Chapter 4

Benefits and Uses of Urban Forests and Trees

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4.1 Introduction

Trees and forests are, because of seasonal changes and their size, shape, and color, the most prominent elements of urban nature. Their benefits and uses range from intangible psychological and aesthetic benefits to amelioration of urban climate and mitigation of air pollution. Historically the main benefits of urban trees and forests relate to health, aesthetic and recreational benefits in industrialized cities. Moreover, green areas have provided people with subsistence by providing food, fodder, fuel, wood and timber for construction (see Chap. 2).

Today, woodland, woods and trees are important to people especially through symbolizing personal, local, community and cultural meanings. They provide aesthetic enjoyment and create a pleasant environment for different outdoor activities. Woodland can provide an experience of nature in the middle of urban life. In particular, old woodland with big trees may provide urban people with the opportunity to recover from daily stress, revive memories and regain confidence. There is also an important educational value of urban forests. Contact with trees, in particular for children, can help people learn about nature and natural processes in an otherwise artificial environment.

Urban trees and woodland also contribute to an attractive green townscape and thus communicate the image of a positive, nature-oriented city. Indirectly, urban trees and forests can promote tourism and enhance economic development. At the local level trees contribute to the quality of housing and working environments and their benefits are reflected in property values. The same urban woodland areas and trees may have multiple benefits that reinforce each other. Recreational woodland, for example, also reduces wind speed and traffic noise as well as improves the landscape in a nearby residential area. To a certain extent the distinction between different categories of benefits is artificial. However benefits have their own special features and therefore can be presented separately (Table 4.1).

While these benefits of urban woodland, other tree stands and individual trees are not new they are still insufficiently recognised in urban planning and development processes (see Chap. 5). There is need to provide more knowledge on the role of urban woodland and trees in improvement of the environment and relate this to their social functions such as fostering mental and physical health.

This chapter aims to give insight into the current state of knowledge about benefits and uses of urban forests and trees in Europe. This is a difficult enterprise due to the complexity of the European continent. Urban forest research is largely national or even

Table 4.1. Benefits and uses of urban forests and trees (adapted from Tyrväinen 1999)

Social benefits	Recreation opportunities, improvement of home and work environments, impacts on physical and mental health. Cultural and historical values of green areas
Aesthetic and architectural benefits	Landscape variation through different colors, textures, forms and densities of plants. Growth of trees, seasonal dynamics and experiencing nature. Defining open space, framing and screening views, landscaping buildings
Climatic and physical benefits	Cooling, wind control, impacts on urban climate through temperature and humidity control. Air pollution reduction, sound control, glare and reflection reduction, flood prevention and erosion control
Ecological benefits	Biotopes for flora and fauna in urban environment
Economic benefits	Value of market-priced benefits (timber, berries, mushrooms ect.), increased property values, tourism

local, and results are often only disseminated in the national language (Forrest et al. 1999). Moreover, the benefits of woodland and trees can differ widely between European cities and towns due their different environmental and socio-cultural background. The recreational and aesthetic benefits are traditionally important especially in the Nordic countries, whereas the protective and climatic uses of vegetation are more emphasized elsewhere in Europe. Furthermore, while the use of trees to shelter from strong winds is an important issue in the north-western part of the continent, shading is a more important concern in hot climates, for example in the Mediterranean. In practice, management of the urban forest is a challenging task not only because of harsh growing conditions but also because of various, often conflicting, demands and goals. Therefore, this chapter will also address geographical and socio-cultural differences in benefits and uses between European regions.

4.2
Social and Aesthetic Benefits of Urban Forests and Trees

4.2.1
Urban Woodland and Parks As a Recreational Resource

One of the generally acknowledged functions of in particular urban woodland and parks is the provision of recreational opportunities. Urban green-space recreation was a genuine phenomenon of the mid-European bourgeoisie culture of the early 19th century. In earlier times, royal and aristocratic parks as well as urban woodland were used as deer parks and hunting grounds to display the splendour of court life. Tree alleys, promenades, malls and the king's way represented the power of the political system (Poëte 1913; Chap. 2). As well in countries with a long democratic tradition such as Switzerland, the role of trees, parks and alleys has been remarkable. In Calvinist Geneva, for instance, there was literally a tree cult from the 16th century onwards and spring was officially announced when the buds of a particular tree appeared and were seen by a state employee (Silva 1996).

The French Revolution put an end to many aristocratic privileges in all spheres of social life and citizens gained free access to parks and forests across the countries. During the Napoleonic wars and in the era of political restoration, the lifestyle characterized by bourgeois values was spread all over mainland Europe. This also paved the way for outdoor recreational use that had so far been unknown. Industrialization led to a massive transfer of labor from the agricultural sector to the newly established centers of industry and mass production. Insufficient hygiene, poor housing conditions and long working hours were major threats to millions of people who had either no access to, time for or interest in green-space recreation (see also Chap. 2).

Only in the late 19th century and in the first half of the 20th living conditions of the urban working class improved. A sports and outdoor movement emerged that used urban green space for recreation. Leisure time, being once a luxury good of the upper class, became more common among other social classes. The formal separation of a person's life time into working hours and leisure time made recreation an explicit social demand. The provision of green space in and around cities became a representation of middle class values. Its design and function became an attribute of urban culture itself and were spread all over the globe. In the post-industrial era of the late 20th century, parks with a postmodern design emerged in large central European cities like Zurich. This has been a remarkable trend as the municipal area of Zurich has a green-space cover of no less than 43%, even with real estate prices higher than the average in central Europe.

Today, outdoor recreation is a type of activity many people participate in, all across Europe. Participation in the most common recreational activity, walking, stands at about 81% in Finland (Pouta and Sievänen 2001) and 74% in The Netherlands (Statistics Netherlands 1997). Many of these recreationists have considered natural environments more attractive as activity settings than built-up areas. Among natural areas, forests are considered one of the more attractive types of nature. In Italy, 96% of the population participates in recreation activities involving the forest (Scrinzi et al. 1995). In Denmark, this proportion is about 91% (Jensen 1999). There are, however, large regional differences in the supply of forests in and around cities. For example, in Finland forests cover about 86% of the land areas and they are also the prevailing type of urban green area, whereas in The Netherlands forests cover only 10% for the total land area. If we look

Fig. 4.1.
Recreationists in the Helsinki urban forest (*photo:* City of Helsinki, Environmental Centre)

at the amount of forest per capita, the differences become even larger: 51 000 m^2 in Finland versus about 220 m^2 in The Netherlands (Sievänen et al. 2000). The attractiveness of forests as a recreational environment is also evident from the distance that people are willing to travel to visit a forest. According to Scrinzi et al. (1995), Italians travel about 32 km (single distance) to a forest visit. This is about the same distance that residents in the western part of The Netherlands – the most urbanized and "forest-poor" part – travel to their most often visited forest site (De Vries 2000).

Accurate information on the actual level and type of recreational use of forests is still relatively scarce for most countries. In Italy a first national study was carried out in 1995 (Scrinzi et al. 1995). For the German-speaking countries a review study including articles from more than 60 periodicals in forest sciences gives a good overview for the period between 1960 and 1995 (Schmithüsen et al. 1997). Moreover, an overview of the recreational use of forest in the Nordic countries has been provided by Jensen (1995). Participation frequencies derived from interviews or mail surveys may not always coincide with figures obtained through observations of actual forest visits; in retrospect respondents tend to exaggerate the number of visits they have made to forests (Jensen 1999). In Denmark, the average annual number of forest visits is somewhat less than 40 times before correction, and about 13 times after correction. In Italy the average frequency of visits is only four times a year, however, the average duration of a visit is almost four hours. Finland scores much higher with an estimate of between 72 and 110 visits per year. The duration of a visit is usually from half to one hour (Tyrväinen 1999). It is unclear to what extent this high frequency is due to the abundant supply of woodland in Finland or caused by different measurement methods. Therefore, more systematic research and international comparisons are needed.

In urban forests walking tends to be the most common recreational activity. Other common activities are cycling, jogging, picnicking as well as picking berries and mushrooms (Fig. 1). However, there exist clear differences between European countries. Cycling within forests is not that common in Italy. Picking berries and mushrooms is relatively infrequent in Dutch and Danish forests, while cross-country skiing in winter is very common in Finland, Sweden and Norway. These differences are related to the recreation possibilities that the nearest forests in one's environment offer, in combination with the forests' proximity. Using a forest environment for daily physical exercise takes place only if such an environment is available nearby (Tyrväinen 2001; De Vries and Goossen 2002).

Experiences that are sought after are predominantly enjoying the natural scenery, and peace and quietness. On a scale from wilderness to developed natural areas, forested areas tend to be located closer to the developed side, although still less developed than urban parks. This is partly a consequence of proximity to a large concentration of inhabitants. If open to the public, recreational use tends to be rather intensive. The Dutch State Forest Service suggests approximately 1 000 visits $ha^{-1}\,yr^{-1}$ to be common for this type of forests. This implies that there are likely to be other people present during one's visit. Although this is not likely to contribute to experiencing quietness, forests have a relatively large 'social capacity' per hectare, i.e. because of the trees there can be many people present without the area feeling crowded. This makes forests a relatively efficient type of resource for nature-based recreation, compared to for instance agricultural areas. The perception of crowdedness obviously also depends on visitor expectations. Although many urban forests are unlikely to be selected as a destination for the opportunities they offer with regards solitude, during some days and time points they might actually provide this experience. However, people's recreational motives vary and different user interests often lead to conflicts. For example, those who want to go for a walk in a quiet and natural environment may feel disturbed by others, who pursue hobbies such as horseback riding and mountain biking (e.g., Seeland et al. 2002).

A rapidly growing segment of the population in many European countries consists of ethnic minorities. Often very little is known on their desires and use of urban green space. Language problems have frequently prohibited their participation in surveys, unless special measures are taken. In the few studies that are available, Dutch ethnic minorities (predominantly people from Turkey, Morocco, Suriname and The Netherlands Antilles) appear to be more focused on recreation in urban green areas than in the countryside (e.g., Jókövi 2000). The social aspect of recreation, being together with family and friends, seems to be more important to them than to the indigenous population. The common Dutch activity of bicycling is less popular among the people from these ethnic minorities. However, the composition of this segment is rapidly changing, due to the large influx of asylum seekers originating from different countries. It is even less clear what the needs and desires of these new groups will be regarding urban greenery and outdoor recreation.

From social demands regarding the type and amount of forests it seems to be only a small step to demands based on ecological motives such as conservation and biodiversity. Most visitors appreciate the idea of the naturalness of an urban forest, and the importance of ecological management has increased during the past decade (Tyrväinen et al. 2003). However, the relation between the ecological and the social function is not a simple one. On the one hand, appreciating nature may lead to increased support for ecological goals, but on the other hand, recreational usage may endanger fragile ecosystems. To many people, however, rare animals and plants are not especially important in selecting a destination area. Some people will not even pay attention to or recognise them during the visit. Environmental information and education, however, can increase the awareness of residents and help them appreciate urban flora and fauna. Furthermore, people like to have easy access to the forest, whereas ecologists prefer to minimize disturbance. For urban forests the primacy of the social function is essential. By offering people ample and high quality recreation opportunities nearby, they will be less inclined to visit ecologically fragile environments located further away. However, even for urban forests with a predominantly social function, some ecological preconditions have to be taken into account, to provide a sustainable recreation environment.

4.2.2
Health Benefits of Urban Forests and Trees

Urban forests and trees contribute to a better quality of living environment in cities, for example by improving air quality and consequently the health of urban residents. The leaves of trees can take up many pollutants, e.g. ozone, nitric acid vapor, nitrogen dioxide, ammonia, sulfur dioxide and particles (aerosols and dust). Some of these pollutants can cause serious health problems. Trees also provide valuable shading from the sun. An individual tree can provide a Sun Protection Factor (SPF) of 6 to 10, which means a level of exposure to ultraviolet radiation of one sixth to one-tenth of full sun (NUFU 1999).

There are also other ways in which urban forests may improve public health. By offering an attractive environment for recreational activities, urban forests may seduce people with a sedentary life style to become more active during their leisure time. Activities such as recreational walking and cycling already have a positive effect on one's health. It has indeed been shown that more green space within the living environment leads to people visiting natural environments more often (e.g., Grahn and Stigsdotter 2003). However, a higher number of visits to green areas does not necessarily mean that these people are more physically active. For example, people living in a less green environment may still walk often, but do so more frequently in a built-up area.

Nearby urban forests and parks are especially important for elderly and young people who are restricted in their capacity to move. The most active users of neighborhood forests are probably children. There are also programs that try to stimulate people to become physically active within the local natural environment, for example in the United Kingdom (Ashcroft 2002). When they do go for a walk, a lack of nearby nature-based opportunities tends to increase the number of people using a car and subsequently leads to driving longer distances to visit an attractive natural area (De Vries 2000). The key factor for active use is easy access to the areas, preferably within walking distance from home. In a survey study in Salo, Finland half of the respondents noted that the main reason for not using urban recreation areas was the distance (Tyrväinen 2001).

An important positive effect of natural scenery on health is its stress reducing effect. Research similar to original studies in the United States (Ulrich et al. 1991) has led to similar results in Sweden (e.g., Hartig et al. 1996). Just visually experiencing a natural setting reduces stress. Stress relief, as measured through muscle tension, blood pressure and electrical brain activity, can be demonstrated within some minutes of exposure to a green environment (Ulrich et al. 1991). Moreover, viewing or visiting natural environments (compared to built urban environments without natural elements) after stressful or mentally fatigued situations, produces greater physiological changes toward relaxation and faster recovery of attention-demanding cognitive performances (Parsons et al. 1998). Research has shown that even quite ordinary urban green areas have a stress-reducing influence in everyday life. In Sweden, Grahn and Stigsdotter (2003) demonstrated that the more often one visits green areas the less often one reports sickness from stress.

It is unclear to what extent the mechanism behind this restorative effect is evolutionary in character and/or cognitively mediated. As a consequence, also very little is known about how to design and maintain urban green spaces in such a way as to optimize their health benefits. A high aesthetic quality may not be required for a stress reducing effect, but might be helpful to attract people to the green area. One precondition, however, is quite generally thought to be important for restorative effects: safety. The (assumed) presence of dangerous others will diminish positive health effects. As mentioned before, common motives for visiting forests are experiencing solitude, peace and quietness. These qualities may also be conducive to the stress-reducing effect. However, crime statistics, for example in the United Kingdom, show that physical attacks are rare in woods, and that such concerns are often based on perceptions rather than reality. One of the key factors for security is visibility, which requires active management of the understorey, and giving the impression that the area is controlled (Tyrväinen et al. 2003).

Another possible mechanism relating nature to health is that of social interaction and cohesion. While European research in this topic is still scarce, several studies conducted in Chicago, USA suggest that green space, especially trees, may help to facilitate (positive) social interaction with neighborhood members (Kweon et al. 1998). This is suggested to reduce feelings of social isolation, which is a risk factor related to depression. Although it is still unclear what are the most relevant mechanisms behind the health effects, recent Dutch research has shown that the relationship between the amount of green space in the living environment and self-reported health is positive, even after controlling for relevant socio-demographic and socio-economic characteristics (De Vries et al. 2003).

4.2.3
Social Potential and Trends in Urban Forest and Tree Benefits and Uses

Nowadays, different sections of urban society tend to share more collective values regarding sound management of the environment, including the importance of green space for the well-being of growing urbanized societies. Ongoing social change and increased pressure on the different types of green spaces is a challenge for traditional concepts of maintenance. Conflicts and maintenance problems have developed during recent decades due to a lack of information about the social needs and expectations of various user groups. Due to this limited knowledge, urban greening projects are often designed according to architectural and aesthetic standards which have little reference to the local population with its specific needs.

The demographic development in the service-oriented societies of central and other parts of Europe shows a trend towards further urbanization, a remarkable increase in the number of elderly people and groups with special demands for a certain social infrastructure (e.g., disabled people, asylum seekers, unemployed people, drop-outs, and so forth), a decreasing tolerance to car traffic, and a desire for close-to-nature recreation in or near cities. With regard to these trends, the need for detailed information on urban woodland, parks and trees on public and private land will only increase. The key issues related to the future benefits of urban forests and trees include what is demanded and perceived by whom from urban green spaces, and to what extent and how green spaces could be preserved in and around cities during modernization of cities.

Beautification of the city with gardens and parks for the sake of an image of splendour and generosity was an important aspect of greening cities throughout the feudal and bourgeoisie eras. To have one's recreational needs served within the living environment was a privilege of only few and closely connected with the location of housing quarters. With an increase of urban population and particularly the middle class, entertainment, sport and recreation went along with a daily or weekly visit to urban green space to counterbalance stress and compensate for the lack of private home gardens. Large private parks in the core cities were often opened up for public use and thus a democratization of green space private property became widespread all over central Europe.

Today, event-culture is provided where attractive entertainment is expected; and this applies to the media as well as to open-air events in public green spaces. What common access meant to the middle and lower classes of an emerging urban society in the 18th and 19th century has become a rising public demand for fun-parks and entertainment facilities at the beginning of the 21st century. Apart from dense networks of paths and other recreational infrastructure, there are often special attractions in urban forests such as zoos, amusement parks and platforms for open-air concerts. Green space with related amenities and social and cultural services to make it more attractive seems to be the demand of today and probably even more for tomorrow.

Although a close-to-nature living environment seems to be a desire to many people, at the same time cities and towns have become more compact. Migration studies (e.g., Willaert 1999) point out a steady flight from Flemish cities with relatively low amount of green areas, especially since the late 1980s. Also in sparsely populated countries such as Finland, nature and peaceful environment attract people from urban areas to more rural surroundings. Compact city policies and 'infill' in existing housing areas has resulted in an increasing demand for land within city limits and demands to build on land allocated to green spaces. This means decreasing amount of green spaces within the easy daily access for residents as well as increased use pressures on the remaining green areas, which often leads to overuse, congestion and the depletion of nature.

In general, as lifestyles in Europe have become more urban, the demands for urban woodland and trees become more diverse. Although urban forests are places for social contacts and bringing people together, at the same time many users are looking for solitude and peace and quiet. Moreover, awareness of the importance of ecology and preserving urban biodiversity is increasing among the residents. Compact city policies, however, provide less green areas resulting in decreased possibilities to maintain natural vegetation in urban areas. In addition, parallel to traditional ways to use urban nature, more adventurous and active forms of recreation have increased including mountain biking, skateboarding, survival games and paintball. In this respect, the social carrying capacity of urban open green areas depends on the type of use.

In conclusion, public green spaces have multifunctional purposes such as those mentioned above practically all over Europe. There is an increasing need to define and promote the socially integrative potential of woodland, parks and trees and to integrate people with specific needs and demands, deriving from their social status age, gender and ethnic background (German-Chiari and Seeland 2004). Due to an increase in the multicultural set-up of urban populations in the wake of European political integration and the influx of non-European immigrants and asylum seekers, and the increment of the number of singles among the urban population because of the fragmentation of families, socializing on the occasion of urban outdoor events (e.g. open-air concerts, summer festival weeks etc.) gains momentum. To meet people outside their homes and working places has always been a major purpose of urban green spaces. Be it urban woodland, parks or trees, there tends to be fewer differences and more commonalties in globalizing societies. Public green space offers a great opportunity for all sections of an urban society to meet in an arena that can be designed and used in a participatory way to benefit all. Public, open green space matters the more where informal social conventions increase. This trend of social inclusion among the younger urban generations is perhaps a counter-current to more and more cyber-based forms of communication and access to reality.

4.2.4
Architectural and Aesthetic Benefits

Architectural benefits deal with the use of vegetation in urban planning and development (see also Chap. 6). The main purpose of trees and forests is to improve and to restore constructed townscapes. Vegetation is used in defining open space and inte-

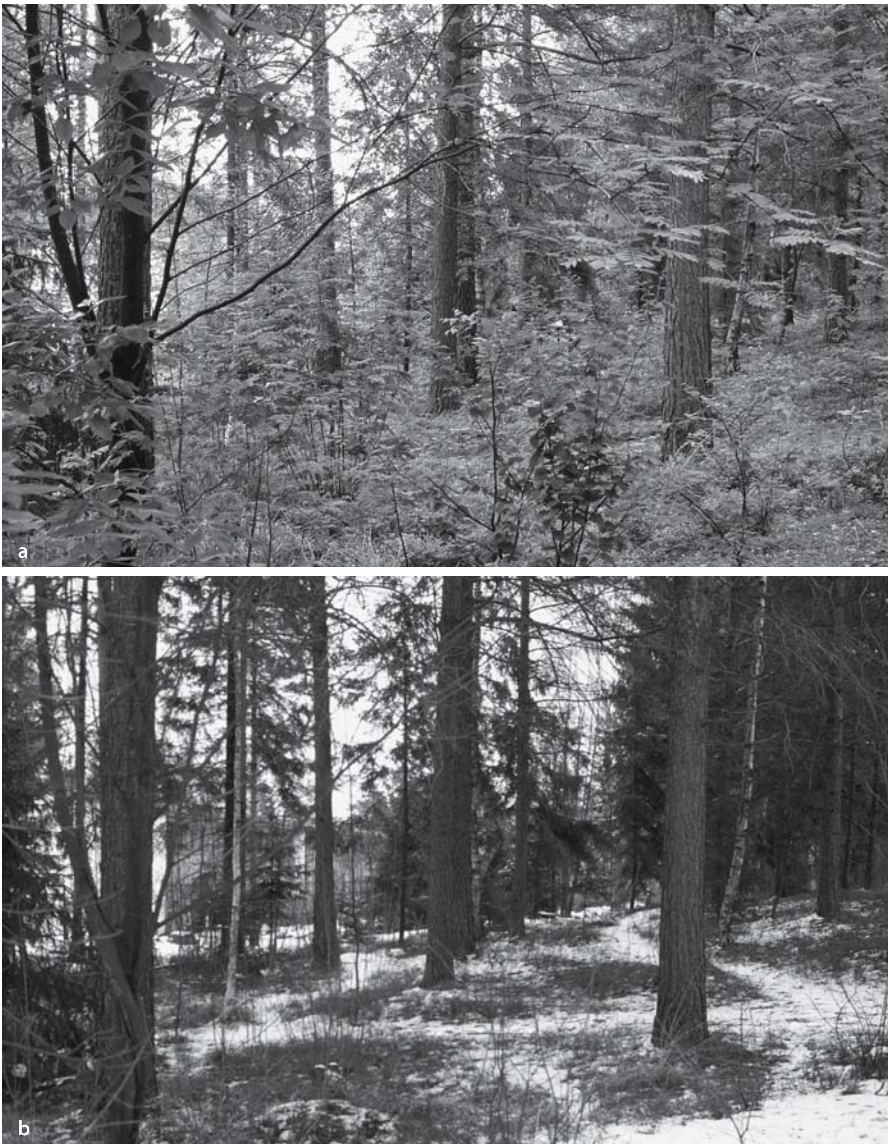


Fig. 4.2a,b. Seasonal variation in urban forests (*photos:* E. Oksanen, Metla)

grating the buildings to the surrounding environment. According to Robinette (1972) plants form walls, canopies or floors of varying heights and densities; these are architectural characteristics. Landscape variation is created through different colors, textures, forms and densities of plants. Urban trees can direct vision, break up large spaces, and define space. They can be used to frame scenes and to provide foreground and backgrounds for landscape features.

Aesthetic benefits relate to people experiencing different colors, structure, forms and densities of woody vegetation (Fig. 4.2). Much of the aesthetic experience is subjective in nature and has impacts on people's mental and emotional state (e.g., Kaplan and Kaplan 1989). Even a single tree carefully placed can make an important contribution to the aesthetic quality of the location. A great deal of the consumption of amenities occurs indoors through a window or from a car or bicycle. Visual variation is often stressed as being a key factor for aesthetic experiences (e.g., Axelsson-Lindgren 1995).

In landscape research there are many different research paradigms dealing with aesthetic values including psychophysical, cognitive (psychological), experiential (phenomenological) and expert approaches (Zube et al. 1982; Daniel and Vining 1983; Lothian 1999). These different research approaches produce different type of information for design and management of urban forests. The psychophysical and expert approaches provide information more easily applicable for practical purposes than other approaches. Psychophysical research has tried, first and foremost, to analyze and rank the preferences of people related to various types of urban forest environments (Daniel and Vining 1983; see also Karjalainen and Tyrväinen 2002). The cognitive approach (Kaplan and Kaplan 1989) has provided a framework for preferences and their links to cognitive aspects of the environment. The most common concepts derived from this knowledge base applied in practical planning guidelines in urban woodland have been diversity, scale, visual accessibility, stewardship, naturalness-continuity and coherence (Ode and Fry 2002).

In preference research aesthetic values are thought to be linked to the evaluation context as well as respondents' characteristics such as education, recreational activity, nature relationship, age and gender. Preference studies mainly from North America have shown that attitudes towards the wooded environments differ between children, teens and adults (Kaplan and Kaplan 1989). Youths appreciate the wild, dense, and hidden forest more than cultivated and open forest. Moreover, adults and children appear to value open-forest landscape more than dense forest. For children, structurally diverse natural places have been stressed as being more inspiring and imaginative, even compared to a well-organized playground (Kaplan and Kaplan 1989; Grahn 1997).

The visual quality of urban forests and people's preference can be examined through various approaches. Verbal information has been shown to have an effect on people's acceptance of various management actions in a recreational forest area (Jensen 1999). The main part of aesthetic perception occurs through the sense of sight and therefore, visualization of landscapes is a central part of forest landscape perception and preference research. Today digital image editing (Fig. 4.3) and in the future virtual landscape simulators offer the most sophisticated means of visualization for landscape research (Karjalainen and Tyrväinen 2002).

People's within-forest landscape preferences correlate strongly with the characteristics of the forest stand. People prefer stands of tall trees, but the preferred tree spe-

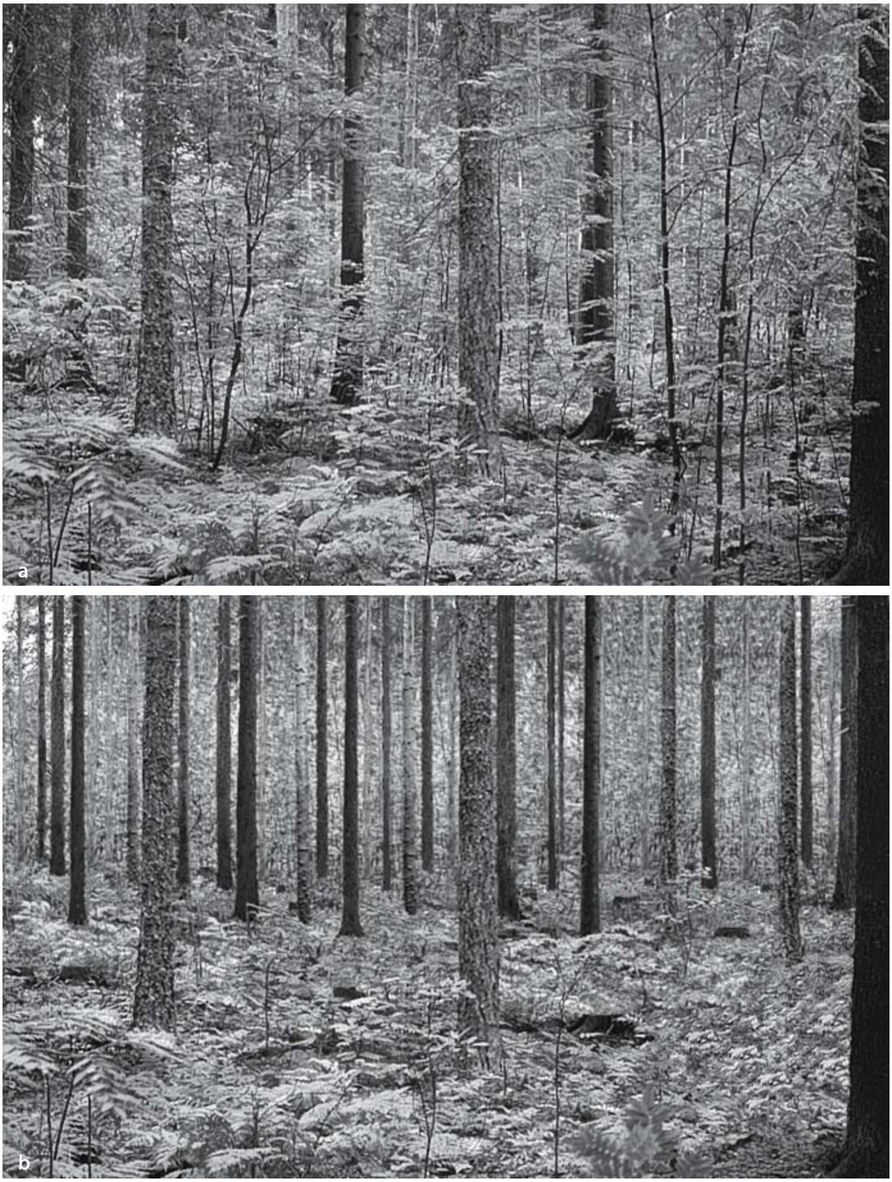


Fig. 4.3a,b. Pair of slides produced by photo manipulation illustrating different management options (*photos:* E. Oksanen, Metla)

cies relate to the specific geographical region in question. In Finland, for example, the most appreciated species in woodland are Scots pine (*Pinus sylvestris*) and silver birch (*Betula pendula*). Furthermore, in urban woodland the within-forest visibility should be relatively good. In general, old and mature forest stands are preferred over young and small trees, but small trees, if they form the lower canopy layer of a two-storey stand, are considered to improve the aesthetic value of the stand. Variation is greatly appreciated, not only due to mixtures with other types of trees, but also combination of trees with fields, meadows and, in particular, water elements (Schmithüsen et al. 1997). In particular, forest edges, which are many in urban settings, are essential for human aesthetic experience and visual perception. A well-designed edge consists of mixture of bush and tree species, which have not only aesthetic but also ecological importance (Lucas 1991).

Moreover, the aesthetic valuations may partially change over time and are influenced by trends, cultural system and knowledge. Studies on forest management preferences show that regeneration, in particular clear-felling, is visually the least acceptable management practice (Ribe 1989). Thinning treatments affect the stand's scenic beauty less than regenerative cuttings. Moreover, the length of time since the treatment has been found to correlate positively with the stands' visual quality (Silvennoinen et al. 2002).

An increasingly important question is whether people find managed forests more attractive than unmanaged ones. Previous forest preference studies conducted mainly during the 1980s suggest that residents prefer managed forests if traces of human activity are not visible. Although both types of results exist, many studies suggest that areas that are thought to be in a natural condition are perceived to be more beautiful than if traces of human activity are visible (e.g., Axelsson-Lindgren 1995). Furthermore, logging residues, dead snags and decayed wood left in the forests are not appreciated. Today, the importance of ecology has increased and values related to woodland are more conflicting than earlier (e.g., Seeland et al. 2002). On the one hand, management is needed because of security aspects and aesthetic reasons, while on the other hand there is an increasing demand for unmanaged areas based on ecological arguments.

In practice, preferences for urban forest management may be rather different among user groups. In a study in Helsinki, Finland, the majority of residents preferred managed forests probably because of security and cultural reasons (Tyrväinen et al. 2003). The most disliked stands were unmanaged forest vistas where young coppice limited sight and accessibility. In general, residents also disliked dead or decayed trees left in the forest. However, younger, higher educated residents and active urban forest users preferred more ecologically-oriented management compared to older, less-educated residents and less active users. Also, housing type was connected to the preferences of urban forests. Residents living in one-family or terraced houses preferred to have managed forests more than residents living in blocks of flats (Tyrväinen et al. 2003).

Forest landscape preferences have a strong cultural dimension. Nordic residents have a relatively abundant supply of woodland within their living environment, but in many densely populated countries in central Europe the daily contact with natural woodland is less frequent. In a study conducted in Redditch, United Kingdom (Coles and Bussey 2000), open structure woods were found to be preferred over woods with a dense canopy cover, in particular because of security concerns but also as open woodland offers a more varied environment. Interviews revealed that escape from urban life and activities was considered the most important motive to visit a wood, in order to seek a sense of tranquillity. Whether the woodland was a plantation or a natural woodland did not appear to matter. Woodland visitors described "natural" mostly as a contrast to the urban setting, and every sign of urban intrusion reduced the pleasure of experiencing nature. Rubbish, signs of vandalism, and management were seen as particularly negative impacts.

Physical design parameters for urban woodland were also investigated by Coles and Bussey (2000) in Redditch. A size of 2 ha was identified as the smallest wood that people wish to visit regularly. Small woods could be attractive when linked together by footpaths. Shape became particularly important in small woods of less than 5 ha in size. Blocks of woodland that allow circular walks were preferred over narrow belts.

4.3 Climatic, Engineering and Ecological Benefits

The urban forest can play a major role in improving urban environmental conditions and safeguarding biodiversity. Environmental benefits do not relate solely to areas of woodland, however; smaller groups, avenues and isolated trees can equally improve environmental conditions in urban areas.

4.3.1 Air Quality

Improving air quality has been an imperative of environmental policies throughout the 20th century. Installation of filtering devices in power plants, the switch to less polluting fuels and other technical measures have achieved significant improvements in this respect. Yet air quality remains a major concern. While the concentration of air pollutants such as sulfur dioxide has been successfully reduced in urban areas, other – mainly car induced – pollutants such as nitrogen oxides, ozone and volatile organic compounds are of increasing concern. Climate change is likely to add further to these air quality problems because rising air temperatures and higher levels of radiation can lead, for instance, to higher concentrations of ozone in the air. Particular attention also needs to be paid to ultraviolet radiation, which can cause skin cancer, in the southern parts of Europe.

A particular challenge lies in the fact that the sources of air pollutants are often diffuse. In this context, the role of urban green space and in particular that of the urban forest in removing air pollutants in urban areas has become of interest. Green spaces and trees are widespread in urban areas and thus could provide an effective means to improve air conditions locally and provide shelter from ultraviolet radiation. A number of studies in the United States have shown the potential of the urban forest for improving air quality (e.g., McPherson 1994; Nowak et al. 2002).

In Europe, evidence is still limited but results of previous studies clearly show that trees have an important role to play in removing air pollutants in urban areas. A woodland in Nottingham was estimated to reduce concentrations of sulfur dioxide and nitrogen oxides in the air by 4–5% (Freer-Smith and Broadmeadow 1996). More important, however, is the function of trees to capture dust. Evergreen tree species, and in particular conifers, filter more dust than deciduous species, but conifers are also more sensitive to damage caused by air pollutants (Däßler 1991; Beckett et al. 1998).

Single trees filter less dust than groups or rows of trees. Trees capture air pollutants most efficiently when they are planted close to the source of emissions. Woodland canopies are more effective than other vegetation types at trapping particle pollutants because of their greater surface roughness (Manning and Feder 1980). Studies in North American cities have estimated the overall removal of air pollutants by trees (McPherson 1994).

While there can be little doubt that the urban forest has a largely beneficial effect on air quality, the emission of volatile organic compounds (VOC; Beckett et al. 1998) as precursors of ozone has recently gained attention. This may be an issue in hot climates with intensive solar radiation such as are experienced in Mediterranean cities. Also, the production of pollen from tree species such as birch needs to be carefully considered when tree species are selected for urban plantings, because of its allergenic effect.

A recent large-scale study in the West Midland region of England estimated the overall removal rates of air pollutants by the urban forest (Stewart et al. 2001). The study was based on a sample of over 30 000 trees. An air quality model was developed to assess the potential of the urban forest to remove air pollutants such as ozone, nitrogen oxides and carbon monoxide and also to estimate potential emissions of volatile organic compounds. At the time of writing, results had yet to be published in their entirety. However, the data that are available suggest that planting additional trees on land theoretically available for this purpose could lead to a significant reduction in concentrations of airborne particles in the West Midlands once these trees have matured. Planting of all available land could achieve a reduction of up to 25% of small airborne particles.

4.3.2
Urban Climates

Thermal imagery has been widely used to assess thermal conditions and develop climate strategies on a city level (e.g., Nachbarschaftsverband Stuttgart 1992). On these images, urban woodland and trees are consistently among the coolest surfaces during hot summer days. On these hot summer days, air temperatures within large parks can be 2–3 °C lower than in the surrounding built-up areas. A significant climatic function can only be expected when park size exceeds one hectare, while a size of 10 ha is required to lower air temperatures by 1 °C (Kuttler 1993). The results from extensive studies in Göteborg, Sweden clearly show the climatic impact of green space (Eliasson 2000). Air temperatures were significantly lower inside parks as compared to the surrounding built areas, but temperatures were also reduced in a transition zone outside the parks. However, even large parks lower the air temperatures in adjacent built-up areas only to a distance of approximately 200–400 m on the windward side on days with low wind speed when the urban heat island effect is strongest. Therefore, it is important to protect the vegetation within urban land uses and to create a dense network of publicly accessible green spaces. An ideal urban climate would offer a great range of different microclimatic conditions within walking distance (= 150 m; Mayer 1990), while avoiding climatic extremes.

Trees are the most effective vegetation element for reducing overheating in urban areas. Figure 4.4 shows the mean surface temperatures for urban surfaces in Munich (Pauleit and Duhme 2000a,b, see also Chap. 3). Open space types, and in particular those with a high percentage cover of trees and water surfaces, were the coolest areas in the city. An increase of tree canopy cover by 10% reduced surface temperatures on average by 1.4 °C

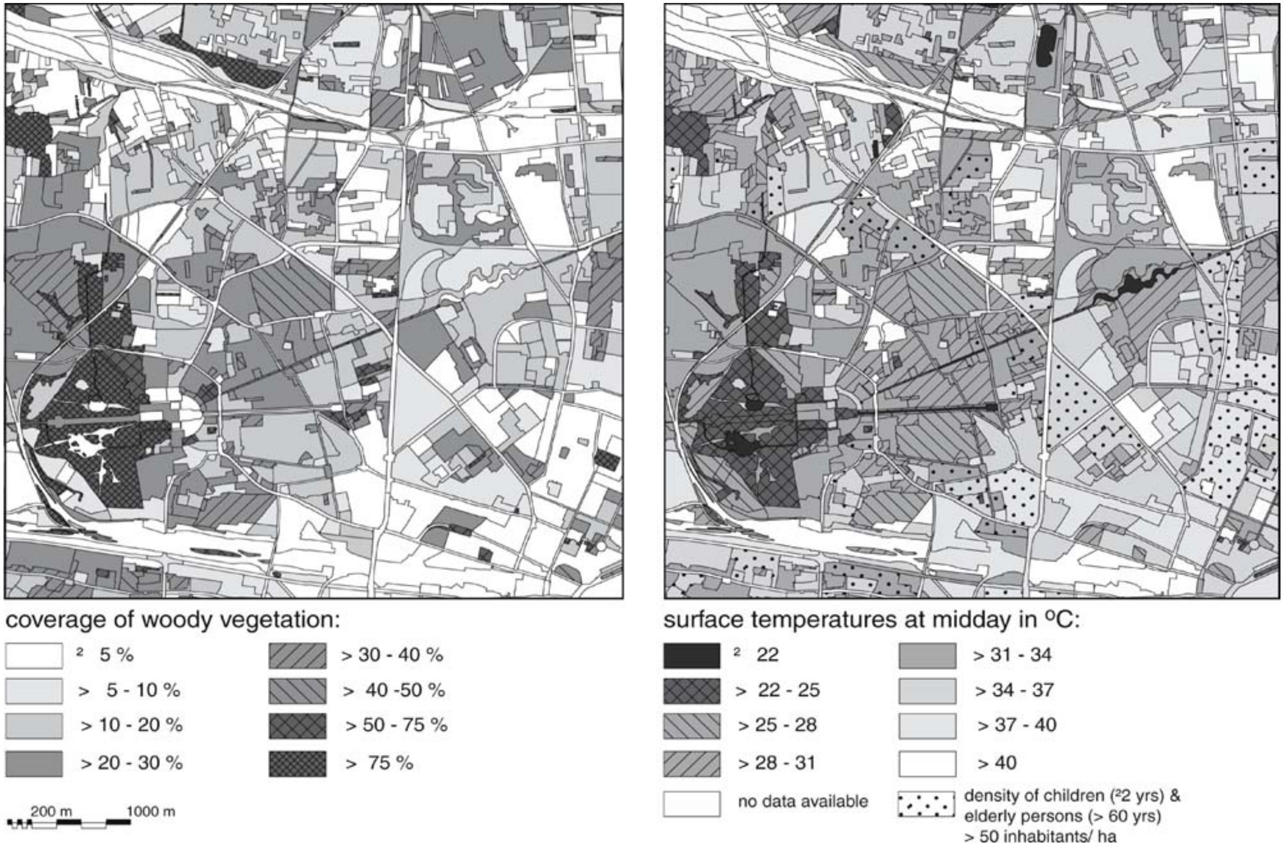


Fig. 4.4. Mean surface temperatures in urban morphology units and cover of trees ands shrubs for the example of Munich, Germany (adapted from Pauleit and Duhme 2000)

during daytime on a hot summer day. Low density residential areas were characterized by a cover of trees and shrubs greater than 20%. These areas were significantly cooler during hot summer days than densely built-up housing and commercial areas.

Temperature reduction by trees is mainly caused by two factors: direct shading and evapotranspirational cooling (Oke 1989). On a hot summer day, for instance, a significant decrease of air temperatures by more than 2 °C could be observed during daytime under trees on a car park as compared with sun exposed sites in front of south facing walls (Brahe 1974). Airflow, on the other hand, can be significantly reduced through tree plantings. This reduced airflow can decrease energy demand of adjacent buildings for heating and air conditioning but it can also have negative impacts, as air pollutants may concentrate under the tree canopy, and sultriness may increase in hot-humid climates (Givoni 1991). Therefore, plantings schemes are required that reduce overheating but maintain good ventilation.

An example of climate conscious planning is the redevelopment of the former Munich airport as a new mixed neighborhood (Burkhardt and Duhme 1996, Fig. 4.5). Approximately one third of the neighborhood was dedicated to green space. A big park of 200 ha size in east-west direction fulfills important climatic functions as a corridor enhancing ventilation of the inner city and the neighborhood (Fig. 4.5, level 1). Green wedges within the built-up area will allow country breezes from the south to penetrate and thus improve air quality as well as reduce air temperatures on hot summer days (Fig. 4.5, level 2). For access streets in east–west direction, it was suggested to plant trees in front of the north facing fronts of the houses (Fig. 4.5, level 3). This would allow good air exchange due to circulation driven by small-scale temperature differences. Planting trees on the north facing side would also avoid strong shading of south facing windows. However, in hot climates such as the Mediterranean, plantings should be preferably made on the south-facing front to avoid excessive temperature loads on the buildings while temperature differences with the north side of the street would still allow for small scale circulation.

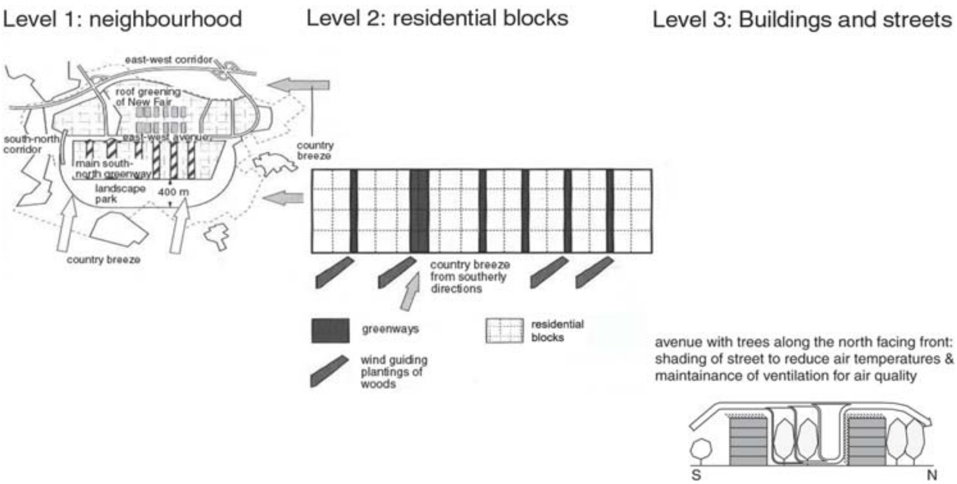


Fig. 4.5. Principles for climatic planning on the levels of residential area, block and street in the new neighborhood of Riem, Munich (*source:* Burkhardt and Duhme 1996)

Deciduous trees with open crowns such as black locust (*Robinia pseudoacacia*), honey locust (*Gleditsia triacanthos*) or Japanese pagoda tree (*Sophora japonica*) would be particularly well suited for this purpose.

Climatic modeling is becoming increasingly available to assess the bioclimatic conditions on urban places and in street canyons (e.g., Matzarakis 2002; Maye and Matzarakis 2003), yet its application in climate planning is still limited (Eliasson 2000). These models assess the effects of trees on air temperature and thermal comfort of pedestrians, and thus provide tools for climate planning from a small scale to the city level.

The role of trees to improve climatic conditions in cities and towns differs across Europe. Overheating of inner cities during summertime is in particular an issue in the countries in the south, south-east and to some extent also in central Europe. In urban areas in the north and north-west provision of shelter from cold winds will be of greater importance, even under climate change scenarios.

4.3.3 Hydrology

Hydrographs show how urbanization increases the peak flow intensity and quantity during rainfall events. Urban forests and trees can reduce surface runoff and thus alleviate the strain from the urban sewage system and dampen peak flows of streams. The main ways that individual trees reduce runoff are by

- the interception of precipitation, which is stored and/or evaporated from the tree (Xiao et al. 2000),
- the increase of rainwater infiltration into the open soil under the canopy,
- an increase of water storage capacity of soils through evapotranspiration,
- the reduced impact of raindrops and consequently less soil erosion and pollutant wash-off.

Protection of riparian woodland can be of particular importance for surface water quality. The hydrological function of urban woodland and trees is increasingly stressed as protection of drinking water resources. For example, in Denmark new woodland areas established close to cities consider this function as a primary one next to recreational benefits (Jensen 1995).

Open spaces covered by trees and other pervious surfaces enable infiltration of rainwater and thus recharge the groundwater in an otherwise sealed urban area. However, no models are currently available to assess these effects quantitatively on the level of cities, neighborhoods or single sites in European cities and towns.

The role of vegetation in reducing surface runoff was estimated using a standard curve method in 11 residential areas for the Merseyside conurbation, England (Whitford et al. 2001). The results show a clear inverse relation between green-space provision and rainwater runoff. A simple approach based on empirical coefficients derived from several studies was used to estimate the hydrological impact of green spaces in Munich (Pauleit and Duhme 2000a). Different runoff and infiltration coefficients were assigned to land cover types. This exercise provided only very rough estimates and would need further refinement and verification. However, the results show clearly how well-greened

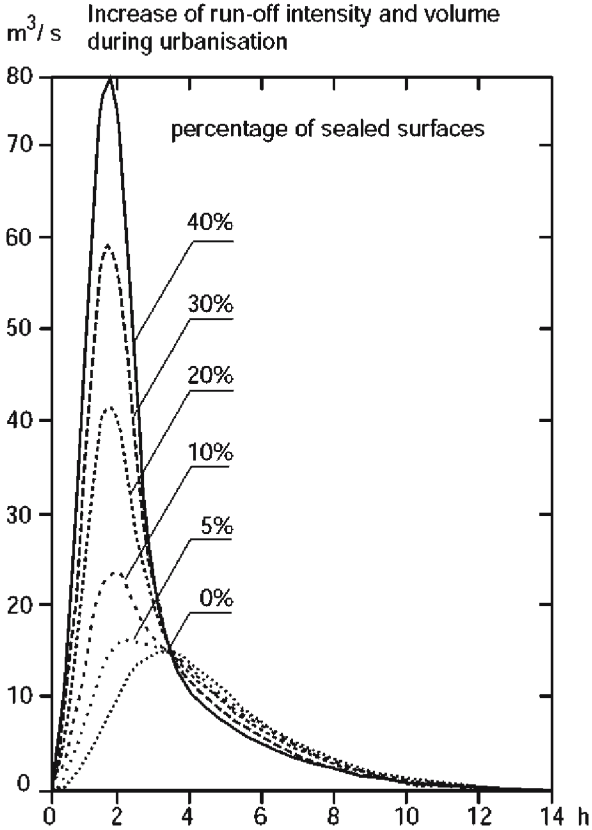


Fig. 4.6.
Runoff curves in urbanized catchment areas (*source:* Emschergenossenschaft/ Lippeverband, 1979, in: SRU 1987, p 299)

urban areas and particularly woodland reduce surface runoff and increase rainwater infiltration compared to built-up areas, as can be seen from Fig. 4.6. In a next step, the amount of pervious surface required to infiltrate the surface runoff completely within the land use unit was calculated. On this basis, the need for green areas in general and urban forests in particular for a more sustainable urban hydrology was quantified.

4.3.4
Energy Demand and Carbon Sequestration

While some North American research has studied the reduction of energy demand through shading of houses in summertime and shelter in winter (e.g., McPherson 1994), no comparable studies have been performed in a European context. Energy studies have concentrated mostly on the built environment. The overall direct carbon sequestration by urban trees accounts for less than one percent of carbon emissions from urban areas (McPherson 1994). Still, more important will be the indirect effects of trees in reducing energy demand of buildings. It has been estimated that, for Sacramento County, California, the urban forest of approximately 6 million trees sequesters 238 000 t of CO_2 per year. The urban forest further reduces energy consumption indirectly as carbon dioxide emissions from the local power plant are avoided by an estimated 75 600 t CO_2 yr; this is because the presence of trees leads to reduced demands for household heating and air conditioning (McPherson 1998).

In Liverpool, United Kingdom, carbon sequestration was estimated for four residential areas with a different provision of vegetation (Whitford et al. 2001). With up to 0.13 t ha^{-1} yr^{-1}, well-treed areas sequestered more than double the amount of carbon than those areas with a poor provision of green spaces. Even more striking were the differences in carbon storage between residential areas. Carbon storage could be as high as 17 t ha^{-1} in a residential area with a mature, dense stock of trees, whereas it was below 1 t ha^{-1} in an area with an overall low provision of green space and almost no trees.

Moreover, the use of wood as a biofuel could substitute for fossil fuels. Modern biofuel and power plants would allow for a wider use of wood without unacceptable impacts on air quality. This could be an interesting alternative in particular for smaller settlements where sufficient land is available for growing energy crops such as poplar plantations or coppice woods.

4.3.5 Biodiversity

The biodiversity of urban woodland in European cities and towns is relatively well investigated (Gilbert 1989; Sukopp and Wittig 1993). The main factors that influence biodiversity of woodland are:

- Woodland origin and naturalness, with a gradient of species richness from relics of primary woodland, over secondary, naturally developing woodland to recently established and managed woodland. Even after several centuries, secondary woodland could be still distinguished from primary woodland by a lack of species of low colonizing ability (Peterken 1974).
- Size: large forests offer more different habitat types as well as habitats for species with larger area requirements. In a study in The Netherlands, only woodland areas of at least 10 ha in size harbored interior woodland birds (Van Dorp and Opdam 1987), but much larger woodland areas would be required to accommodate more demanding wildlife ($\gg$100 ha).
- Intensity of interventions through management and use: Intense recreational activities may have a negative impact in particular on breeding birds and other disturbance sensitive species (Van der Zande 1984). Monoculture woodland mainly planted and managed to produce timber is less biodiverse than naturalistic plantations.

Moreover, single old trees in parks can be an important habitat for birds, bats and invertebrates. Habitat surveys and floristic and faunistic studies have shown the importance of tree cover in urban land uses such as residential areas for biodiversity. Tree crowns can provide habitat for birds and invertebrates in otherwise intensively managed and used gardens. Density of tree cover, overall extent of stands of trees and age of trees are especially important factors influencing biodiversity. An overall tree cover of at least 20% was proposed as a target for urban forestry planning for residential areas on this basis for the City of Munich (Duhme and Pauleit 1992). In fact, the biodiversity in urban areas is in part high because of human influence and due to many exotic species. This richness of species in urban nature could be used more for educational purposes, i.e. to show the residents that city nature has its own special features and diverse values (see Chap. 8).

While the importance of urban areas for biodiversity is increasingly recognised, there is a significant lack of guiding models for biodiversity planning on the city and neighborhood level. One approach is the linking of individual sites, through wildlife corridors or green corridors into a "green network" of wildlife sites and open spaces (Barker 1997). Whilst research findings are calling into question assumptions about the functioning of ecological connectivity within urban environments (Dawson 1994), there is little doubt that both people and wildlife benefit from connections to the overall landscape. Urban woodland is a major component of green networks. This requires strict protection of existing natural woodland that cannot be recreated. Furthermore, although in North-Europe woodland areas preserved from natural forest vegetation are common they are often intensively managed. For example, in Finland there is an increasing demand to leave unmanaged areas also in urban forests to create habitats for old growth forest species in the long run. In practice, the more the urban forests become fragmented in a city structure the more difficult it will be to reach the ecological objectives.

Furthermore, increasing attention needs to be placed on successional woodland on post-industrial land. These areas offer significant opportunities for the creation of urban woodland (Perry and Handley 2000), providing valuable habitats and creating a new landscape character. Therefore, the model of compact cities and the redevelopment of brownfield sites (i.e. abandoned former industrial sites) needs to be carefully balanced against their value for recreation, biodiversity and landscape character. Landscape ecology also stresses the importance of patch shape and boundaries (e.g. hard or soft, straight or curved) for biodiversity. An overview of landscape ecological principles for the design of woodland is provided by Bell (1999). Finally, the Munich study shows how targets for urban forests within urban land uses can be developed based on habitat surveys (Pauleit and Duhme 2000).

4.4 Economic Benefits of Urban Forests and Trees

4.4.1 Economic Values of Urban Forests

In environmental economics a specific taxonomy of values related to natural resources has been developed, although definitions of these values seem to be somewhat unclear or overlapping (Turner et al. 1994). The values attached to public environmental goods are usually classified as use values and non-use values. Use values are divided further into consumptive and non-consumptive use values, while non-use values are often divided into option, quasi-option, bequest and existence values.

The consumptive use values of forests include values of market-priced products such as timber, game, berries and mushrooms. Timber is traditionally seen as the most important market-priced product of forests in many rural areas across Europe. However, the values of timber production and of picking mushrooms and berries in urban forests are lower than in rural areas. This is because the environmental conditions for growth are limited due to pollution, fragmentation of forests and trampling effects. In addition, the net revenues from timber are usually fairly small if any, because management of areas is relatively expensive due to small-scale management practices. Moreover, the market price of berries and mushrooms reflects their true value only partially, as the recreational value of their picking is excluded. The value of game is also unimportant as hunting is often not allowed in urban areas.

In fact, the main values of urban and peri-urban forests have no market-price. These values are termed as non-consumptive use values and include benefits derived for example from a pleasant landscape, clean air, peace and quiet, as well as recreational activities (Fig. 4.7, Tyrväinen 1999). This category also includes benefits such as reduced wind velocity, balanced microclimate, shading, and erosion control, the economic value of which may be determined through for example reduced costs of heating or cooling or alternative costs of environmental control.

The non-use values (option, bequest, existence) may be less important in urban than in natural forests but still worth taking into consideration. The possible motives for these values are altruism, heritage or existence, but theoretically the different value categories have not been consistently defined. Option value is defined as individual willingness to pay (WTP) for ensuring the future availability of a particular amenity. These values can be attached for example to well-known public parks such as Central Park in New York or Bois de Boulogne in Paris, which can be expected to have importance for people other than residents of the city. A related form of value is bequest value, a willingness to pay to preserve the urban forest as a resource, not for the current valuators, but for a potential future use by their descendants (Turner et al. 1994). Many parks have, among other values, this type of cultural and historical importance. Moreover, the existence value is derived from the knowledge that the resource continues to exist and it is often connected to extinction of species. There are species, for instance, that have found suitable habitats only in urban environment.

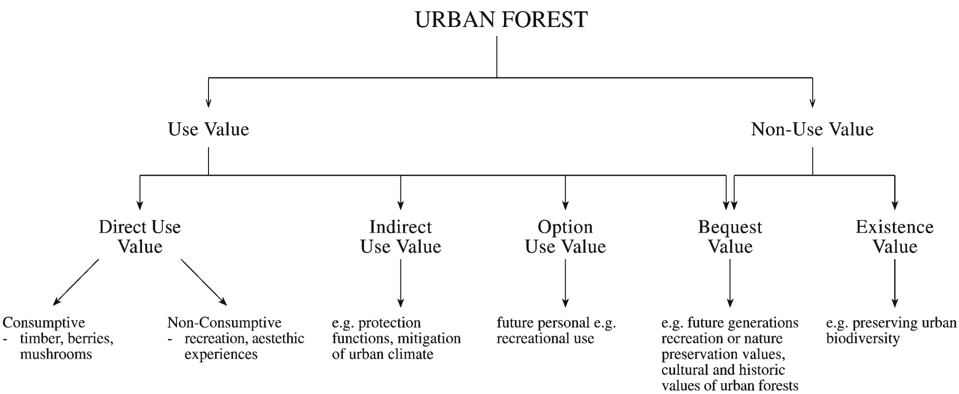


Fig. 4.7. The total economic value of urban forests (Tyrväinen 1999, adapted from Turner et al. 1994)

4.4.2
Quantifying Amenity Benefits in Monetary Terms

The economic value of urban forest can be estimated in different ways. Traditional methods include opportunity costs, estimation of maintenance costs and of the production value of forest. These methods are based on valuing market-priced goods and therefore their use in urban forests is limited (Tyrväinen 1999). The quantification of amenity values of urban forests is complicated, because these are not sold and bought through markets. The urban forest resource can be viewed as a public good, but not a pure one. Usually municipalities are in charge of providing the services, excluding urban trees on private property, and in principle everyone has a possibility of consuming, for example, the pleasant wooded landscape. However, households also have an option of paying for the environment as a joint product with a job or a house by, for example, choosing a house close to a public park.

The methods used in estimating non-priced benefits of forests include the contingent valuation method (CVM), the hedonic pricing method (HPM), and the travel cost method (TCM). Furthermore, approaches such as tree pricing and environmental benefit valuation have been applied in assessing urban forest benefits (Tyrväinen 1999). The methods have different abilities to capture different benefits (Table 4.2). For example, hedonic pricing mainly captures recreational and aesthetic benefits of green areas, whereas environmental benefit valuation focuses on air quality and the energy saving function of trees.

In the first approach, *CVM*, hypothetical markets for the environmental goods are created, i.e. the respondents are asked what they are willing to pay (WTP) for the preservation/establishment or improvement of urban forests. The researcher can then estimate the monetary value of the asset by calculating the average WTP of respondents and multiplying this by the total number of consumers (Mitchell and Carson 1989). In Germany, Elsasser (1996) applied the CV method for valuing the recreational use of two large urban fringe forests in the Hamburg region. The

Table 4.2. Methods of estimating the amenity value of urban forests in monetary terms (Tyrväinen 1999)

Method	Types of values	Suitability	Constraints
Hedonic pricing	Use values (option value)	All green spaces	Data restrictions, difficulty in defining environmental quality variables
Contingent valuation	Use and non-use values	All green spaces	Hypothetical, assumptions on peole's behaviour
Travel cost	Use values on-site	Parks or recreation areas	No or small travel costs to neighbourhood parks, time excluded
Tree pricing	Use values	Individual and groups of trees	Not suitable for forested areas, mitigation effects of climate excluded
Environmental benefit valuation	Part of non-consumptive use values	All green spaces	Aesthetic values excluded, data restrictions

data set was exceptionally large (3 500 respondents). The mean WTP/year for the use of the forests was around €42 person^{-1} yr^{-1}. In Finland, Tyrväinen (2001) asked people's willingness to pay (WTP) for forested recreation areas in two study towns, Joensuu and Salo. More than two-thirds of the respondents were willing to pay for use of the recreation areas. Good location and active management raised the average WTP. The average use value per visitor in different recreation areas ranged from €5.2–12.7 per month.

In the second approach, *hedonic pricing*, the value of the urban forest amenities for people is observed through housing market transactions. If a household wishes to enjoy a view onto a forest or a park or to have easy access to wooded recreation areas, it will buy this type of property and pay a premium for it. A hedonic price model can be computed from data concerning the prices and different features of properties (Palmquist 1991). The main advantage of the method is that it relies on actual market data rather than hypothetical valuations. In Finland, Tyrväinen and Miettinen (2000) demonstrated that a one kilometer increase in the distance to the nearest urban forest area led to an average 6% decrease in the market price of the dwelling (Fig. 4.8). Furthermore, dwellings with a view onto forests were on average 5% more expensive than dwellings with otherwise similar characteristics. In The Netherlands, Luttik (2000) found that a pleasant view alone leads to a considerable increase in house price (6–12%), particularly if a house overlooks water or open space. Proximity of public parks, however, yielded ambiguous results; only when water was a distinctive feature in the park could a premium on the house be demonstrated.

However, it is worth noting that proper maintenance of urban forests is essential to sustain the flow of green benefits. A deteriorated park, for example, may become a negative externality within a neighborhood, and may also prompt decision-makers to consider it for non-park development options. Moreover, social congestion caused by a heavy use of public parks may cause negative externalities to adjacent houses and may even decrease their prices.

The basic idea of the *travel cost method* is to estimate the demand for recreational benefits using the costs of travel, which are used as a proxy for price. The method is problematic in urban settings because there are usually no or only small costs involved in traveling to the site (e.g., Tyrväinen and Väänänen 1998). However, the method is useful in a setting where large urban forests within city limits are scarce and people have to travel further to reach the areas.

Tree pricing assumes that the tree value is based on several factors such as size, expected age, aesthetic value, location, form and other special features (Table 4.3). The method is based on a cost depreciation approach, and it is widely used in many large European cities due to its practicality. Determining prices for single trees has been necessary for estimating the compensation of injuries to the landowner caused, for example, by vehicles or construction. This is, however, based to some extent on subjective judgment. Tree pricing has typically been used for single or groups of trees, but it is not suitable for forest areas. Moreover, it does not explicitly account for environmental services such as shading and adsorption of pollutants that trees provide.

Table 4.3. Example of a tree pricing formula used in Danish cities (Randrup et al. 2003)

VAT 03 – Valuation of Trees – a Danish model, developed in 2003			
Locality		P_n = price, new tree	
Species		C_n = circumference, new tree	
Date		C_d = circumference, damaged tree	
Reg. no		E = establishment costs	
		a: actual age (years)	
		b: expected age (years)	
		Average is given with two decimals	
		Result is denoted in 100 Kr.	
		If $a < b/2$, then $A = 1$	
Basis value (*B*) $= E + (P_n / C_n) \times (C_d - C_n)$			$B =$
Health (*H*)		**Location (*L*)**	
Give points (0–5, with 5 as highest)	Points	Give points (0–5, with 5 as highest)	Points
Roots		Adaptation	
Stem		Architecture	
Main branches		Aesthetics	
Smaller branches		Visibility	
Twigs, leafs, buds		Environment	
Total / 25	$H =$	Total / 12.5	$L =$
Age (*A*) $\sqrt{\frac{(b-a)\times 2}{b}}$			$A =$
Value of the tree $= B \times H \times L \times A =$ Kr.			

Valuing the environmental benefits of trees aims at quantifying the impact of trees on urban climate (shading, evapotranspiration and air flow modification). These benefits can be valued through the alternative costs of environmental control, such as people's WTP for air pollution control and noise abatement, or directly through, for example, energy savings in heating or cooling (McPherson 1994). Nowak (1994) found that a 5–10% improvement in localized air quality was possible in areas with relatively high tree cover. In 1991 the researcher estimated the value of pollution removal to be US$1 million for trees in Chicago. Furthermore, the potential of trees to reduce the residential heating and cooling energy was investigated. An increase in tree cover of 10% (approximately three trees per building) could reduce heating and cooling energy by 5–10%. Although the approach is suitable for valuing all green areas, many countries have insufficient quantitative information on the impacts of trees on urban climate.

4.4.3
Cost–Benefits Analysis in Urban Forestry

Frequently, the amenity benefits of urban forests are not well enough articulated in land use decisions and green-space policy-making. In many cities there are increased pressures to convert urban forests to other use, as well as financial problems related to management of the areas. If the socio-economic value of ecological factors can be demonstrated, for example through a premium on house price, this strengthens the position of existing green areas in the policy decision process. Today land-use planning procedures and greening projects do not include any systematic quantitative assessment of the benefits of green areas (Tyrväinen 1999). Decision-makers compare economic factors like contribution to the tax base and employment or the value added to the local economy against the value of environmental factors. By expressing the latter in monetary terms they become comparable to the former. This will put more weight on environmental factors in the decision making process, although by no means all environmental values can be put into monetary terms (Luttik 2000).

Economic estimates of benefits of urban forests and trees are useful in decisions regarding town planning, urban forest policy and budget allocation. The application possibilities include an assessment of lost benefits due to 'densification' or 'infill' of town structure and reduced tree canopy as well as economic gains of establishing new green areas. At the municipal level it is necessary to assess whether the provision of recreation services is in balance with the demand. The analysis also provides information for assessing cost efficiency and alternative management structures. The use of economic analysis in decision-making has different levels. At a minimum level it might stimulate public and policy-makers' awareness of potential values. At the project level, it could influence or identify decisions through cost–benefit analysis.

Frequently, the costs of urban forest management are poorly documented in cities and towns. A study in Munich, Germany, addressed the question of how to optimize management costs of the urban green structure. An economic approach was used to structure the quality of urban forests in relation to necessary maintenance to get this quality. Information on resources and average time spend on certain management tasks in different areas was gathered. An optimization model was applied to plan the use of management resources (Steidle-Schwahn 2002).

The total value of a green area depends on its location, size, quality, use intensity and the amount of available substitute areas. In general, the scarcer the resource becomes, the higher the value per hectare. Moreover, the value of single trees in a city is not the same, even if trees are identical and in the same location. The law of decreasing marginal benefits applies to aesthetic and recreational values of trees: the first tree in an open area makes the biggest difference after which every additional tree counts for less.

So far, research seeking to determine the amenity benefits in monetary terms has been limited in Europe, although the level of activity and the results have more or less passed the demonstration stage. There are cultural differences in attitudes towards the urban forests and the supply of the green areas varies. Therefore, results are not easily transferable. More research is needed to create feasible models for assessing the benefits in practice. By monetary valuation methods it is possible, however, to create local or regional estimates for the economic value of green areas.

4.4.4 Tools for Decision-Making

Valuing Benefits of Urban Woodland

Property Value Models

The next example shows how a property value model can be used to calculate the value of an individual urban forest park indirectly. The idea behind this procedure is (*1*) that the total value of the forest/park views is determined and (*2*) that attention is given to the effect of the distance to the forest park. Here the calculation is illustrated by using the property value model (Tyrväinen and Miettinen 2000) presented in the previous section (Fig. 4.8). In this example it is assumed that size of the forest park is one hectare and it is circular. Given the average yard size of 400 m^2, the number of dwellings next to the park is 35. The total value of these apartments is approximately €2.24 million, and the value of the forest view is 4.9% of the total value of dwellings, which is €110 000. Here, the average size of an apartment is 90 m^2 and the average unit price was at the time of investigation €710 per m^2.

Moreover, according to the semi-logarithmic model an increase in distance of one kilometer reduced the average price of a dwelling by 5.9% (Fig. 4.8). Here the price effect is calculated only up to 600 m, because it is the case of a small park. The total value of apartments within 600 m from the park is €76.35 million. The aggregate value of the park reflected to dwelling prices is €3.73 million and can be calculated geometrically using the price model. When the value of the view is added to this figure, the total value of the park is €3.84 million. If conversion of the park into other use is considered,

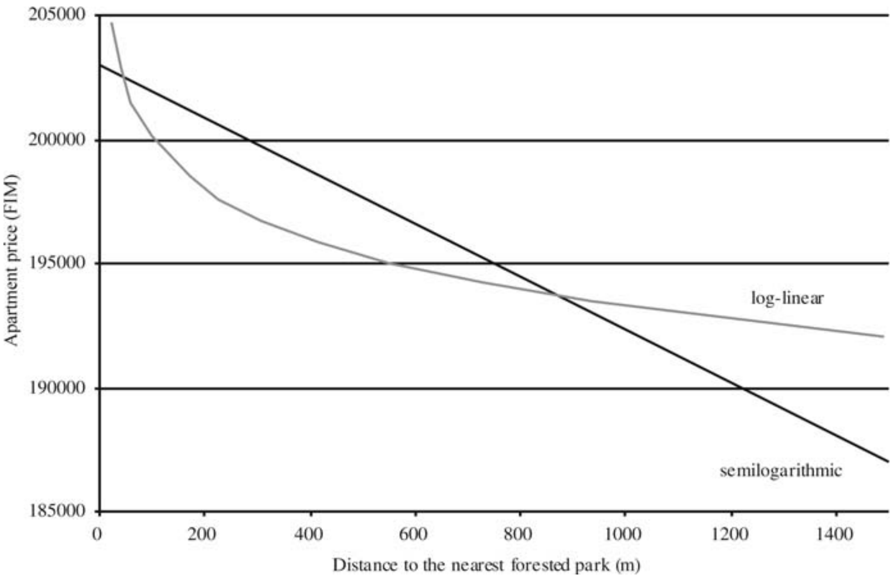


Fig. 4.8. Effect of distance to the nearest forested area on apartment price (1 FIM = €0.168) (Tyrväinen and Miettinen 2000)

this value should be compared to increased costs when providing the building sites somewhere else. A more detailed calculation example is presented in Tyrväinen and Miettinen (2000).

In this example it was assumed that the park was the only one influencing the apartment prices within 600 m. If the construction intensity is higher (i.e. there would be mostly blocks of flats), the estimated value of the park would also be considerably higher, approximately €11–15 million. Here it should be stressed that the social and ecological carrying capacity of the green area are limited. After a certain limit, the high use of the park becomes also a nuisance and may decrease property values.

It should also be noted that hedonic models express only the benefits associated with housing. Excluded are recreational benefits by others than residents in the area. The residents may not be aware of other benefits such as rainwater and erosion control. Therefore, the approach capitalizes only a portion of urban forest benefits to nearby properties and the method gives just a minimum value for the areas.

Use of Economic Estimates from CV Studies

The next examples demonstrate the use of economic estimates derived form CV studies. The cases deal with urban fringe woodland and therefore it is relevant to compare the amenity value of the areas with timber production benefits. In this analysis information on forest stock (inventory data) and timber values is needed. On the cost-side information on annual maintenance costs of vegetation and recreation facilities is required. Moreover, the costs should include opportunity cost of land, i.e. reduction in timber values due to management adjustments such as prolonged rotation period and small-scale management units required by the recreational use. In the Nordic countries, usually the loss of timber production value in recreation areas compared to commercial forests is between 10–30% (Tyrväinen 2001). On the benefits side, the aggregate amenity benefits can be estimated by calculating the average WTP of users and multiplying this by the total number of consumers.

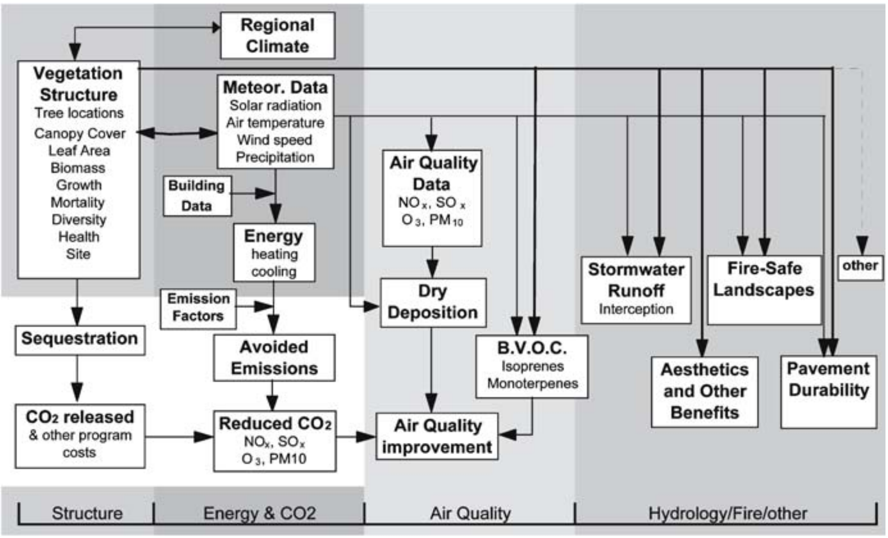
Tyrväinen and Väänänen (1998) estimated the present timber value of the study area (46 ha) in Joensuu, Finland to be €0.19 million and the residents' total WTP for keeping it in recreational use was €1.38 million (1997) using a 5% interest rate. On this basis the amenity value of urban forests was 7.3 times higher than the value of the area in timber production. It has to be kept in mind, however, that the recreational use of the area does not completely exclude timber production, but rather decreases the received economic benefits and vice versa. Furthermore, Tyrväinen (2001) also showed in a comparative study that amenity benefits of various recreation areas in two study towns were clearly higher than their current management costs. The estimated aggregate recreation value was 7 to 26 times higher than the total costs of providing recreation services in the area depending on their characteristics, management and use intensities.

Moreover, the infill of existing housing areas may lead to a considerable loss of amenity benefits of urban forests experienced by the local residents. In the study of Tyrväinen and Väänänen (1998) people were willing to pay most for the green space where the development scenario meant condensing the housing area. The aggregate total WTP for preserving this urban forest was €1.38 million. It exceeds the value of similar size, unimproved land area by €120 000. This sum can be used to cover the increased costs of infrastructure when building elsewhere, for example, at the urban fringe. This example suggests that infill of present housing areas is not always worthwhile from the point of view of society, if the losses of green-space benefits are taken into account.

Valuing Benefits of Street and Park Trees

Recently, some large research projects, most of these undertaken in the United States, have studied the benefits of the urban forest, for instance to improve urban climates and abate air pollution (McPherson 1994). American Forests, a non-profit citizens' conservation organization, has developed a geographical information system, which allows rapid assessment of the benefits of trees on urban green space (CITYgreen 2003). This kind of information system informs planning and decision-making on the role trees and woodland play in the urban environment.

CITYgreen is a GIS-based software product, which has been used to analyze the local ecosystem and to calculate the benefits from urban forestry in Garland, Texas, United States. Ten sites were selected to represent a broad spectrum of land use and land cover, including single family residential, commercial and industrial sites. The main problem in the town was storm-water management. The computer software package calculated the effects of urban tree cover and impervious surfaces on forest health, air quality, carbon sequestration, energy use and storm-water runoff. An important characteristic of the software is the ability to put dollar values on all these effects. The software can calculate the financial benefits from tree cover (compared with a zero tree cover situation).



Conceptual approach to modeling urban forest benefits. Information on vegetation structure is primary input for modeling functions such as energy savings, atmospheric CO_2 reductions, air quality improvement, stormwater runoff reduction, aesthetic and other benefits.

Fig. 4.9. Conceptual approach to modeling benefits or street and park trees (McPherson and Simpson 2002)

A study by McPherson and Simpson (2002) analyzed the benefit–cost ratios of street and park trees in two cities, Modesto and Santa Monica in California, United States. The approach considered functions such as energy savings, air quality improvement, storm-water runoff reduction and atmospheric CO_2 reductions and aesthetic benefits (Fig. 4.9). The estimated benefits of trees were 1.85 to 1.52 times higher than the actual costs. The aesthetic and other benefits accounted for a large part, 50–80% of total benefits, while pruning accounted for half of the maintenance costs.

4.5 Conclusions

Nowadays, urban woodland and parks in or in the vicinity of large cities serve as areas for recreation and entertainment, as well as space for biodiversity to compensate for the built parts of the city. It is therefore important to emphasize the multifunctional use of trees, green spaces, parks and woodland and draw the attention of city dwellers towards the maintenance of biodiversity, of plant succession and the dynamics of low-cost ruderal places. This may allow them to develop a more conscious attitude towards nature in their immediate surroundings. In this context, more research will have to be done on how wilderness is perceived and accepted or demanded by urban dwellers. So called 'loose-to-fit' green spaces, where people can participate to design public green space according to their own taste and recreational preferences will have to be given more attention. Increasing maintenance costs of intensively managed parks with flower beds and urban woodland with a neat infrastructure will favor a trend towards low-cost greens.

Most of the research on the recreational function of urban green space has not yet been translated into generally accepted practical guidelines and criteria, or into other types of policy and management instruments. Partly this is due to the normative content that is almost inherent to such guidelines and criteria: they fall within the domain of the policy-maker as much as within that of the researcher. Suitable guidelines and criteria depend on the goals that have been set. What is an adequate local supply of outdoor recreational opportunities measured both quantitatively and qualitatively, however, is still unclear. Although a start has been made (see e.g., Van Herzele and Wiedemann 2003), more work remains to be done before empirically founded policy making and planning with respect to urban greening is put into practice.

In the future, a comprehensive picture about the perception and acceptance of trees should be obtained. Today, there is considerable loss of trees in urban areas due to pollution, vandalism, traffic damage, use of de-icing salt, storm events, lack of adequate space to grow and over-aging. Substantial research on these topics has been done representing a need and strength of the technical and green-space management sciences. Economical valuation studies have brought about many valuable insights into the benefits and costs of urban green spaces and their management at the end of the 20th century that was previously not available.

There is also an increasing need to define and promote the socially integrative potential of woodland, parks and trees and to integrate people with specific needs and demands. Parks and woodland areas at the peri-urban belt of large agglomerations are important social meeting places for elderly people, youth, ethnic minorities of different cultural background and disabled citizens, to mention only a few. The role of cities as focal points of cultural life has been supplemented by providing their inhabitants with green spaces designed close to nature. Multicultural residential areas showing a preference for certain tree or other plant species and outdoor amenities are particularly important.

The results from various research studies stress the importance of the quality of the near-home environment and encourage the maintenance and establishment of new green areas near homes. Economic valuation studies indicate that on social grounds urban forests are a cost-effective concept. Although there is increasing evidence also of the environmental benefits of the urban forest, most of this evidence is gained indirectly, for instance more generally investigating the urban climate and the role of green space therein. There are few studies in Europe on the environmental performance of forests, and the different advantages and disadvantages of spatial forest patterns and types of tree plantings. The information available is mostly limited to a few urban areas; there is a significant lack of comparative information of cities across Europe. There can be little doubt that the environmental functions and benefits of the urban forest will vary widely between cities in southern, central and northern Europe, depending on regional climates, the specific structure of the urban forest (Chap. 3) as well as local needs. Yet, until now these differences have not been explored. As a consequence, there is a lack of guiding principles for urban forest planning specific to the different regions of Europe.

The particular challenge for the future will be to establish links between the environmental, social, economic and aesthetic functions of the urban forest, for instance to assess how mitigation of heat island effects and the improvement of air quality are related to human health. This agenda has only recently become addressed (NUFU 1999, 2002) but there is still a significant lack of information. Collecting this information will support the development of urban forest policies on a strategic level and the setting of clear targets for provision of trees and woodland in urban areas.

In many countries innovative means to raise public awareness and also funding for management and establishment of green areas are needed. Concretizing the amenity benefits of urban forests and trees through various types of research contributes to raising the decision-makers awareness of the consequences land use alternatives and compact city policies. Moreover, this will produce more information on the benefits that people actually receive from various types of green areas for practical planning. The amount and quality of urban forest is, in the end, a political question and a matter of whose interests are to prevail in decision-making. Given many residents' high appreciation of urban forest benefits, it is worth to fully account for urban forest benefits and elaborate more detailed criteria for green-space development in European cities.

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Part II Planning and Design of Urban Forests and Trees