Ecosystem Services Provided by Urban Vegetation: A Literature Review

Christiane Weber and Lotfi Medhi

Abstract Since the blossoming of environmental awareness in the 1970s and the emergence of sustainable development, the interest of development of urban vegetation and green spaces has increased tremendously. New disciplines and approaches, following the example of ecology and urban forestry are emerging in particular to assess the ecosystem services provided by vegetation in urban areas. This research takes place into a large project on Greening spaces in urban areas and especially on the ecosystem services provided by vegetation and the effects upon atmospheric pollutants and air quality. A specific objective has been to identify and characterize these urban ecosystem services over the past decade. Among 200 scientific literature papers, 170 have been selected to identify ecosystem services that are the most studied, according to pre-established criteria a database has been created to identify the predominant characteristics of these studies. No fewer than 55 ecosystem services were identified as the principal focus of the research work or simply mentioned. The effect of vegetation on air quality (pollution) appears to be the major ecosystem services studied during the last decade in various disciplines.

Introduction

Nature's Services, the book directed by [4] and the publication in Nature of Costanza *et al.* publication "*The value of the world's ecosystem services and natural capital*" in 1997 [5] correspond to the publications often noted as important milestones in the emergence of the notion of ecosystem services. Indeed these publications attempt to identify and measure the role of nature and its ecological functions, for both, determine a baseline for the degradation of ecosystem services provided by nature towards society [5], and develop a systemic approach of a "natural capital" into various dimensions [4]. The ecological hypothesis used here, as "the existence of a

C. Weber (✉) · L. Medhi
Laboratoire Image, Ville et Environnement (LIVE) UMR 7362– CNRS, Faculté de Géographie et d'Aménagement, 3 rue de l'Argonne, 67000, Strasbourg, France
e-mail: christiane.weber@live-cnrs.unistra.fr

L. Medhi
e-mail: lotfi.mehdi@live-cnrs.unistra.fr

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degree of replacement or substitution of such services", appears in fact earlier in the SCEP study (Study of Critical Environmental Problem) in 1970. "Environmental services" was used for the first time in this report, for the UN conference on "human environment" in 1972; it introduced the concept of ecosystem services recognized as a semantic tools to identify the impact of human activities on the biosphere "*The gradual decline in ecosystem function brings with it a decline in services for man*" (p122). The ES concept has been institutionalized acquiring an universal vocation all through the process leading to the publication of the Millennium Ecosystem Assessment (MEA) in 2005 [14]. Later the TEEB study (the Economics of Ecosystem and Biodiversity, 2007) initiated by the UN and European commission focused on the economic consequences of biodiversity erosion and the necessity of protection or conservation of various species. This report claims the integration of economic values of biodiversity and ES provided by ecosystems in territorial decision-making. Since this period Ecosystem Services have been considered mainly through economic values, actually cultural or ethical values are envisioned to complete the evaluation panel.

The increase of urban population and urban sprawl transform definitely the landscape through fragmentation of natural habitats, expansion of imperious surfaces, negative outcomes of human activities etc. inducing strong pressures over environmental systems. Urban ecosystems have been compared [18] to "*parasites in the biosphere*" but they are also part of a global system equally biological, social, built and geophysical. As such the Ecosystem Services (ES) generated by urban ecosystems have a crucial importance for urban quality of life of citizens e.g. providing beside usual maintenance processes (physical, chemical and biological), resources (wood, fiber, air, water), regulation (climate, air quality, soil maintenance, extreme event moderation…) and cultural (traditional knowledge, recreation, tourism, ethical) services. Some of these benefits, such as vegetation's effects on air pollution or on urban pollution more generally, have already been the object of several studies [8, 15, 21]. In fact, an increase of articles from 200 to more than 1000, between 2004 and 2010 in several disciplines shows a strong interest [20]. Another point that might be pointed out is the scale of the ES, locally generated [2] they may provide a solution to deal with local problem such as those due to traffic. This might be considered as a key in local decision-making processes.

Among the urban ES the most often cited by citizen and local authorities in Europe, the vegetation is the one associated to a strong effort done by municipalities. Looking backward throughout the XVIII to the XX centuries, vegetation has been considered in various status: for Victorian philanthropists and humanists ideals vegetation is considered as an integral part of city development process, filling the needs and welfare of citizens (fresh air and refuge to alleviate the consequences of the industrial age). City planners in the XIXe introduced the concentric model of towns establishing the "Green belt" to define cities boundaries, and in the XXe, E. Howard moved further with the "Garden City concept" inducing communities connected with livable residential areas where green spaces are the support of healthy living conditions and social and cultural activities. The Charta of Athens (1933) has amplified the zoning processes towards modern and functional cities, greens spaces

being considered as an aesthetical choice accompanying the construction of collective housings.

Thus for several decades, new status have been attributed to urban vegetation without assessing really their impact on ecosystem dynamic or human/natural interactions. At the same time, urban decision, planning design, and management procedures have ignored numerous vegetation functions [6, 8, 9]. Due to the interest of the international community for biodiversity and local aspiration for "nature" in cities, the status of vegetation has changed one more time, becoming a valuable ecological good [13]. It is therefore interesting to deepen the questions related to the role of urban vegetation, requiring research based on relevant information that can be understood and shared by scientists, professionals, and policy-makers [9]. It has indeed to be noted that the engagement of life science or environmental science researchers has appeared rather later than the one of social and humanities sciences [3]. Some domains of interest have been already studied: Health and social realm, ecological and environmental features, and cultural and patrimonial issues. Urban ecology discipline stresses especially the ecological processes within vast urban regions, considered as socio-biophysical complexes.

The objectives of this article through a critical review of scientific papers focused

The identification of the urban ES studied during the last decade by the scientist community and the approaches employed to assess these ES and the determination of the discipline the most involved and the reviews the most concerned;

For the most representative urban ES, an analysis of the benefits has been summarized and some perspectives enunciated. This investigation will provide some insights about the evolution of ES as a concept but also as a driver for the community of scientists and decision makers.

To set up the design of this study no exhaustive list of these services has been compiled, nor have the studies devoted to them or their disciplinary affiliations been elucidated in detail [8]. The difficulty in this type of exercise lies in the ambiguity of the key notions, for their meanings vary from one discipline to another [6, 10].

This article is divided in four sections. The first presents the conceptual framework of the study referring to the ES of urban vegetation; the second describes the methodological and analytic design adopted. The third section presents and develops the results of the analyses. And, the last section is devoted to a discussion of the results and of items to guide both further research into ecosystem services and their consideration by policy-makers.

Conceptual Framework

The concept of ecosystem services has emerged progressively, especially since the 1960s [5]. The definition of ecosystem service used here is the one proposed by Constanza et al. [4] further developed by Bolund and Hunhammar [2]: *ecosystem services are defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions"*. Daily [4] refers to these functions as ecosystem

services and defines them as those conditions and processes through which natural ecosystems, and the species that inhabit them, sustain and fulfill human life. More specifically, ecosystem services are defined by their contribution to human well-being, since they are end products of various ecosystem functions such as climate amelioration and recreation because they are enjoyed, consumed or used by humans. Ecosystem goods, a subset of ecosystem services, can be defined as tangible material products such as wood, fuel, or food that results from ecosystem processes [7].

The inventories of urban ES might be gather is several groups according to the number of ES identified: the Millenium Ecosystem Assessment [14], the Ministère de l'Ecologie, du Développement Durable et de l'Energie (France) respectively with 23 and 43 ES. Costanza et al. [4] identified and classified 17 of the principal ecosystem services. Some ES are defined especially for green areas: Bolund and Hunhammar [2] counted 6 ES, Nowak and Dwyer [17] 14 ES, Niemela et al. [15] 16 ES and Dobbs & et al. [8] 13 ES. Thus the number of urban ES is associated to the initial objectives of the studies and the values (financial or cultural) associated to the ES regarding the society references.

Methods and Materials

The global objective of the literature review attempts to catch the evolution of the urban ES concept and the characteristics of this evolution, especially for the ES provided by the urban green areas. A remark has to be done at this point. In the literature the notion of green areas stay rather "poor", since it designs particularly urban trees or urban forests. Few are attached to the singled tree; lawn and bushes are seldom mentioned.

Selection of Articles

To select the most pertinent articles a particular attention was given to keywords. They were intended to choose a representative sample of articles from the work done in this domain, work characterized both by its abundance and its heterogeneity. At the same time, a selection based only on a normative approach might be too rigid to ease the recognition of the functions studied. The "Image, Ville, Environnement" unit (LIVE- CNRS UMR7362) of the University of Strasbourg (France) has free access to various types of bibliographic resources: Databases: Francis, Pascal, Georef, ISI, Scopus, etc; Electronic periodical databases: Science Direct, SpringerLink, Revue.org; Catalogues: UdS[1] libraries catalogue, Sudoc[2], etc.

[1] Université de Strasbourg, http://www.unistra.fr/.

[2] Système Universitaire de Documentation, http://www.sudoc.abes.fr/.

Table 1 Variables used in the multiple correspondence analysis MCA

Variable	Meaning
Ecosystem services provided by urban vegetation	55 ecosystem services were identified. (Appendix 1, 1–16)
Discipline of first author	13 different scientific disciplines have been identified according to the first authors' discipline. We first listed all of the authors' disciplines and then grouped them in more general domains: biology, ecology (including botany), forestry (including urban forestry), geography, the environment (including climate studies, soil science, hydrology, etc.), urban planning and policies, landscaping (including architecture), sociology, agriculture, political science, economics and pharmacy
Year of publication	Most of the articles selected were published between 1999 and 2011. Nonetheless, 12 important articles published before 1999 were included in the data table
Journal	Journals were classified according to the number of their articles listed in the table
Country where first author works	The country of the first author affiliation has been considered

The key words used for this research were: linked to the urban ecosystem components: "urban", "city"/"tree", "vegetation"/"biodiversity" and to the benefices or the impacts of human activities: "pollution"/"well-being", "human health"/"ecosystem services". To refine and enlarge the sample, supplementary key words have been added regarding spatial information: such as "green spaces", "wooded areas", "urban forest"; other key words stamping the disciplines have also be used like "urban ecology", "urban forestry" etc. It is probable that some articles dealing with the topic of ecosystem services used other synonyms for the key ideas mentioned above. To fill this gap, several studies have been selected being identified in the references of the articles already selected to complete the lexical field. For the most part, these articles were published over the past decade [20]. Nonetheless, several earlier publications considered of particular interest were retained (Table 1). It was necessary to examine meticulously all of the elements developed in each article: questions addressed methodology, case study, results, etc. Finally, 170 articles over 200 were selected, including reports, dissertations and book chapters. These initial results allow identifying 55 ecosystem services provided by urban vegetation). According to the type of service chosen, some authors chose to study a single service, while others dealt with several. For this reason, two supplemental criteria were added; the first concerns the articles summarizing all of the services provided by vegetation, while the second considers a combination of variables related to the interaction with air quality only (see Appendix 1, 1–16). As indicated above, the principal constraint here lies in the variability of the meanings of the key ideas, according to the specific discipline considered, title reflecting more or less the content of the article.

Data Analysis

The information collected was dispatched in: scientific domain, country of affiliation of the first author, journal, year in which the article was published.

These choices allowed answering related questions such as: "Which of the ES characteristics are the most studied?" "What discipline is most dynamic in this domain?" "Is any country more active than others?" "What journals are most representative of this field?" "Are there any temporal variations in the appearance, disappearance or emergence of concepts?" To analyze all of the information collected, a multivariate analysis was performed to synthesize them and to evaluate the strong forms that emerged from the overall set. A multiple correspondence analysis [16] was run followed by an ascending hierarchical classification (AHC) in order to identify the groups maximizing intergroup variance. The statistical analyses were performed with Xlstat software (http://www.xlstat.com/).

Critical Review

The results are divided into two packages, one considering an external critical review highlighting the topics, the reviews or the authors and allowing pointing out the major trends, the efforts concentrated in various scientific areas and their evolution, the major reviews and so on. It is a way to envision the evolution and the fluidity of the scientific streams in this domain. The second package deals more about the content of the articles providing: the scientific research results obtained by the community and some operational features promoted in the papers to be transferred to decision makers.

Characteristics of the Selected Studies

Seven main themes came out of the 55 ecosystem services studied and/or mentioned (Appendix 1; the 16 first): air quality; links with soil and water quality; social well-being; landscape quality; economic services *per se*; urban planning; ecological balance and conservation. The preliminary results indicate that the effects of the vegetation on air quality, pollutants or energy are the objects the most detailed topics in the research projects. This may be explained essentially by both, the recent technical advances in this field, which allow deepen analyses and the growing interest in understanding the interactions between vegetation and air to help alleviate the effects of human activities and reduce the impact of emission on climate at various scales. Biodiversity but also green planning covers the remaining part.

Over the past decade, 2 years concentrate the highest numbers of articles published (2002 and 2006) respectively 17 and 24 articles, respectively). This trend is

confirmed by the study of Potschin and Haines-Young [8] on general ecosystem services.

Nearly half (44%) of the authors could be attached to environmental sciences. If we separate the life and earth sciences (environment, ecology, biology, agriculture, and pharmacy) from the social sciences (geography, urban planning and policies, sociology, economics, and landscape), authors from the first category account for at least two thirds of the total. That said, these results must be interpreted cautiously because the disciplinary frontiers remain fuzzy. Finally, *Landscape and Urban Planning* (31 articles) is the journal that has published the larger amount of articles in the field of ecosystem services (nearly 20% of all article), followed by *Urban Forestry & Urban Greening* (18) and *Environmental Pollution* (14). A little more than a quarter of all the articles were published in journals appearing only once on our list. This last information shows that even if an effort is still to be done in pluridisciplinary approaches, from planning and biology for instance, the reviews chosen privileged to diffuse the results are addressing a large scope of potential readers.

Scientific Results

Improvement of Chemical Air Quality

The studies have attempted to quantify and characterize the process of the elimination and fixation of chemical elements and atmospheric particles by the vegetation cover. Depending on the case studies, they have dealt with species selected in compliance with criteria set in advance (i) often trees and bushes: *Platanus x acerifolia Willd/Platanus racemosa Nutt/Populus nigra L, Pinus needle;* (ii) wooded areas, or (iii) urban green spaces (in their vast diversity). They are based mainly on experiments and measurements taken in the field, comparing plant and environmental data. It is difficult to generalize the results, because the effect of the species studied depends on the biotope in which they develop.

Improvement of the Physical Air Quality for the Well-being of Inhabitants

Numerous authors have tried to understand the mechanisms of the urban atmospheric processes, as affected by vegetation, especially through computer simulation. Some studies have neglected or even excluded from their analyses interactions between species and environmental variables, which may increase the gaps between the simulation results and findings in the field. Vegetation is even sometimes considered as an "inert" physical barrier in relation to urban atmospheric processes, as the built environment and some equipment also are. Other studies have looked at the role of vegetation cover both to diminish urban pollution (noise, smells, microbial germs, etc.) and to improve the well-being of city-dwellers (Fig. 1).

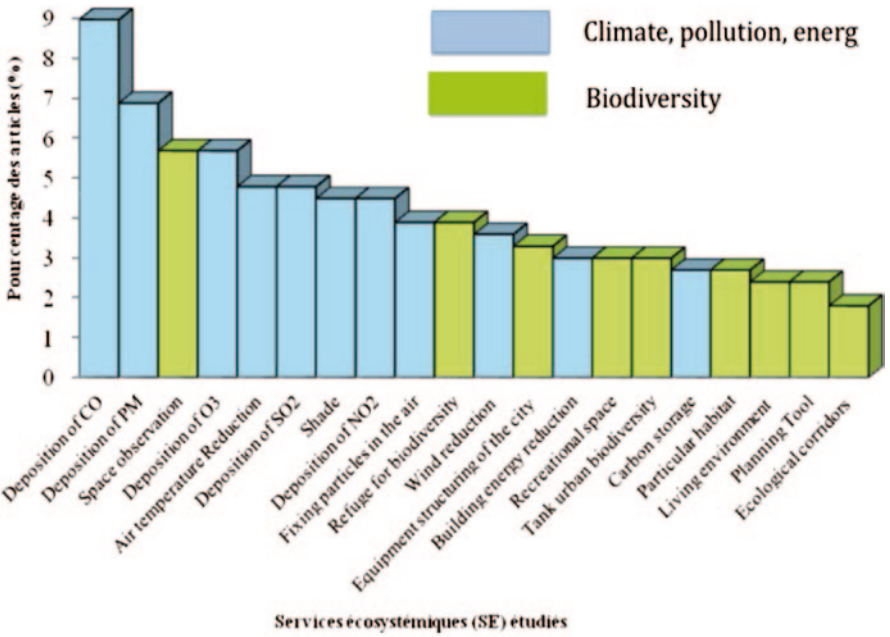

Fig. 1 Preliminary analysis: results of summary table of articles. Distribution of ecosystem services by number of articles in which they were treated or referred

Contribution to Sustainable Development and Ecosystem Conservation

Most of the ecosystem services studied are associated with this category. They are linked to all of the disciplines and journals. In France and Canada, the study of green spaces covers especially the quality of multifunctional public spaces. These articles are published most often in *Environmental Pollution.* On the other hand, looking at the services most commonly discussed in these articles, authors from the United States and the United Kingdom have concentrated on the functions. Most of their articles have been published in *Landscape and Urban Planning* and *Urban Forestry and Urban Greening*. These authors have also developed some guidelines based on sustainable development. A large scope of listed functions is attributed to the urban green belt, from leisure and citizen well-being to protection of biodiversity and fight against global warming.

Operational Results

Some general trends might be illustrated through the results obtained. Lists of vegetation (trees or bushes) have been selected for pollution emission purposes:

- Lists of species that might be more useful (Europe). Regarding particulate matter: bushes like '*Salix incisa*, *Pinus mugo*, *Skimmia japonica* and *Spirea cine-*

rea and trees: *Pinus sylvestris*, *Taxus media*, *Taxus baccata* and *Betula pendula*. Species less relevant are *Acer platanoides*, *Prunus avium* et al. *Tilia cordata*. To reduce ozone concentration Paoletti [19] shows that 2 species of cedar loose less COVs. Silver Mimosa (*Acacia dealbata*) has also a good impact on ozone but produce lot more COV. Another study in Barcelona shows that among ornamental species, 11 contribute positively to the COV emission in urban atmosphere [16].

- Normative index: Some studies allow defining the most resistant species face to pollution and pollutants capture and established normative indexes like the APTI or API (Air Pollution Tolerance Index) or the TBI (Tree BVOC—Biogenic volatile organic compounds—Index) to characterize the plant less productive in COV. The West Midlands metropolitan area, (UK) has also proposed a specific score regarding the impact of various species on air quality.
- Adaptation trend: Species more adaptable to extreme heat event have also be selected like *Gleditsia triacanthos*. [16].

Discussion

This study highlights the principal characteristics of the changes in the approaches linked to urban ecosystem services and allows identifying new trends and research questions.

Trends in Studies Reviewing Ecosystem Services

Over the past decade, ecosystem services studies have been marked by two trends, which developed jointly: the ecosystem services provided by all ecosystems (including urban ones), while others have focused solely on the role of urban vegetation [5] and experimentation and measurements in the field [17, 21].

Moreover, since 2005 (when the Millennium Ecosystem Assessment was published), an emergence of particular interest toward assessment of ecosystem services and their integration in the decision-making process (planning, design and management of vegetation areas can be noticed) [6, 15, 21]. Even if current planning methods continue to draw their references from functional urban studies based essentially on socioeconomic considerations. The articulation between ecological or energetic features like urban vegetation, amount of carbon stored by woodlands, low energy buildings and society values, representations, opinions or perceptions open largely several options of research.

Perspectives

This paper attempts to precise the current knowledge upon urban ecosystems services, mainly dealing with the functioning of urban green areas and their ecosystem services.

James et al., [9] and Bentsen et al. [1] propose innovative and promising avenues in this domain stressing the interest of studying the management of green spaces and the importance of multidisciplinary and interdisciplinary approaches to research like experimental platform for instance, on an international level, to understand the relations between urban vegetation and the well-being of city-dwellers.

Several directions have emerged from this study: the evaluation of the efficiency of the indicators suggested for each of the services. In such a case, the multidisciplinary approach is an ineluctable procedure, especially in its weaving of the associations between the social sciences, life sciences, and earth sciences illustrated by the need of articulation between disciplines using modeling as merging capacities. In the case of urban green ecosystem services, it would be interesting to define bridges according to the objectives of each scale. Gain will come from a real integration of the vegetation characteristics according to the aim and the scale of use.

The results have shown a flagrant lack of knowledge about some ecosystem services, specifically:

- Economic aspects: little work, for example, has been devoted to ornamental production intended to develop green spaces, or to the impact of vegetation on the attractiveness and market value of parks. In some countries (such as Germany), trees have been used as billboards of a sort, to finance their planting and management. Little research has attempted to understand such arrangements.
- Esthetic and cultural aspects: a lack of knowledge has also been observed about the role of vegetation as a landscape component that develops the image of the city or serves as a barrier to protect its citizens' private lives.
- Planning aspects: Many countries apply urban planning practices considering green spaces as real estate can be developed. Species inventories, measurements and generalization in urban area (*in situ*) or experimental plate-forms might participate to better planning practices, where trees or plants are chosen according their biologic capacities instead of just ornamental aspects. Economic, social but also ethic studies might complete, these aspects connecting with inequity or spatial justice issues.

Conclusion

This study has extracted from a literature review a large number of ecosystem services that vegetation is likely to provide in urban areas. Studies on this topic are various in aiming the ecosystem services, their characteristics and the objectives of their use.

Appendix 1 Summary table of key ecosystem services (15 first over 55)

	Ecosystem services	Direct (D) or indirect (I) services	Percentage of articles considering the ecosystem services	Authors most involved	Type of vegetation studied most
	Air quality				
	Air pollution removal				
1.	Deposition of carbon monoxide CO	D	13,53	Nowak D J/and others	Woodland
2.	Deposition of ozone O_3	D	9.41	Nowak D J; McPherson G E/ and others	Some species of trees or shrubs—Lawns (herbaceous)
3.	Deposition of nitrogen dioxide NO_2	D	7.65	Nowak D J/and others	Some species of trees or shrubs
4.	Deposition of particulate matter	D	7.65	Nowak D J; McPherson G E/ and others	Some species of trees or shrubs—Lawns (herbaceous)
5.	Deposition of sulfur dioxide SO_2	D	8.82	Nowak D J; McPherson G E/ and otherss	Some species of trees or shrubs—Lawns (herbaceous)
	Other Services				
6.	Low VOC Emissions	D	0.59	Karl T; Kirstine W	Woodland Lawns (herbaceous)
7.	Air temperature reduction	D	9.41	Akbari H; Shashua-Bar L/and other	Woodland
8.	Carbon storage	D	5.29	Jo H K; Akbari H/ and other	Woodland
9.	UV radiation reduction	D	0.59	Hermans C	Some species of trees or shrubs
10.	Low allergenicity	D	6.47	McPherson G E; Nowak D J/and other	Woodland
11.	Wind reduction	D	6.47	Gromke C; Akbari H/ and other	Woodland
12.	Building energy reduction	D	5.88	McPherson G E; Nowak D J/and other	All VUA—Shrubs
13.	Noise reduction	D	6.47	McPherson G E; Nowak D J/and other	Woodland
14.	Odor	D	6.47	McPherson G E; Nowak D J/and other	Woodland
15.	Decrease in the quantity of germs	D	6.47	McPherson G E; Nowak D J	Woodland

The selected articles have underlined three research trends:

- The effect of vegetation on chemical air quality, and pollution impacts;
- Other ecosystem services are less identified and characterized: the well-being of inhabitants, ecological balance, the role of esthetical values, etc. If the interactions between urban climate and vegetation are the major topics for the moment in the research community other types of ecosystem services seem emerge in some articles through multidisciplinary vision enriching our understanding of the ecosystem services provided by types of plant species other than trees.
- Finally, since the emergence of urban ecology the multifunctional aspects of urban green spaces seem to favor an increasing interest. Functionalist urban planning at the beginning of the 20th century attributed to green spaces only social and leisure roles. This trend is being modified, thanks to numerous studies showing measurements enriching a multifunctionality insight of urban green spaces useful in designing and managing public space.

References

1. Bentsen P, Lindholst AC, Konijnendijk CC (2010) Reviewing eight years of Urban Forestry and Urban Greening: Taking stock, looking ahead. Urban forestry and urban greening 4: 273–280. doi: 10.1016/j.ufug.2010.06.003
2. Bolund P, Hunhammar S (1999) Ecosystem services in urban areas. Ecological economics 29: 293–301. doi: 10.1016/S0921-8009(99)00013-0
3. COST Action C11 WG1B (2001) http://www.greenstructureplanning.eu/COSTC11
4. Costanza R, d'Arge R, de Groot R, Farberk S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Suttonkk P, Belt MVD (1997) The value of the world's ecosystem services and natural capital. Nature 387: 253–260. doi: 10.1016/S0921-8009(98)00020-2
5. Daily GC (Ed.) (1997) Nature's services. Societal dependence on natural ecosystems. Island Press, Washington, DC, pp 392. ISBN 1-55963-475–478
6. de Groot RS, Wilson MA, Boumans RMJ (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecolog Econ 41: 393–408. doi: 10.1016/S0921-8009(02)00089-7
7. de Groot RS, Alkemade RL, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7:260–272. doi:10.1016/j.ecocom.2009.10.006
8. Dobbs C, Francisco JE, Wayne CZ (2011) A framework for developing urban forest ecosystem services and goods indicators. Landscape and urban planning 99: 196–206. doi: 10.1016/j.landurbplan.2010.11.004
9. James P, Tzoulas K, Adams MD, Barber A, Box J, Breuste J, Elmqvist T, Frith M, Gordon C, Greening KL, Handley J, Haworth S, Kazmierczak AE, Johnston MJ, Korpela K, Moretti M, Niemela J, Pauleit S, Roe MH, Sadler JP, WardThompson C (2009) Towards an integrated understanding of green space in the European built environment. Urban Forestry Urban Greening 8:65–75. doi:10.1016/j.ufug.2009.02.001
10. Lamarque P, Quétier F, Lavorel S (2011) The diversity of the ecosystem services concept and its implications for their assessment and management. C R Biol 334:441–449. doi: 10.1016/j.crvi.2010.11.007

11. Lebart L, Piron M, Morineau A (2006) Statistique exploratoire multidimensionnelle, Visualisation et interface en fouille de données. Dunod, Paris
12. Leuzinger S et al (2010) Tree surface temperature in an urban environment. Agricultural Forest Meteorology 150:56–62
13. Mehdi L, Weber L, Di Pietro F., Selmi W (2012), Évolution de la place du végétal dans la ville, de l'espace vert à la trame verte ; to be publsihed Vertigo, Vol. 12, numéro 2
14. Millenium EA (2005) Ecosystems and human well-being: current states and trends. Washington. Island press. http://www.maweb.org/documents/document.358.aspx.pdf. Accessed 28 March 2007
15. Niemelä J, Saarela SR, Söderman T, Kopperoinen L, Yli-Pelkonen V, Väre S, Kotze DJ (2010) Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. Biodivers Conserv 19:3225–3243. doi:10.1007/s10531-010-9888-8
16. Noe SM et al (2007) Monoterpene emissions from ornamental trees in urban areas: a case study of Barcelona, Spain. Plant Biol 10:163–169
17. Nowak DJ Dwyer JF (2007) Understanding the Benefits and Costs of Urban Forest Ecosystems. In Kuser JE (ed) Urban and Community Forestry in the Northeast, Springer, pp 25-46. http://books.google.fr/books?hl=fr&lr=&id=PCycWgOkZwC&oi=fnd&pg=PA25&ots=nrf9t2pxKS&sig=_AWzfLE_P5IrpmLFWj3wNpFDTtc#v=onepage&q&f=false. Accessed 28 March 2007
18. Odum EP (1971) Fundamentals of Ecology. Saunders, Philadelphia pp. 574
19. Paoletti E (2009) Ozone and urban forests in Italy. Environ Pollut 157:1506–1512
20. Potschin MB, Haines-Young RH (2011) Ecosystem services: Exploring a geographical perspective. Prog Phys Geogr 35:575–594. doi: 10.1177/0309133311423172
21. Young RF (2010) Managing municipal green space for ecosystem services. Urban forestry and urban greening 9: 313–321. doi: 10.1016/j.ufug.2010.06.007