12 Forests, Human Health and Well-Being in Light of Climate Change and Urbanisation

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Abstract: The importance of forests for human health and well-being is well documented in the literature. Forests provide a wide range of ecosystem services beneficial for human life both in urbanised and rural areas, from temperature regulation and air filtration to provision of food and medicinal plants. It is also well documented that forests are important arenas for recreation, aesthetic appreciation and stress relief for people, all of which are of high importance to the health of an increasingly urbanised population. Many of these positive effects that forests have on human health and well-being may be altered as a result of climate change and subsequent changes in forest structure and forest cover. The chapter shows that there is reason for concern about the possible changes in human health effects that may come with climate change. In tropical areas, many forest living people who rely heavily on forests in their household economies will be highly vulnerable to forest degradation. Increase in pressure on urban forests and their capacity to provide ecosystem services, reduced availability and quality of recreational areas and higher risk of exposure to vector borne-diseases are some of the effects discussed in this chapter.

Keywords: climate change, health, urban forests, forest structure, public preferences, environmental services

12.1 Introduction

Health is a top concern for governments and policy-makers. People rate health second only to financial worries when they are asked which problems facing their families they find most important (World Health Organization 2008). Commonly, many of us think of health as the absence of disease. In this chapter, however, we use the World Health Organisation's (WHO) broader definition of health, which embraces aspects of well-being. WHO defines health as, "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity". This definition is well-suited for a discussion on forests and human health in relation to global climate change. The topic is very broad and complex. It includes both negative and positive effects that forests, and changes in forests, can have on human health and well-being. Similarly, the topic of forests and human health involves issues related both to disease and to aspects of forests that can promote health and well-being.

According to the WHO, the distribution of death and disease has shifted from infectious to chronic and non-communicable diseases – including depression, diabetes, cardiovascular disease, and cancer. The increased importance of these diseases as causes of morbidity and mortality can likely be explained by urbanisation, aging, and globalised lifestyle changes, such as reduced physical activity. Behavioural, social, and mental health problems, such as depression, are not limited to western societies, they are seen as problems in all parts of the world (Desjarlais 1995).

There are many factors reflecting on the interaction between forests and human health and well-

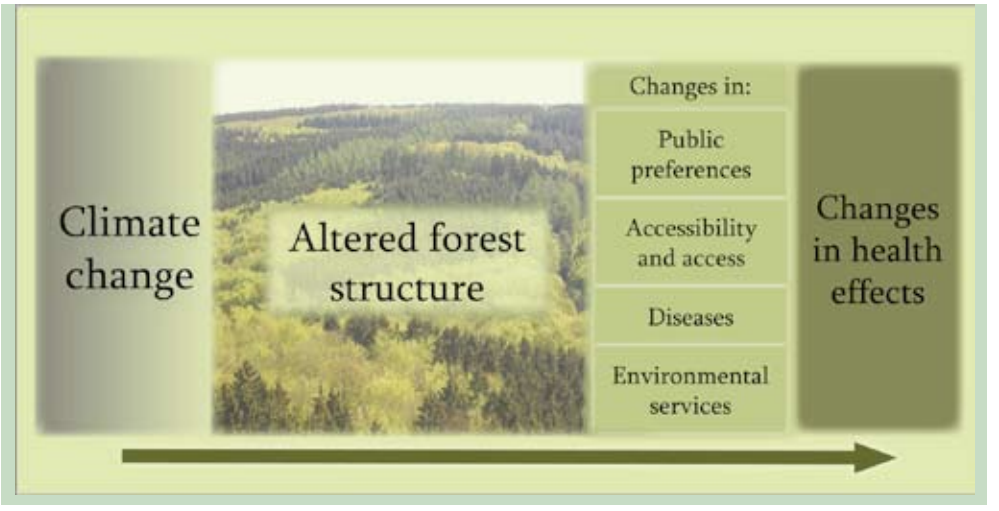

Figure 12.1 Health effects of climate change through consequences of changed forest structure (developed by Maria Dolores Velarde and Mari Sundli Tveit).

being; it is not possible to address all of them in depth within the scope of a single chapter. Instead, we have chosen to focus on urban forests and the possible impacts that climate change and subsequent changes in urban forests may have on human health and well-being. With an ever-increasing part of the world's population living in urban areas, we believe this is an important topic to highlight. To illustrate the complexity of the broader topic, other key issues concerning forests and human health and well-being are highlighted in standalone boxes, which also give references to further reading. These boxes outline the effects of climate change on vector-borne diseases (Box 12.1), forests and human health in tropical areas (Box 12.2), and forests as a source of health-promoting and bioactive compounds (Box 12.3).

Different climate change scenarios have been forecast, and their effects on forest structure are being discussed and analysed both in the short and long terms. The overall effects of climate change on forests have been analysed in detail in Chapter 2. The focus of this chapter is to highlight some of the effects that projected changes in forests may have on human health and well-being, such as changes in the visual qualities of forests, changes in access to forests, changes in the flora and fauna of forests, and changes in the ecosystem services that forests can provide (Figure 12.1).

12.2 Positive and Negative Health Effects of Forests

There is increasing focus in western urbanised societies on the positive psychophysiological effects on human health and well-being that result from exposure to nature. Forests, and other green areas, are known to be a source for recreation that counterbalances a stressful and sedentary lifestyle. We know through a large body of landscape preference studies that natural environments are visually preferred environments, especially when compared to common built environments. This has been demonstrated in many studies covering different kinds of natural environments and with respondents from different cultural backgrounds (Lamb and Purcell 1990, Purcell and Lamb 1998, Asakawa et al. 2004, Ode et al. 2009).

Visually attractive and preferred environments seem to promote good mental health because people are better able to face uncertainty and confusion when they are in pleasant environments (Kaplan and Kaplan 1989). This strong preference for natural environments is a basis for the expectation that those would also be environments that confer positive effects on human health and well-being. A substantial body of empirical research shows that viewing nature induces positive impacts on physiological and cognitive functions, including reducing physiological stress (Ulrich 1993) and restoring the ability to focus attention (Kaplan 1995). The main theoretical background for this research rests on the assumption that throughout evolution, humans have adapted to react positively to particular structural and spatial arrangements and to broad classes of environmental content, such as vegetation. However, as Velarde et al. (2007) found in their review of landscape types in environmental psychology, the categories of nature compared in the studies on restorative effects have been coarse and did not address specific elements of nature to any particular extent. On the other hand, extensive research on landscape preferences has explored aesthetic appreciation of specific landscape elements and landscape types. Several empirical studies show that there is a relationship between preferences and restorativeness, i.e. evaluations of the likelihood of

Box 12. 1 Climate change and vector-borne diseases

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Many zoonoses and pathogen groups have their reservoirs in forests and forest animals. Vector-borne diseases are related to insects, invertebrates, and ecto-parasites carried by mammals and birds (De Casas and Carcavallo 1995), all of which can be found in forested areas. The predicted rising temperatures related to climate change can alter the distribution of vector-borne diseases, extending the geographical areas affected by such diseases (Zell 2004). Current occurrence of vector-borne diseases extends from tropical and sub-tropical areas into temperate zones (Martens et al. 1995). With increases in global temperatures, tropical insects and other vectors may expand their habitats into more northern and southern latitudes and to higher elevations, bringing pathogens to extended areas. The incidences of mosquito-borne, rodent-borne, and tick-borne diseases are known to be affected by weather changes, and are likely to increase in frequency with increasing temperature (Zell 2004). In a review of climate change and infectious diseases in Europe, Semenza and Menne (2009) found it clear that climate is an important geographical determinant of vectors. Ticks are other common forest-dwelling vectors, and as temperature affects the tick's developmental cycle, climate change is likely to already have affected the tick distribution in Europe (Semenza and Menne 2009). Ticks transmit tick-borne encephalitis (TBE), and an increase in the incidence of TBE has been reported as far north as Sweden and Norway (Lindgren 1998, Lindgren and Gustafson 2001, Semenza and Menne 2009). Milder, shorter winters and warmer, drier summers affect tick distribution and the duration of their activity season. Such climate changes may cause increased risk of TBE infection, Lyme borreliosis, and Crimean-Congo haemorrhagic fever. Vectors carrying West Nile fever and dengue fever are also favoured by climate change, and are expected to extend their distribution into Europe, raising the possibility of West Nile fever and dengue transmission in new areas. Also, the vectors of other mosquito-borne diseases, such as Chikungunya fever and malaria, can find more favourable habitat conditions due to climate change in Europe. A disease such as Leishmaniasis, a protozoan parasitic infection caused by *Leishmania infantum*, is transmitted to humans by sandflies. The sandfly is affected by temperature, and climate change may cause dispersion northwards. Other examples of vector-borne diseases likely to be sensitive to climate change are Chagas disease, where the vector is Triatomines, and Schistosomiasis, where snails are the intermediate host (Haines et al. 2006). Rodent populations are affected by climate conditions, and a number of rodent-borne diseases are likely to increase as a consequence of climate change. Rodents carry a number of human diseases, acting both as intermediate infected hosts and as hosts for arthropod vectors, such as fleas and ticks. Zoonoses, such as plague, and virus infections, such as hantaviruses, are both carried by rodent vectors and can increase in frequency in various parts of the world (Semenza and Menne 2009).

Climate change is one factor affecting vector distribution (Molyneux 2003). Local effects must be considered. There is not necessarily a linear relationship between climatic indices and vector suitability (Jonsson and Reid 2000). However, climate is seen to be the dominant factor limiting species distribution (Sutherst et al. 1998).

an environment to provide restoration (Purcell et al. 2001, Staats et al. 2003, Tenngart Ivarsson and Hogerhall 2008), which support the hypothesis that preference involves implicit expectations for restoration. The assumed relationship between landscape preferences and health is shown in Figure 12.1.

Forests are not only a source of restoration and positive effects on human health and well-being. There is also extensive research on some negative health effects of exposure to forests, often related to direct injuries and encounters with organisms living in the forests. Among these are higher frequency of encounters with diseases and parasites that forests may harbour, including vector-borne diseases (see Box 12.1), such as malaria and dengue fever (Hitz and Smith 2004). Also, macro-social effects can occur, such as increased vulnerability of forest-dependent communities suffering from insecure outcomes of forestry in the face of global climate change (Davidson et al. 2003). People living in tropical forests are typical examples of communities facing both increased disease load and outside pressure on their social and cultural systems (see Box 12.2).

Box 12.2 Forest and human health in tropical areas

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Tropical forest dwellers often suffer from many physical illnesses. Their psychological health is also affected by outside pressures on their social and cultural systems. At the same time the health needs of these peoples, who are among the world's poorest, are often ignored and under-reported. The number of forest-dwelling peoples is small. This affects their access to health services in countries where formal health services are already scarce. The complexity of the issues involved and the fact that evidence and information span so many different disciplines has also made it difficult for researchers to give clear answers about the direct causal links between forests and human health – a fact that, in turn, can cause policy-makers to be reluctant to take action. Leading scientists on the topic are calling for more systematic comparative, interdisciplinary, and longitudinal research to clarify those links.

Six key topics linking forests and human health have been identified: 1) forests as providers of food, 2) forests as providers of medicinal products, 3) forests as sources of diseases and other health problems, 4) cultural beliefs and practices related to human health, 5) environment-health links and, 6) governance and institutions. Forests provide important nutrients to many populations. The food-provisioning function of forests in the maintenance of the health of forest peoples, which is particularly important for vulnerable groups, is often under-recognised. Food from the forest also functions as a safety net (seasonality, famine, war), and forest products can contribute significantly to the household economy. However, forest degradation, habitat shrinkage, and over-exploitation are threatening this food resource, as well as the medicines that the forest provides. In addition to the related reduction in wild, medicinal species, adulteration and substitution have been found to reduce quality, safety, and effectiveness. At the same time, rapid urbanisation in developing countries, combined with cultural preferences for traditional medicine, can increase the demand for medical products from the forest. Herbal medicines, and combining Western with traditional indigenous medical methods, are becoming increasingly popular in developed countries; this adds to the harvesting and species extraction pressures on forests. Apart from health problems that are food-nutrient related, forest people are heavily affected by many serious and preventable diseases, such as malaria, tuberculosis, and yellow fever. Many of these are vector-borne and, as environmental changes alter the behaviour of the vectors, humans may come in more frequent contact with the vectors, resulting in a higher incidence of these kinds of diseases. The connection between land cover change and disease varies, and local conditions are important. However, it appears that, in many cases, deforestation can be linked to an increased disease load on people. A health problem that is rarely clearly connected to forests is air pollution. The pollution results both from indoor cooking fires and from forest fires; both also affect communities living outside the forest.

It is generally agreed that human health is linked to the ways in which forests are managed. The maintenance of the forest can also be seen as dependent on the health of forest peoples, insofar as healthy people have more energy to manage the forests that surround them. This also highlights the connection between people's health and sustainability, both cultural and ecological. Much work, however, remains to be done to uncover the exact mechanisms, specific links, and causal relationships between human health and forests in tropical areas.

For a comprehensive review, discussion, and recommendations on the topic, see Colfer et al. 2006 and Colfer 2008.

12.3 Health Effects of Nature – Earlier Reviews

The idea and common knowledge of nature as positive to health and well-being has ancient roots (Cooper-Marcus and Barnes 1999). The renewed and increased interest in nature as a cure for some of the health challenges of modern urbanised populations (such as stress, depression, obesity) has highlighted the need to review the empirical evidence for connections between nature and human health and well-being. Several such reviews have recently been made (Health Council of the Netherlands 2004, Velarde et al. 2007), and there are emerging recommendations for research agendas (Bell et al. 2007, Bell et al. 2008, James et al. 2009). The reviews point to gaps in the knowledge concerning the physical attributes and types of green space (Velarde et al. 2007, James et al. 2009); the benefits to key target groups like children, disabled and elderly people; and barriers to the use of green spaces, such as fear of crime (Bell et al. 2007). Some reviews go so far as to state that in research on green space, a focus on health and

Box 12.3 Forests as a source of health-promoting and bioactive compounds

Tytti Sarjala

Forests are a diverse habitat and a rich source of plant-derived medicines and bioactive compounds that contribute to health (e.g., Kris-Etherton et al. 2002, Moutsatsou 2007). As many as 50% of prescription medicines are derived from molecules occurring naturally in plants. The search for new pharmaceuticals from nature has increased during the last few decades. There have been more than 100 000 plant secondary metabolites isolated so far, although until now, less than a third of the known plant species have been phytochemically examined (Wink 2008). Trees, other plant species, and berries, are well-known sources of forest-derived, bioactive dietary supplements. Several health-promoting ingredients – such as xylitol to inhibit tooth decay (Uhari et al. 1996), and sitosterol and sitostanol to lower blood cholesterol (Miettinen et al.1995) – used in so-called functional food, are produced in large amounts these days.

The most studied phytochemicals in plant research are phenolic compounds. For example, lignins, lignans, and flavonoids have been extensively investigated in order to characterise their antioxidant activities against cancer, and cardiovascular and neurodegenerative diseases (Willför et al. 2003, Webb and McCullough 2005, Boudet 2007).

Numerous fungus species with anti-microbial and anti-cancer properties have been recognised, especially in Asian countries. Also, in Europe, several commonly used fungus species have been reported to have anti-tumour or immunostimulating activity (Wasser 2002). However, the most recent estimates suggest that at present we only know a small fraction of the total number of fungus species. Therefore, they may very well constitute an infinite pool of secondary metabolites.

All plants in natural ecosystems appear to be symbiotic with fungal endophytes. Those microorganisms that reside in the tissues of living plants are relatively unstudied. The diversity of metabolites that have been isolated from endophytic fungi show a wide spectrum of anti-mycotics, immunosuppressants, and anti-microbial and anti-cancer activities (Tan and Zou 2001). Many natural product medicines are actually produced by microbes and/or by host plants that live in interaction with endophytic microbes (Newman and Cragg 2007).

Major problems with sustainable use of forests as a source of bioactive compounds are both diminishing rainforests and climate change, which may threaten medicinal plant species or their habitats (Karjalainen et al. 2010). In future, modern tissue culture and bioreactor techniques for the production of bioactive compounds in plant tissues and microorganisms should be further developed and used to avoid the overharvesting of rare species.

well-being is the least developed and is surprisingly weak (Bell et al. 2007). It is not a bold conclusion to say that little is known about what types of outdoor environments are linked with which types of health benefits. Similarly, the mechanisms and causal relationships are not clear and little is known about why health benefits are different for different groups of people, and how we should design and manage outdoor spaces to accommodate the needs of different groups of people. This is a knowledge gap that has to be bridged if the research is to have substantial impact on the practical design and management of everyday environments. A review of the evidence provided in earlier literature shows that research so far has directed attention towards psychological and psychophysiological effects of exposure to nature, connections between health and distance and accessibility of green space, the role of green space to promote physical activity, and nature as a positive factor in pedagogic and therapeutic settings.

If the evidence concerning health effects of nature is sparse, there is contrarily quite a lot of research on preferences and experiences of natural landscapes and forests. Some of the forest changes projected to occur due to climate change will greatly impact on the visual appearance of forests and the way they are perceived. Based on the assumption that a link between preferences and restorativeness exists, we find it appropriate in this chapter to also consider studies on visual preferences as part of the basis for suggesting a link between nature and forest experiences and human health and well-being. Changes in forest structure will impact the visual qualities of forests; this, in turn, will affect the health effects that forests can provide. Changes in forest structure may alter the potential psychophysiological effects and the accessibility of forests, as well as change the negative health effects, such as exposure to forest-related risks. We will return to projected forest changes and the impacts on visual experiences later in this chapter.

12.4 Urban Forests and Human Health

The evidence on the importance of forests for human health and well-being, and particularly the evidence concerning urban greenery, is growing. It is expected that within 30 years, two-thirds of the world's population will be living in urban areas, and most of this growth will happen in regions and countries with few economic resources (Desjarlais 1995, Vlahov and Galea 2002). At the same time, the trend in urban planning is densification, which threatens the quality and quantity of green spaces in cities. Hence, it is not surprising that there is currently a focus on urban green spaces and urban forests in the empirical research on nature and human health and well-being. Urban areas are in focus also in relation to sustainability issues, and recent reviews have pointed to both the possibilities and the need to link human and ecosystem health to achieve sustainable cities (Tzoulas et al. 2007, James et al. 2009). However, questions arise concerning how urban greenery, including street trees and parks, will respond to climate change (James et al. 2009).

The urbanisation process has increased pressure on forests and green spaces both within cities and in the surrounding countryside due to the increasing number of people living in proximity to urban forests and using them for recreational purposes. Urban forests are simultaneously facing high development pressures from cities' needs for more infrastructure, housing, and commercial uses (e.g. Amati and Yokohari 2006).

Both physical activity and exposure to nature are known separately to have positive effects on people's health. Research has found that natural environments, such as urban forests, seem to promote and stimulate physical activity (Bell et al. 2008). Physical activity is key to fighting many of the contemporary health problems facing modern society, such as obesity, type 2 diabetes, and coronary/vascular diseases.

Research is also suggesting that besides improvements in physical health, exercise in green environments also affects our mental health. Studies have found that exercises performed in a green environment could lead to a significant improvement in self-esteem and mood disturbance (with anger-hostility, confusion-bewilderment, depression-dejection, and tension-anxiety all improving post-activity) (Pretty et al. 2005, Pretty et al. 2007).

Distance (or proximity) has been shown to be one of the most influential factors determining the number of visits to urban forests. Areas close to where we live are visited more often (Coles and Bussey 2000, Hörnsten and Fredman 2000, Grahn and Stigsdotter 2003, Neuvonen et al. 2007). Studies have further shown that this relationship is not linear, which emphasises the importance of green spaces in the immediate vicinity (within 250 m) of residential areas. This is especially true for groups in society that are less mobile, such as children and elderly people. Research supports that the distance to green space influences our health and well-being. A shorter distance to green space is connected to better self-reported and self-perceived health (de Vries et al. 2003, Maas et al. 2006). This seems to be true for both urban and rural people. Both urban and rural respondents with green environments within 1–3 km had better self-perceived health (Maas et al. 2006). Positive effects on actual measures of health have also been reported, such as lower mortality of elderly people living in the vicinity of green space (Takano et al. 2002).

Closely connected to the concept of distance is accessibility, or how easy it is to get to an urban forest and its different parts. Accessibility can also be used to describe to what degree we are allowed to visit the area (e.g., legal accessibility) and to what degree different user groups face barriers and hindrances (e.g., wheelchair access). Without access to natural environments, people cannot benefit fully from the health-enhancing functions these provide. Both distance and accessibility are important concepts for linking urban forests with human health and well-being (Bell et al. 2008).

How much green space is available also seems to affect health benefits gained from urban forests. Studies in descriptive epidemiological research have shown that there is a positive relationship between the amount of green space available in people's everyday environment and people's physical and mental health (Groenewegen et al. 2006). Studies into the use of urban forests have shown that the use of these areas is diverse and multifunctional (Tyrväinen et al. 2007). The green spaces in the urban and peri-urban landscape, therefore, need to be able to meet the needs of different types of recreational users and uses. The availability of a larger amount of green space close to residential areas would often mean a wider spectrum of forest types available, and hence a larger variation of daily recreational opportunities.

With global climate change and increasing urbanisation, it is expected that there will be subsequent development pressures on green spaces and urban forests. An important challenge to be met by urban foresters, city planners, and politicians is to provide urban forests that will serve all sectors of the population. There is a need to develop policies and practices to safeguard this resource. These should include the maintenance of a sufficient amount of urban forests and green spaces within easy reach of people's everyday environment. To meet the requirements of different users and user groups, the forest resource should optimally also include a range of different characteristics, such as varied tree species composition (open deciduous forest to coniferous

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Photo 12.1 An important challenge is to safeguard a sufficient amount of urban forests and green spaces within easy reach of people's everyday environment (Panama City, Panama).

wintergreen forest), different degree of management (ranging from more undisturbed areas to highly managed areas with facilities), and variation in path surfaces (access for disabled users as well as more challenging paths). In order to meet these requirements, we need to develop appropriate decision support tools that would allow for analysing the contribution of urban forests to human health issues, taking into account distance, accessibility, and the amount and type of forest resources available. Some of the developed approaches include the development of appropriate monitoring systems. This would enable analysis of the deficiency of urban forest resources (as shown by van Herzele and Wiedemann (2003) for the Flemish region of Belgium). Monitoring could also provide an effective tool for detecting on-going processes of change and providing the means of reacting to these changes. Other approaches involve identification of areas with high pressure on existing green space, as measured through visitor numbers. Ode and Fry (2006) suggest an approach that relies on easily obtained spatial data for their prototype model applied to southern Sweden. Developing models that could be based on remote sensing data could provide a powerful guidance tool for strategic regional planning and management levels. For strategic planning, it is also necessary to identify the best locations where new urban forests would be most suitable. Van Elegem et al. (2002) suggest a multi-criteria based approach for identifying suitable locations for new urban forests, mainly focusing on recreational and ecological aspects. This approach could provide a potentially valuable tool for identifying the best locations, on a strategic level, related to health issues.

12.5 Urban Forests as a Provider of Ecosystem Services

In addition to their importance to the health and well-being of urban citizens, urban forests are also providers of a range of ecosystem services that have a variety of impacts on human health. Ecosystem services can be broadly defined as environmental processes that support human health and well-being, either directly or indirectly (Millennium Ecosystem Assessment 2005, Boyd and Banzhaf 2007, Elmqvist et al. 2008). Urban trees and green spaces have important ecological and biological functions, including reducing soil erosion, conserving water, and promoting ecosystem diversity. Urban ecosystems provide air filtration, microclimate regulation, noise reduction, mitigating the urban heat island effect, rainwater drainage, flood control, and sewage treatment (Bolund and Hunhammar 1999, Elmqvist et al. 2008). All these services provided by urban greenery have direct or indirect importance to human health and well-being. Direct positive health effects are gained from

reduced air pollution and lower noise levels, while other functions have indirect effects through their importance for the functioning of the urban system and infrastructure. Noise levels cause problems for human health in areas with heavy traffic. Soft ground vegetation and trees can mitigate noise problems as well as shield from the visual disturbance of traffic (Bolund and Hunhammar 1999).

Air pollution is a major public health problem in cities; vegetation can significantly reduce air pollution through filtering gases and particles from the air. Different plant species have different filtering capacities, which increase with leaf area. Coniferous trees have the highest filtering capacity due to the larger total surface area and because needles are not shed during winter, when air pollution is usually worse, due to home heating and increased use of private transportation. However, as coniferous trees are more sensitive to air pollution, a mixture of coniferous and deciduous trees is the most beneficial species assembly (Bolund and Hunhammar 1999).

The phenomenon called "the urban heat island effect," caused by large areas of heat-absorbing surfaces in combination with high energy use in cities, can be significantly reduced by having natural ecosystems in cities, including urban forests and water areas (e.g., streams, ponds, small lakes, fountains). Heat is absorbed by the plants' evapotranspiration process, and the shadow and shelter from wind provided by trees alter the energy consumption levels necessary for heating and cooling (Bolund and Hunhammar 1999). Urban greenery can lower a city's average surface temperature; parks are several degrees cooler than the surrounding neighbourhoods (Gill et al. 2007). This is an important factor to consider with the increased risk of urban heat waves that will most likely occur in the wake of climate change (Frumkin and McMichael 2008); a climate change that the city trees themselves can help to fight by capturing and storing carbon dioxide. Vegetated areas also contribute to preventing or solving problems related to rainwater drainage by allowing water to seep through the surface, as well as absorbing water through the process of evapotranspiration, thus reducing the likelihood of problems with a high rate and amount of surface run-off.

Despite its highly fragmented nature, urban greenery – including street trees, lawns and parks, urban forests, cultivated lands, lakes and streams – provides habitats for a rich and diverse variety of plants and animals. Enhancement of biodiversity in urban ecosystems can have a positive impact on the quality of life and education of urban dwellers, and can facilitate the preservation of biodiversity in natural ecosystems (Savard et al. 2000). Urban dwellers appreciate many bird species; various studies have investigated the people-bird interaction and how to enhance bird abundance and diversity in cities (Savard et al. 2000). Urban green structures function both as wildlife corridors and as habitats (Angold et al. 2006). Urban habitat patches often suffer from isolation, although a recent emphasis in planning has been put on enhancing connectedness and connectivity in urban green structures (Ahern 1995, Linehan et al. 1995). Urban forest fragments can have specific qualities of high ecological importance. In a study of red-listed bird species, Mortberg and Wallentinus (2000) found that urban and suburban forests had a vast range of deciduous forest, especially broad-leaved, and a lower intensity of forest management than in rural areas, which resulted in a sufficient number of mature and decaying trees meeting the breeding requirements of birds. High biodiversity in urban forests can also be important in providing food for local people. In many societies, forests are actively used for gathering food, such as fruits and nuts (Vinceti et al. 2008).

According to Mooney et al. (2009), the capacity of ecosystems to provide services essential to society and human health and well-being is already under stress, and the situation will worsen under most projected climate change scenarios. As locally generated ecosystem services can have substantial effects on human health and quality of life in urban areas, studies conclude that this should be addressed in land-use planning (Bolund and Hunhammar 1999), a conclusion that can only be strengthened with the challenges of climate change.

12.6 Changes in Forest Structure and Effects on Forest Landscape Preferences and Human Health

Changes in forest structure affect the visual qualities of forests and, assuming that there is a relationship between landscape preferences and health, this in turn may influence the health effects that forests can provide. Chapter 2 of this book indicates that the following components of forests are sensitive to climate change: tree level processes (e.g., productivity), species distribution, site conditions (e.g., soils and moisture/temperature regimes), stand structure (e.g., density, height), and disturbance regimes (e.g., fires, pests, and diseases). Some of these projected forest changes are highly visual and will affect the way forests are perceived, and consequently the health effects related to those perceptions. This can impact both the psycho-physiological health of people, and the way that forests promote physical activity. It is, however, important to note that uses of, preferences for, and attitudes towards forests differ between cultures and regions of the world, and, although changes

will be perceived, they may not affect all people in the same way.

The climate change-related projections regarding forest species distribution include changes in plant assemblages and changes in habitats for different species (von Oheimb et al. 2005, Wesche et al. 2006, Iverson et al. 2008, van Zonneveld et al. 2009). These projected changes are likely to affect the visual characteristics of forests in ways that alter the landscape, and therefore affect people's perceptions, either positively or negatively. Several authors have found preferences for certain species and species compositions (Kellomäki and Savolainen 1984, Tyrväinen et al. 2003, Gundersen and Frivold 2008). In their review of forestry-related preferences in three Nordic countries, Gundersen and Frivold (2008), found species composition to be an important factor shaping preferences. The species that will be favoured under future climate conditions will differ between regions. Depending on the species, changes in people's perception of the forest can be positive or negative. Thus, the changes in psychological and psychophysical effects of forests can also be positive or negative in relation to perception.

Climate change can also bring about changes in the stand structure in forested areas; e.g., age class distribution, forest density, and openness of landscapes. Changes in perceived openness are known to affect people's landscape preferences (Gundersen and Frivold 2008, Tveit 2009). Openness is strongly related to some of the main theories regarding the restorativeness of natural settings, such as Kaplan and Kaplan's Information Processing theory (Kaplan and Kaplan 1989). Appleton (1975) put strong emphasis on the openness of landscapes in his *prospect-refuge* theory, emphasising the human evolution-based need for landscapes that provide possibility for both overview and hideouts. A climate change leading to denser forests with less perceived openness could have a negative effect on forest landscape preferences and subsequently on human health and well-being.

Visual landscape preferences are prone to disturbances, to which people generally react in a negative way (Tveit 2006). There is not enough data to predict how the frequency or severity of different disturbances will be affected by climate change. Local, regional, and global changes in temperature and precipitation can influence occurrence, timing, frequency, duration, extent, and intensity of disturbances, and each disturbance affects forests differently. Changes in wind speed and shifts in wind directions can lead to increased probability of wind damage on forests (Blennow and Olofsson 2008). Droughts and hurricanes, heavy rainfalls, and landslides can lead to increased tree mortality and loss of forest cover (Dale et al. 2001, McNulty and Aber 2001, Davidson et al. 2003, Maracchi et al. 2005, Hoeppner et al. 2008). Climate change could also lead to an earlier start of the fire season and significant increases in the areas experiencing high to extreme fire danger (Flannigan et al. 2000, McNulty and Aber 2001). Many of these disturbances are likely to affect people's perception of forests in a negative way, not only in terms of the visual effect, but also in terms of safety and accessibility.

Large scale disturbances can drastically alter large areas of forest. These changes not only cause visual disturbances, which have negative effects on people's perception, they also affect the accessibility of forest areas and available trails and footpaths. Popular hiking areas can be severely affected by forest fires and windfall, restricting access to areas used for physical activity. Early successional stages after such occurrences can also be dense and of lower value for recreation, such as the dense regrowth of scrub and deciduous trees that are often found in clear-cut areas. Evidence of severe attacks of forest pests and diseases, such as bark beetles, can also make forests less attractive as recreation areas. Climate change may also lead to an increase or decrease in the size of forested areas and alter the visual characteristics of forests, such as higher tree lines in mountainous areas, increased forest density (as a result of the warmer climate), forest dieback, or even loss of forest cover (Tømmervik et al. 2009). Distance to and accessibility of the natural environment have been shown to be important for its ability to promote human health. Without access to natural environments, people cannot benefit from the health-enhancing functions these provide.

Sheppard and Picard (2006) reviewed the visual quality impacts of forest pest activity and found visual quality ratings in the middle ground landscape to generally decrease significantly as pest damage increased. In some studies, quite low thresholds were identified (in terms of the area of the visible landscape affected by pest activity), below which perceived visual quality drops significantly with increasing visible pest damage (Sheppard and Picard 2006).

12.7 Conclusions and Recommendations

The importance of forests for human health and well-being is well documented in the literature. Forests provide a wide range of ecosystem services beneficial to human life both in urbanised and rural areas, from temperature regulation and air filtration to the provision of food. It is also well documented that forests are important arenas for recreation, aesthetic appreciation, and stress relief, all of which are of high importance to the health of an increasingly urbanised population. As the above discussion shows, there is

reason for concern about the possible changes in human health effects that may come with climate change. Although the review has revealed some potentially positive health effects of changes in forest structure, e.g., more attractive species compositions, the majority of predictions imply negative effects on the health effects that forests can provide.

Reduced forest cover as a result of climate change combined with population growth will decrease the relative availability of forest areas for people. At the same time, the global urbanisation process will increase the demand for urban forests and green spaces, and put increased pressure on those same areas. A warmer climate also alters the ecological conditions for urban greenery. As shown in the section about ecosystem services, e.g., regulation of micro climate and mitigation of urban heat-island effects, these will be increasingly needed under many climate change scenarios. Thus, we should increase our focus on maintaining healthy urban forests as another of the challenges of climate change on ecosystems.

As described in the highlight boxes on forests and human health, climate change can lead to increased pressure on already vulnerable forest-dwelling peoples. People living in close dependency upon forests for their household economies will be highly vulnerable to forest degradation. In many parts of the world, climate change will also increase the disease load on forest people, at the same time as increased outside pressure will make it more difficult for them to sustain their social and cultural systems. The likelihood of increased occurrence of vector-borne diseases and the spread of such diseases as a consequence of climate change is described in the separate box on vector-borne diseases. Many zoonoses and pathogen groups have their reservoirs in forests and forest animals. The incidences of mosquito-borne, rodent-borne, and tick-borne diseases are known to be affected by weather changes. With increases in global temperatures, tropical insects and other vectors may increase their habitats into more northern and southern latitudes, and to higher elevations, bringing pathogens to larger areas. Climate change also threatens the habitats of medicinal plant species, and may impact negatively on the potential to develop new pharmaceuticals and functional foods.

The ability of forests to adapt to new climate conditions, and the stability of forest ecosystems will affect both the ecosystem services they can provide and the attractiveness of the landscapes for restoration and recreation. People's perception of forest landscapes, and the ability of forests to promote recreation are likely to be affected by climate change. To be able to predict with more accuracy how species composition, openness, and other visually important characteristics will affect the restorativeness and other psycho-physiological measures, more research is needed, both regarding the visual structure of forests in the process of climate change and in investigating how these changes are perceived by people. There will be regional differences both in the effects of climate change on forest structure and in perception and recreational patterns that need to be addressed in future studies. However, access to attractive forest areas will be as important for human health and well-being in the future as it is today, and climate change seems to challenge this through its effects on forest distribution and structure.

Mitigation of the negative effects discussed in the above sections can be achieved through changes in forest management. For example, increases in forest density can be mitigated through thinning and, in the event of severe disturbances, efforts to clear trails and secure access to recreational areas will be necessary. Monitoring programmes and tools for landscape analysis can help in identifying needs for intensified management or restrictions on use in high pressure areas. It is clear that many forest and health issues are complex and call for more systematic and interdisciplinary research to give clear answers that can inform policy. Climate change adds to the urgency of these tasks.

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