developed [83].

In spite of some good examples of the integration of research results into policy-making and practical work, major implementation of research results is still lacking. The potential of stress-reducing effects of forests is not yet entirely recognized, and only a fraction of pharmaceutical and nutraceutical compounds derived from forests have been identified, let alone manufactured. Science-based policy-making would require not only more communication between scientists, policy-makers, and practitioners, but in many fields also more meta-analysis and other gathering of existing knowledge. In some areas, for example, forest therapy, a solid scientific basis for practical applications will be needed. Furthermore, cooperation between different policy and practical sectors, e.g., health and environmental professionals, is not yet sufficient to gain the full benefit of forests for human health.

Climate change, loss of biodiversity, and other ecosystem modifications pose severe threats to human health that need to be addressed. Global warming and forest clearance may lead to increasing risk of vector-borne diseases. Deforestation, ecosystem alterations as well as diminishing of green spaces in cities weaken many of the important ecosystem services that forests provide and also decrease the possibilities to gain beneficial mental and physical health effects through forest visits. Forest food and medicinal plants are threatened by deforestation, overharvesting, and ecosystem degradation.

Utilization of forests for improving human health conditions and the minimization of forest-related health risks require still stronger efforts both in research and in delivering knowledge into practice. The promotion of both research and transfer of knowledge on the health effects of forests into practice calls for strong cooperation between different sectors, especially between health and environmental professionals. The impact of forests and green areas on human health should not be treated in isolation, but should be integrated with other positive and fundamental benefits of forests to mankind. Only in this way can the

health-promoting effects of green areas be fully recognized and utilized.

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