Carrying Capacity - An Old Concept: Significance for the Management of Urban Forest Resources

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Abstract

In most countries, urban forests have been mainly used for recreation, at least, during the last 30 to 40 years. The information on the actions to be taken to prevent these problems is related to the concept of carrying capacity - a basic issue in resources management - that is the link between demand for outdoor recreation and supply of recreational opportunities. A great many definitions have been proposed, but four approaches are clearly recognised; ecological, sociological or perceptual, physical, and economic carrying capacity. The concept is multidimensional, and it is used as a planning and management framework. It can be judged only against the management objectives for a specific area. Urban forests are the first recreation resources that accept pressure from the city and town dwellers, thus the need to organize management around the capacity idea is essential. The relevance of the concept to that of sustainability adds to its value. The review revealed a limited research work on the various aspects of carrying capacity. Feedback with reliable research information is essential to sustain the urban forest resources and their benefits over the long term.

Résumé

Ces 30 à 40 dernières années, l'utilisation principale des forêts urbaines dans la plupart des pays est la récréation. L'information sur les actions qu'on doit entreprendre pour prévenir ces problèmes est liée au concept de capacité de charge - une question majeure dans la gestion des ressources – c'est-à-dire la connexion entre la demande de récréation en plein air et l'offre d'opportunités de récréation. On a proposé de multiples définitions, mais quatre approches peuvent essentiellement être cernées: la capacité de charge écologique, sociologique ou perceptuelle, physique et économique. Le concept est multidimensionnel et il est utilisé comme un soubassement de la gestion. Il peut être évalué seulement par rapport aux objectifs d'aménagement de la zone spécifique. Les forêts urbaines sont la première source de récréation et elles sont exposées à la pression des citadins. Par conséquent, il est nécessaire d'axer l'aménagement sur la notion de capacité. La pertinence de ce concept par rapport à celui de durabilité en augmente la valeur. Notre étude montre que la recherche sur les diverses aspects de la capacité de charge est limitée. Voilà pourquoi il faut intégrer toutes les informations disponibles pour soutenir les ressources des forêts urbaines et garantir leurs bienfaits à l'avenir.

1. Introduction

Human life depends on healthy ecosystems, which supply life-sustaining resources and absorb wastes. The industrial revolution stimulated the greatest human migration in history. This migration is still in the process of transforming many parts of the world, through the mass movement of people from farms and rural villages to cities. The seeming abandonment of the countryside is creating an urban world. Eighty per cent or more of the people in some so-called industrialized countries now live in towns and cities (Rees, 1996).

Urban forests are significant and complex ecosystems with intricate links among their physical, biological, and social components, as well as with other elements of urban and natural resource systems. Urban forests are also dynamic systems strongly influenced by the relatively slow growth and development of trees in the context of rapidly changing urban environments. To sustain forest structure, health, and benefits throughout urban ecosystem over the long term, comprehensive and adaptive management approaches are needed. The management of urban forests has important implications for the health and well-being of the residents of urban and urbanizing areas, with its influence extending well beyond the boundaries of urbanizing areas (Dwyer et al., 2000).

The main land-use of urban and forests in most countries at least during the last 30 - 40 years has been recreation, due to factors such as more leisure time, higher income and greater mobility.

The increased participation in recreation has caused concern among planners and managers of these forests, which stems from the evidence that recreational use causes damage to the resource and from the consideration that increasing demand results in possible visitor dissatisfaction. Information, therefore, is sought on what action should be taken to prevent these problems. This kind of information relates to the concept of carrying capacity, which is the link between demand for outdoor recreation and supply of recreational opportunities.

2. Evolution of the concept of carrying capacity

Carrying capacity is a basic issue in resources management. It has a biological origin and it has been strongly linked with the concept of sustained yield. It is not a new concept. For example, between the 13th and 16th centuries Germany regulated timber cutting and thereby introduced sustained yield (Bernhagen, 1974).

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In traditional ecological usage, carrying capacity is a complex concept broad in meaning, but it can be defined in a general way as the total number of individuals of a species that can live in an ecosystem (or habitat) under certain conditions (Knight, 1965). The "certain conditions" causing the complexity include individual, population, and environmental interactions and feedback mechanisms.

In range management and game management, the term has come to mean the number of a species the environment can support on a sustained yield basis (e.g. number of cattle per Ha per year). It has been given quantitative expression in such widely varying environments as the moorlands and crofting areas of Scotland and the "public" rangelands of western U.S.A. (Tivy, 1972).

Carrying capacity has also been inherent in man: land ratios, defined in subsistence economies as "the maximum number of people that a given land area will maintain in perpetuity under a given system of usage without land degradation setting in" (Allan, 1949). There are, however, other contexts in which carrying capacity has been used. It has been used to refer to the ability of foundations, materials or structures to accommodate a given load, in terms of either weight or volume and to the numbers of cars a freeway can carry smoothly. In zoning terms carrying capacity is easily determined as, for example: one house for every residential zone unit, one car for every three customers in the store, one parking space for every three seats in the restaurant, and enough impervious road surface to access the properties, etc. In recreation planning and management, carrying capacity has received much attention only since the 1960's, but the concept is much older. Ohmann (1973) states that overcrowding in National Parks in the U.S.A. and consequent loss of wild land values were noted in the 1930's by Adams (1930). He also notes that Wagar (1964) recognised the same concept in the restriction of hunting rights to the nobility during the reign of Charlemagne (768 – 814 A.D.).

As early as 1960 the Californian Public Outdoor Recreation Plan stated as one of its basic hypotheses "that each recreation resource type within a region has a maximum user carrying capacity (number of users per acre per day and season); when used beyond this capacity the character and quality of the resource are altered or destroyed". Within the U.S. Forest Service research workers had by 1964 struggled to define and assess the implications of the concept of carrying capacity for either recreational land or wilderness areas. Wagar (1964) defined recreational carrying capacity as "the level of recreational use an area can withstand while providing a sustained quality of recreation". Lime and Stankey (1971), taking earlier attempts at defining recreational carrying capacity into account, defined it as ".... the character of use that can be supported over a specified time by an area developed at a certain level without causing excessive damage to either the physical environment or the experience of the visitor".

Recreational carrying capacity has been the subject of study by scientists from different disciplines. Geographers, sociologists, psychologists, economists, foresters, biologists and engineers have been dealing with the problem. As a result, a great many definitions have been proposed each reflecting the background of its author.

In international bibliography, four approaches to carrying capacity are recognised. One is an ecologically determined capacity (ecological carrying capacity). _ second one is a sociologically or perceptually determined capacity (social, perceptual, psychological, aesthetic carrying capacity). _ third one is the planner's approach (physical carrying capacity), and a fourth one is the economist's approach (economic aspects of carrying capacity).

A frequently used indicator to assess the price competitiveness of a country's foreign trade is given by the relationship between export prices and import prices, expressed in the same currency, known as the exchanging price ratio. For the purposes of this study, the following formula has been adopted to express the price ratio between Turkey and the EU:

3. Ecological carrying capacity

Ecological consideration of carrying capacity determination includes the impact of recreational activities upon the environment. Ecological studies have been concerned mainly with the need to prevent or limit damage to natural or semi-natural habitats that may include areas of great intrinsic ecological interest, while still allowing some limited, or at least controlled, recreation use. These enquiries adopt a practical approach to specific ecological problems, and many conclude by drawing up a series of recommended management proposals for the area studied. In doing this, the existence of a capacity figure is implied, this capacity representing the desired level to which use should be limited according to each author's individual set of priorities. In these ecologically oriented studies, the figure is related to the level of ecological change and physical damage associated with a given level of recreational use (Burton, 1974).

The problems to be solved when making any estimation of ecological carrying capacity are: (1) to understand the nature of recreational use and its distribution in space and time; (2) to understand the nature of the ecosystem with which recreation use interacts; (3) to quantify the amount and type of recreation use which will bring about an unacceptable degree of change; (4) to define what constitutes an unacceptable resource state. The last one is an evaluative decision and the question arises as to whose values must prevail. Brotherton (1973) has answered this question considering the primary land use of the area. He points out: "Even in the unlikely event of two areas having precisely the same ecological conditions, different criteria will be needed to determine acceptable ecological

change if primary land uses, which determine the overall management aims, are different".

Planners and managers of recreation areas want to know from ecologists the amount of change that will occur under specific levels and types of use and they require advice on the level of change which, from an ecological viewpoint, could be regarded as acceptable in different habitats which are used for recreational purposes.

Work by ecologists relating to carrying capacity and making contributions to satisfy the needs of planners and managers, has been mainly of four kinds: (i). descriptive work of the impact of recreational activities upon the environment; (ii). work relating quantitatively the effects of recreational pressure in field situations; (iii). controlled experimental work on the effects of trampling (in the field or laboratory); (iv). work on the recovery or recolonisation of damaged sites.

Ecological studies have undoubtedly contributed towards a better understanding of the effects of recreational use upon different ecosystems. Foci of recreational activity are the first parts of an area to be affected, and can be used to forecast changes likely to occur elsewhere in the event of increasing intensity of use. Speight (1973) has comprehensively reviewed the literature up to 1972 on the ecological effects of outdoor recreation in natural/semi-natural areas.

Burton (1974) states that the most obvious results of recreational use appear to be a decrease in the height of the vegetation, a decrease in the number of species present and a marked increase over the normal percentage of bare ground.

In Poland, Kostrowicki (1970) applied geobotanical methods in appraising fitness of areas for purposes of recreation and rest. He gives an index of the maximum number of people who for eight hours might be permitted to move about freely without causing irreparable damage to the vegetation cover.

In Finland, Kellomaki (1973) carried out experiments on the trampling tolerance of forest vegetation in a Myrtillus site type, using a trampling simulation method. He based the trampling estimation on coverage and biomass determination and found that trampling tolerance of the bottom layer of vegetation is greater than that of the field layer, and grasses and dwarf scrubs have a higher tolerance capacity than herbs. He states that despite certain deficiencies, the simulated trampling gave parallel results to those obtained from real trampling.

In another study (Kellomaki 1977) he investigated the trampling tolerance of forest ground cover of the Calluna, Vaccinium and Myrtillus site types and found positive correlation between the site fertility and trampling tolerance of plant communities. Annual trampling at a level of about 16,000 visits per hectare decreased the biomass of the ground cover to almost half the original amount, and annual trampling of about 160,000 visits per hectare completely destroyed the forest ground cover irrespective of site fertility. He states that comparisons made between herb and grass cover showed that herb and grass cover is in the long run the best alternative for the management of ground cover in intensively used recreation areas.

Recent research, again in Finland, has among its objectives the production of information about the minimum size of ecologically sustainable forest patches, and the ecological effects of fragmentation and consequent increasing recreational use on vegetation and forest structures. Furthermore, the knowledge derived from this research on the effects of trampling on different types of urban forests (different biotopes, site types, soil fertility etc.) can be used to predict the susceptibility of various kinds of forests and biotopes to trampling. This information will be included as variables when developing methods that will take forest biodiversity into consideration in the best way in the planning procedures (I. Löfström, pers. comm., 1999).

4. Perceptual carrying capacity

Sociological factors limiting carrying capacity are those dependent on the attitudes or social behaviour of recreationists that is on the characteristics of the visitors.

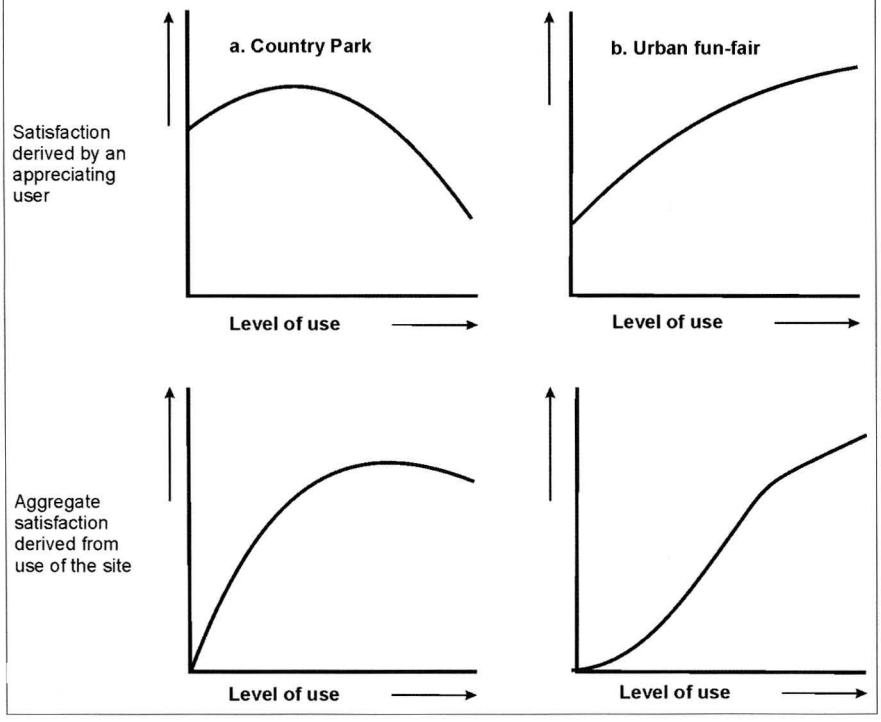
Perceptual carrying capacity has been defined as "the maximum level of recreation use, in terms of numbers and activities, above which there is a decline in the recreation experience from the point of view of the recreation participant. Different users could have a different view of the perceptual capacity of the same area according to their activity" (Countryside Recreation Research Advisory Group, 1970). In much of the existing research work, the concept is related to the effect of crowding on the level of satisfaction derived by the recreationist from the use of the recreation areas.

Tivy (1972), in her review on the determination of recreational carrying capacity in the U.S.A., reports that social limits to carrying capacity are dependent on a variety of characteristics and mentions a few of them, such as age group, income levels and educational standards.

Brotherton (1973) gives curves, which relate the satisfaction derived by an individual at different situations (types of recreation use, such as country park, fun fair) to the level of use (Figure 1), and argues that, since all individuals do not have the same reaction to crowding, in order to determine the aggregate benefit derived from the use of each type of area the individual satisfaction curves should be plotted. It seems reasonable to take the levels of recreation use that maximize aggregate benefit to participating individuals as the perceptual capacity.

Veal (1973) sees perceptual carrying capacity as contributing to the recreationist's decision-making - on whether to enter, visit, leave or move about in a recreation site - and as contributing to his enjoyment of or satisfaction with, the recreation experience. He also points

Fig. 1 *Satisfaction curves derived from Brotherton*



out (Veal, 1974) that for most users of most outdoor recreation sites it is likely that increasing numbers of other users leads to reduced satisfaction. But it should be borne in mind that for many recreation activities, increasing numbers of other participants, up to a certain level, increase satisfaction. Examples are fairgrounds and most spectator or audience events.

Recent research in the Urban National Forests of California (USDA Forest Service, 2001a) revealed that at some sites in these forests there are so many visitors that sites are closed to additional visitors who where hoping to recreate at those sites. One area, located on the Angeles National Forest in southern California, is frequently closed to additional visitation because of the crowded conditions. Data were collected from visitors to this forest in order to learn more about recreation patterns and the preferences of visitors for handling crowded conditions. Managers must consider all the options available to them including teaming with other agencies and groups to serve the populous and diverse southern California.

5. The planner's approach to carrying capacity

Planners need capacity estimates that will guide them in their effort to achieve the goals set for a specific area. It appears to have become accepted among many planners that once capacity standards have been defined, the process of relating demand and supply of resources will become a more straightforward task than without the use of any standards (Burton, 1974).

Physical capacity figures are found in outdoor recreation literature and recreation management and development plans but they have little or no scientific basis. They have mainly been decided by trial and error because of the difficulties inherent in any objective assessment of carrying capacity.

Most standards of capacity have been based on American experience and particularly related to intensive use of land and water in managed recreation areas. In a 1959 nationwide survey of recreation resources in the U.S.A., the Forest Service attempted to develop guidelines by which the capacity of recreational areas could be estimated. Efforts were directed at creating "converting factors" which represented the acreage of a recreation resource needed to satisfactorily accommodate one man-day for that resource. In response to the growing demand for assistance in the establishment of "space standards" that could be used by planners, the Bureau of Outdoor Recreation published a survey of Outdoor Recreation Space Standards in 1965, which was revised in 1967. It included the most reliable and comprehensive examples of guidelines currently available for use in providing adequate recreation areas and facilities. It lists acreage: population ratios recommended by a variety of private and public agencies for facilities in certain types of areas and for different types of activity. The Wisconsin Outdoor Recreation Plan of 1966 also lists four though not mutually exclusive types of standards: design standards, use standards, health and sanitation standards or codes, facilities standards or acres per unit of population (Tivy, 1972).

In the U.S.A. again, the National Recreation and Park Association (2001) recognizes the importance of establishing and using park and recreation standards as:

- A national expression of minimum acceptable facilities for the citizens of urban and rural communities.
- A guideline to determine land requirements for various kinds of park and recreation areas and facilities.
- A basis for relating recreational needs to spatial analysis within a community-wide system of parks and open space areas.
- One of the major structuring elements that can be used to guide and assist regional development.
- A means to justify the need for parks and open space within the overall land-use pattern of a region or community.

The purpose of these guidelines is to present park and recreation space standards that are applicable nationwide for planning, acquisition, and development of park, recreation, and open space lands, primarily at the community level. The standards should be viewed as a guide.

Table 1. *Examples of carrying capacity standards*

N	Resource and/or activity	Capacity standards	Source
1	Detroit parks around fringes	10 persons/ acre	Patmore (1970)
2	a. Family picnicking	4 – 8 family units/acre	Smith and Matthews (1972)
	b. Group picnicking	10 – 25 units/acre	
3	a. Grassy areas in parks	100 - 200 persons/ha	Sidaway (1974)
	b. Forest area of park	10 - 20 persons/ha	
4	Static holiday caravan sites	60 – 75 caravans/ ha	Spon Ltd (1974)
5	a. Park areas near cities	40 persons/ha	Heytze (1976)
	b. Pinewoods or moors outside urban areas	3 persons/ha	
6	Carriage roads of Acadia National Park (USA)		Jacobi and Manning (1999)
	a. A two-hour visit in the peak zone	Visitors should experience no more than:	
		2 bicyclists travelling at excessive speed	
		2 bicyclists passing from behind without warning	
		1 visitor obstructing the road	...cont/d
		2 dogs off leash	...cont/d
	b. A two-hour visit in the no peak zone	Visitors should experience no more than:	
		1 bicyclist travelling at excessive speed	
		1 bicyclist passing from behind without warning	
		1 visitor obstructing the road	
		0 dogs off leash	
	b. A two-hour visit in the no peak zone	Visitors should experience no more than:	
		1 bicyclist travelling at excessive speed	
		1 bicyclist passing from behind without warning	
		1 visitor obstructing the road	
		0 dogs off leash	

In Holland absorption capacity standards have been established based on the assumption that the various environments to which the standards refer retain their potential properties. These standards are expressed in terms of number of persons per hectare of park areas near cities, pinewoods and moors outside urban areas, etc. (Heytze, 1976).

In Britain, Hockin et al. (1977) gathered information on the minimum physical standards required by a number of outdoor recreation activities (minimum user requirements) and on the possible constraints of each activity. The requirements serve as design standards to guide the development of a site for local recreation purposes in terms of the space needed, layout, number and type of facility required.

There is no doubt that capacity standards are valuable to planners and managers and should be used when practicable. But it is evident that they have only local value. In a repetitive landscape or in relation to sports facilities, it is possible to arrive at standards that can be applied from one place to another. But landscapes are rarely repetitive, so each site must be evaluated individually to determine its capacity.

Urban forests are mainly for people, so planning professionals must integrate the art and science of management of this kind of forests in order to balance the various resource values. Carrying capacity standards related to urban forests can be found in many sources, such as Patmore (1970), Smith and Matthews (1972), Sidaway (1974), Spon Ltd (1974), Heytze (1976), Jacobi and Manning (1999), and some selected examples from these sources are presented in Table 1.

6. The economist's approach to carrying capacity

Economists seem to have approached carrying capacity in various ways. Brotherton (1973) states that economic capacity relates to situation of multi – purpose usage (recreation plus some other land use), and depends upon the economic interaction between different intensities of two or more uses on the same site. It can be viewed as defining the intensities of the different uses at which maximum aggregate benefit accrues from the use.

Bury (1976) explains how financial carrying capacity could be viewed: financial capacity may be the point at which management cost per visitor served begins to increase markedly. If accurate cost records for development and operation are available this point can be determined rather well. Alternatively, financial carrying capacity might be set as that number of visitors that can be accommodated with the approved level of program funding under accepted criteria for maintenance and operations. Or it could be the point at which income from visitor fees would equal costs plus reasonable profit – or it might be the point at which the cost of minimizing adverse environmental impacts begins to rise steeply.

In an urban context, economic aspects of carrying capacity have found application, where optimal levels of use take into account the distribution of benefits and costs to resident populations (Canestrelli and Costa, 1991).

Recent research related to economic aspects of carrying capacity and organized around the concept of Sustainable Urban Ecosystems, includes the Cooperative Regional Research Project in the USA (USDA Forest service, 2001b). In this project "sustainable urban ecosystems" are defined as landscapes that are designed and managed to minimize impact on the environment and maximize the value received for the money expended in the long term. The main objectives of this study focus on the benefits, costs, and sustainability of ecosystems, including: identification, designation, and promotion of practices that maximize net benefits and minimize adverse effects on urban

vegetation; the use of regionally native plants for landscaping; and the development of demonstration and extension projects.

7. Other approaches to carrying capacity

Burton (1974) introduces the term landscape capacity and states that it could be defined as the ability of the landscape to absorb recreational use. There are landscapes that may be very intensively used (in terms of people or cars per acre), but, because of their physical characteristics, they may not appear to be so; in such landscapes a relatively low number of cars or people can be seen at any time. On the contrary, there are landscapes that could appear relatively intensively used, even though the actual level of use was low. Most forest, woodland and scrub environments could be classified as high-capacity landscapes, whereas open woodland and down land are low-capacity landscapes.

Related to the above aspect of carrying capacity is the environmental capacity mentioned by Patmore (1970), and Harding et al. (1972), and defined as "the maximum number of cars/persons that a site may carry without detracting from the visual amenity of the area".

8. Conclusions

All aspects and approaches mentioned above are integral parts of the capacity idea, which has not an absolute value, and there is no generally accepted approach of how it should be determined. The criteria for defining carrying capacity are very subjective and vary from location to location depending upon the sensitivity of the resources, and differ from individual to individual based upon their own expectations. Carrying capacity is a multidimensional concept, which is used as a framework around which recreation planning and management are organised.

The bibliographic and other work presented in this paper leads to the following main conclusions:

- Carrying capacity is a complex concept. It relates to many aspects of use in addition to numbers of users.
- Carrying capacity can be judged only against the management objectives for a specific area. Without explicit and specific management objectives, carrying capacity is an elusive notion.
- Apart from management objectives two other factors are equally important. These factors are the impact on the physical resource and visitor attitudes. All factors are equally important but their significance varies from one opportunity to another.
- The physical extent of an area and economic considerations have also been identified as factors affecting the determination of carrying capacity.
- Carrying capacity is a management system directed toward maintenance or restoration of ecological and social conditions defined as acceptable and appropriate.

Urban forestry is an essential and highly valued component of large-scale, long-term environmental and community sustainability. In developing management programs to maintain the resource and enhance important forest benefits, the diversity, complexity, connectedness, and dynamics of urban forests must be considered. These features have an array of management implications, particularly regarding the scale of policies and programs, types of management activities, duration of efforts, and links with a wide range of urban initiatives and individuals and groups involved in the planning and management of urban forests (Dwyer et al., 2000).

Urban forests are the first recreation resources that accept pressure from the city and town dwellers, almost every day, which reaches its peak during the weekends and bank holidays. The need therefore to organize management of these forests around the capacity idea is necessary.

The relevance of the concept of carrying capacity to the concept of sustainability adds to its value as an organizing management framework. Implementing the sustainability concept, environmental values should not be used up faster than they are produced. The capability of the resource base to continue to provide for recreational use is generally viewed through the concept of carrying capacity (Papageorgiou and Brotherton 1999).

In a European context, management of urban forests for carrying capacity means management that it is in accordance with the resolutions on sustainable forest management, use and protection of forests, and on the conservation of forest biological diversity of the Helsinki Ministerial Conference on the Protection of Forests in Europe, as they appear in the Progress Report of the Conference, published by the Portuguese Ministry of Agriculture, Rural Development and Fisheries in 1996. In this report sustainable forest management is defined as the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems.

To facilitate comprehensive and adaptive management to help sustain the entire urban forest ecosystem, the following topic areas need to be emphasized in the years ahead (Dwyer et al., 2000):

- Improving inventory and monitoring
- Improving dialogue among owners, managers, and users
- Fostering collaboration among agencies and groups
- Improving the understanding of how forest configurations influence forest use and benefits
- Increasing knowledge about factors that influence urban forest health
- Improving dissemination of information about urban forests and their management.

As urbanization continues and urban populations in-

creasingly dominate the social and political structure of many countries, understanding and managing urban forest resources will be a critical mechanism for connecting people with ecosystems.

Choosing the best management approach involves judgment and is dependent upon good information about desired conditions, current conditions, and the consequences of alternative management actions. Attention should be focused on critical problems at specific locations, and the public should be involved throughout the planning process. Monitoring is necessary to provide feedback to periodically modify management actions or, in some cases, standards or objectives. By carefully organizing management of urban forests within the framework of carrying capacity, managers should be able to avoid restricting and regulating visitors when and where it is truly necessary.

At the European level, and internationally, research on the various dimensions of carrying capacity is very limited. As an organizing framework for recreation planning and management, it needs feedback with reliable information derived from research. In this respect, investigating even selected aspects of carrying capacity would be very useful.

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