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Article

Interpreting Sustainability for Urban Forests

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Abstract: Incisive interpretations of urban-forest sustainability are important in furthering our understanding of how to sustain the myriad values associated with urban forests. Our analysis of earlier interpretations reveals conceptual gaps. These interpretations are attached to restrictive definitions of a sustainable urban forest and limited to a rather mechanical view of maintaining the biophysical structure of trees. The probing of three conceptual domains (urban forest concepts, sustainable development, and sustainable forest management) leads to a broader interpretation of urban-forest sustainability as the process of sustaining urban forest values through time and across space. We propose that values—and not services, benefits, functions or goods—is a superior concept to refer to what is to be sustained in and by an urban forest.

Keywords: sustainability; urban forest; urban-forest sustainability; urban forest management

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1. Introduction

Much has been written about how urban forests are valued positively by citizens and how they help mitigate some daunting environmental problems [1]. However, little has been said about the way sustainability is interpreted for urban forest systems. Most authors explore urban-forest sustainability through fairly narrow definitions of a sustainable urban forest, and thus lead to singular interpretations

of the concept as the maintenance of tree health. These definitions lack consideration of the wealth of knowledge about sustainability in general and sustainable forest management (SFM) in particular.

The purpose of this paper is to further the thinking around urban-forest sustainability and to reveal alternative interpretations of the concept. To do so, three relevant conceptual domains are explored: concepts behind urban forest systems, interpretations of sustainability through the concept of sustainable development, and SFM. An analysis of interpretations to date is delivered and an argument is advanced on how sustainability could be understood better for urban forests.

2. Three Conceptual Domains

2.1. The Urban Forest

Urban forests can be broadly defined as the natural and planted trees in urban areas. Urban forests have several characteristics that make them different from hinterland forests. These characteristics have been thoroughly documented and are summarized below.

2.1.1. Structure

Urban forest structure refers to the biophysical and geographical characteristics of the urban forest. Urban forest structure may include the arrangement of trees in relation to each other and to objects, the forest composition and diversity, as well as age classes and health status. It may also include other geographic characteristics that imply nature-society interactions, such as the location of trees in different property categories. Urban forest structure determines the way urban forests function and the services they provide [2].

2.1.2. Connectedness

Urban forests do not display the biophysical connectivity of hinterland forests and are highly fragmented. However, they have intricate connectedness to their wider physical and social environment. The trees benefit or take a toll on people's lives, and they are in turn affected in myriad ways by human decisions and actions [3].

2.1.3. Dynamics & Driving Forces

Urban forests have a complex dynamic in the sense that they couple natural development processes and human processes, both of which operate at a variety of rates. The following forces can alter urban forests: (1) anthropogenic direct actions (e.g., removal of vegetation cover); (2) anthropogenic indirect actions (e.g., budget cuts); and (3) natural forces (e.g., fires, storms, insects) [4].

2.1.4. Values

The terms goods, benefits, functions, services and values have all been used interchangeably to mean what is important to sustain in and by urban forests. A discussion on how these concepts might be differentiated will aid our exploration of urban-forest sustainability as a concept.

Goods are economically constrained, as they can be broadly defined as something for which you pay to increase utility [5]. This term does little to encompass all the non-economically-valued characteristics of ecosystems. As for benefits, these are usually associated with costs (as in the well-known technique called benefit-cost analysis), and an economic overtone is also implicit with this term. The typology of ecosystem functions is diverse and sometimes contradictory. In a broad interpretation, functions may mean processes and structures by which ecosystems influence nature and/or people [6]. Many uses of the term inherently imply that ecosystems function for people, and not for themselves or for nature, therefore entailing a utilitarian, and usually economically-oriented, interpretation [7]. However, many services and/or values associated with the urban forest are not physical and cannot be understood through typologies that refer to physical structures or processes. The narrow perspective implied by the terms good, benefit and function is not inclusive of all what urban forests provide and do for society.

Services and values are, then, more appropriate terms. However, the widest definition of services is what is provided by society to better people's lives. In that sense, services say nothing about the social or even psychological underpinning behind ecosystem management and the values humans put to nature [8]. As for values, these can be defined in many ways. By values people refer to an adapted abstraction that emerges from social dialogue [9], or to fundamental orientations, life goals, or guiding principles, which serve as the basis for organizing individuals' beliefs and attitudes and guiding their respective behaviours [10]. However, these definitions refer to broader socio-cultural and moral categorization, and not to particular human-nature relationships.

In the forest literature, a value can be a characteristic, component, or quality considered by an interested party to be important in relation to a forest [11]. The concept of value behind a human-nature system can be broad, but it is also flexible, and can be furthered categorized as assigned value (a value for humans) or existence value (a value in itself) [12]. This further categorization reflects a semantic flexibility not possible with the use of other terms, such as goods, benefits, functions and services, and an ability to reason our way through their meaning without changing typologies. Because of this flexibility and broadness, the term values conveys the most comprehensive account of what must be sustained in urban forests.

The values associated with the urban forest may fall within three broad categories: ecosystem, social and economic. Ecosystem values include air pollution removal [13], carbon capture [6], regulation of the hydrological cycle, *i.e.*, rainfall interception [14], regulation of the micro-climatic environment [15], harbouring wildlife [16], among others. Social values include positive psychological effects [17], aesthetic quality [18], and emotional and spiritual benefits [19], among others. Economic values include increased real-estate values [20], recreational values [1], savings due to carbon dioxide sequestration and air pollutant removal [21], among others.

2.2. Sustainable Development

An interpretation of sustainability for urban forests implies an interpretation of sustainability itself. Sustainability may be broadly defined as the persistence or continuation of a system over time. In trying to capture what this means for natural and human systems, scholars have found it easier to interpret sustainability by defining a series of associated concepts, such as sustainable development.

This term is used as a synonym for sustainability in some instances, though it has completely different interpretations in other instances depending on the field of knowledge and/or the management regime being addressed. Because of this, and because it is the most extensively defined term in the sustainability literature, a brief, but by no means exhaustive, review of its most useful definitions is important in our examination of sustainability (see Table 1)

Table 1. Some useful definitions of sustainable development.

Definition of Sustainable Development	Source
The capacity to maintain ecological, social and economic stability in the transformation of biospheric services into human ones	[22]
Meeting or optimizing present and future generations' needs	[23]
The persistence of a necessary and desired system (socio-political or natural) over an indefinite future	[24]
The integration of ethical, economic, social and ecological aspects of human life into a coherent view of the world so that current and future generations of people and other living organisms may continue indefinitely	[25]
Meeting needs and fulfilling aspirations under environmental, social and technological constraints	[26]
Living in harmony with nature and with one another	[27]
Keeping quality conditions in the relationship between humans and nature	[28]

Before the most useful interpretations of the above definitions can be explored, it is worthwhile to note that any interpretation of sustainability implies adhering to a specific view of sustainability. For example, sustainability can be viewed mechanically. This is favoured by technical people, who assign ideal quantitative measures to criteria-and-indicator frameworks that help characterize ideal states of a system. Examples of this view in the urban forest sector abound, as it would be discussed later. Because the possibility of such sustainable states is doubtful, as our understanding of what is sustainable may change over time, the mechanical view is challenged by another view of sustainability, the evolutionary view. In this view, one admits that a sustainable state can never ultimately be achieved because the benchmarks are ever-changing. Thus, sustainability is a process or journey because it can never be fully achieved [29], and no stable specification of a particular future sustainable system is possible.

Others see sustainability impressionistically: what does one think of when the word sustainability is brought up? The World Commission on Environment and Development's [23] definition serves this view. This view has considerable value in garnering participation in sustainability discussions by non-technical people. Another view of sustainability can be termed empirical—whatever people say is sustainable at a specific time and place is what is indeed sustainable.

There can also be a comprehensive view of sustainability which calls on managers to sustain everything that is valued. Criteria-and-indicator frameworks are also embodied in this view, trying to cover all possible grounds for pursuing sustainability [30]. Advocates of this view may also strive for an ideal sustainable state, as with the mechanic view, but both quantitative and qualitative indicators may be fitted into such a framework, making it possible to develop non-mechanical interpretations.

Another view of sustainability is dogmatic where people hold strongly to specific principles, such as the precautionary principle. Such normative approaches constrain sustainability strictly to one or a

few management principles. Finally, a rule/tool view of sustainability is recognized, in which one simplifies matters to the sole application of certain rules or tools. In the forest-management context, for example, people's penchants to call for the abolition of clearcutting, chemical pesticides and genetically modified organisms represent this view.

The seven basic views of sustainability above are not mutually exclusive. Many views may be interplaying at one time, yet, usually, we attach ourselves to one or another depending on the system being studied and our motivation for addressing sustainability at the moment. However, no view holds the definitive answer about what sustainability really is or how it is to be achieved. The views that bound the most useful interpretations of sustainability, including our own, will be discussed below.

As evident in Table 1, early definitions of sustainable development [22,23,25] were tailored to agree with a classic definition of development as the process of economic growth and the alleviation of poverty. These definitions usually lead to mechanical interpretations. For its advocates, achieving sustainability requires a mere shift of the elements involved in the development process. This leads many technical people to try and fit new technologies and economic measures around a defined sustainable state. However, merely modifying the economic and technological elements of development can not capture the whole spectrum of ideas behind sustainability [27]. Indeed, many definitions of sustainable development force the term to be used lightly for mechanistic purposes [31] and try and fit an interpretation that does not do true justice to what sustainable development is about.

Mechanical interpretations are premature, as it is already known that no particular definition of what sustainability is at a given moment may satisfy all fields of knowledge [32]. To foster a broader interpretation of sustainability, later definitions of sustainable development [24,26-28] tried to adhere to a broader conceptual framework of sustainability. In this approach, sustainable development starts to be synonymous with sustainability as a complex body of theory. However, it is important to recognize that definitions of sustainable development do not define sustainability by themselves.

It is then in our interpretation of sustainability where the real meaning of the concept lies. In interpreting the definitions listed in Table 1, a few essential qualities of sustainability stand out: the need or inherent goodness of the continuation of the natural world; the ecological constraints on economic growth; the promotion of intergenerational equity; and sustaining social, economic and environmental values. The first qualities described can be seen more as principles of sustainability, since they do not imply operational strategies but rather philosophical assumptions behind sustainable human-nature systems. The last quality, however, has operational utility. Because value is a superior concept than service, as discussed earlier, this interpretation implies seeing sustainability, in its broadest form, as the process of maintaining the values associated with human-nature systems in the future. This interpretation is determined by both a comprehensive and evolutionary view of sustainability, as explained above, as they try to refer to the action of sustaining the myriad environmental, social and economic values people have, and recognizing this as a process that changes over time. This interpretation is perhaps the broadest and most useful interpretation of the concept, and may apply to the majority of human-nature systems, one of which is the urban forest system.

2.3. Sustainable Forest Management

The concepts used to explain SFM have had a rich history and provide further insights for interpreting sustainability for urban forests. The general idea of forest sustainability was conceived early in the environmental movement [33]. However, until the early 1990s, when the term SFM was coined, the early understanding of SFM emphasized sustained yield. This referred to the maintenance of forest resource productivity and the maintenance or enhancement of outputs of a narrow range of objectively measurable products and services. The first move to broaden the SFM concept was by coupling sustained yield with a broader sense of integrated forest management and ecological integrity [34]. This process of conceptual development was furthered with time (see Table 2).

Table 2. Some useful definitions of Sustainable Forest Management.

Definition of Sustainable Forest Management	Source
The maintenance of all specific natural processes or ecological features of a forest site to meet human needs	[35]
The conservation of the ecosystem base of forests equated with a management that is ecologically sound, economically viable, and socially responsible	[36]
The maintenance of the biodiversity, productivity, regenerative capacity, vitality, and the potential to fulfil relevant ecological, economic, and social functions	[37]
The recognition, association and sustainability of values associated to forests	[38]
The process in which forests are used to produce goods and environmental services that increase, or at least maintain, the welfare of people living today, while protecting for future generations the environment and natural resource base on which future production will depend	[39]

Some believed that a fullsome statement about the fundamental principles behind SFM and a true interpretation of SFM could only be accomplished through the development of criteria and indicators [40]. Some mid-1990s criteria-and-indicator reports were delivered, but not until the Montreal (for boreal and temperate forests) and Helsinki (for European forests) processes did a real momentum start for developing a common framework. Eventually, many such frameworks and SFM models were developed, but a few nations remain exemplary in practice, e.g., Canada, [41].

The SFM criteria-and-indicator approach reflects many of the issues discussed above for interpreting sustainability. First of all, modern SFM is not bound to a definition by this approach but rather an interpretation. A so-called "constructive ambiguity" is seen as the more useful way to interpret certain concepts such as SFM [42]. Second, some SFM criteria-and-indicator frameworks reflect many views of sustainability. For example, some reflect a comprehensive view of the concept, as they adhere to the general idea that SFM should be as broad and complex a concept as possible so as to help converge the full amplitude of values and elements that should be part of it [43]. Key qualities in recent SFM criteria-and-indicator frameworks reflect an advanced version of this notion. For example, many criteria-and-indicator frameworks today embrace an extremely wide range of forest values, much beyond timber exploitation, and include recreation uses, water and air quality, carbon storage, special forest products, scenic quality, traditional land uses of Aboriginal peoples, and others.

Terms such as integration and consideration of multiple values are commonplace in exemplary SFM criteria-and-indicator frameworks [44].

Some SFM criteria-and-indicator frameworks also reflect a mechanical view of sustainability, as they focus on quantitative indicators. Many scholars recognize that this notion is troublesome, as the number, ranking and weighing of indicators would always need consensus on technical ordinance [45]. In fact, many recent criteria-and-indicator frameworks respond to this limitation by adopting an evolutionary view and redefining the criteria-and-indicator approach as an ever-ongoing process, or by considering qualitative indicators to assess unquantifiable sustainability issues. Other qualities are also important to consider in the SFM criteria-and-indicator approach. For example, time and space frames are explicitly considered in modern SFM criteria-and-indicator frameworks, with both having been dramatically expanded. For example, time horizons for forest planning now extend to several centuries in many jurisdictions [11].

In many ways, interpreting SFM through the key qualities above enriches a now outdated and mechanical, quantitative-only SFM definition and is clearer in expressing how SFM is conceptualized today [46]. This interpretation echoes the most useful interpretation of sustainability drawn above, that of sustaining the values associated with human-nature systems, though it adds the inclusion of expanded time and space frames. As with the interpretation of sustainability, this interpretation may apply to the majority of human-nature systems, one of which is the urban forest system.

3. Interpreting Sustainability for Urban Forests

The concepts of urban forests, SFM and sustainability discussed above guide our quest to find strong interpretations of sustainability for urban forests. Our launching pad rests on the several attempts that have already been made to interpret urban-forest sustainability.

3.1. Interpretations of Urban-forest Sustainability

Most of the urban forest literature tries to give meaning to sustainability as applied to urban forests through definitions of the concept of a sustainable urban forest. This ideal sustainable urban forest model is seen in the early literature as one where species selection and diversity, inventory and landscape planning, tree care and wood utilization, and public relations and support are the main elements to consider [47]. Others favoured comprehensiveness in their definition of sustainable urban forests, and define the concept as the process of maximizing energy efficiency, minimizing waste production and pollution, capturing the benefits of natural processes while minimizing damage from natural events, and meeting the economic and social needs of all people in a manner that does not degrade or destroy the productivity or health of its natural systems [48]. Later, a sustainable urban forest came to mean healthy and functional vegetation that provides the long-term benefits desired by the community [49]. Such interpretations are useful in that they try to embrace some of the most pressing issues behind sustainability, but are focused on interpreting the concept through a definition of an ideal state, and do so by addressing the more operationally relevant considerations. Indeed, such an approach is only possible if the concept is combined with a technical backdrop of tree maintenance, mainly standards such as pruning, species diversity, and so on; standards against which the sustainability of the urban forests is to be assessed.

As with SFM, many saw that a useful interpretation of sustainability as applied to urban forests could only be achieved through a criteria-and-indicator framework that described a sustainable urban forest model. One of the best efforts to present such models, in that it has been extensively referenced in many urban-forest management plans in North America, is that of Clark and Matheny [50]. In this model, issues related to the urban forest are associated with quantitative performance indicators. Though some performance indicators can be measured in the field, other measures of sustainability rely on the judgement of urban foresters [51]. All in all, though, the empirical measurement is arbitrarily designed according to an ideal state of the urban forest. Other models of this kind exist [52].

3.2. Analysis of Urban-Forest Sustainability Interpretations

Most of the interpretations of urban-forest sustainability discussed above come up short in two significant ways. First, the concept is given meaning through a definition of a sustainable urban forest, an ideal state of the system, focusing solely on trees and their caretaking. Models of sustainable urban forest management that attach to this view usually have a strong technical component, and indeed, in many it is the only component. For example, urban forest management plans in North America include goals that define the sustainability of their urban forest by striving for the general health of trees, canopy cover goals, a maximum representation for a single tree species, a standard of planting native species, and so on [53,54]. Our exploration of promising interpretations of sustainability suggests a process of sustaining all values associated with that system. Keeping trees healthy does not automatically satisfy all urban forest values, even if people's values respond to their maintenance. Indeed, although what people value in the urban forest is not independent from its biophysical structure, other value considerations may be also important in progressing towards sustainability.

Second, a deeper gap in such an interpretation of urban-forest sustainability is that the concept has been viewed for a long time as a mechanical problem, a technical-ecological issue. As the discussion about sustainable development and SFM demonstrated, interpreting sustainability through a mechanical view brings it down to the level of a biophysical process. Allocating an arbitrary empirical measurement to urban-forest sustainability according to an ideal state of urban forests, defined via standards of tree health, canopy cover, species mix, and other urban tree maintenance yardsticks, is too restrictive. Relying heavily on technical and numeric standards is not only a sterile way to describing the sustainability of a system but disregards unquantifiable indicators. Indeed, social issues associated with urban forests also contribute to the definition of a sustainable urban forest but do so in a non-quantitative way. Indeed, agreement among experts and stakeholders in the ranking of value-laden issues may be impossible to achieve.

Nonetheless, certain aspects about mechanical approaches are practical for certain constituencies. Coupling urban-forest sustainability to canopy cover, for example, is practical for an urban forester and tree care-takers because the concept conforms to an easily operationalized measure of progress. This point is illustrated by how people who deal daily with urban trees define a sustainable urban forest, stressing the importance of the biophysical health of trees. Others define the concept in terms of the interest and commitment of groups of people who deal with urban trees. Urban forest stakeholders, experts and non-experts alike, have widely differing views of sustainability [55].

The complexity of defining a sustainable forest portends considerable difficulty in serving society's needs well if one grounds an urban-forest sustainability framework in the above interpretations. Urban-forest sustainability is a broader concept and includes the concepts, principles, operational framework and applications associated with the urban forest system and how to get to any desired state. Thus, though not entirely devoid of mechanical techniques, urban-forest sustainability is much more complex an issue that requires a more inclusive interpretation.

3.3. How Sustainability Could Be Interpreted Better for Urban Forests

Our examination of the sustainable development and SFM literature reveals useful interpretations of sustainability for human-nature systems, such as the urban forest system. A vision of sustainability for urban forests may well be that at any point in the foreseeable future (a viable timeframe of, say, 100 years), the management of urban forests applied today should be able to provide a strong array of values at all times, with acceptable spatial distribution, except when natural or human catastrophes prevent such.

This interpretation reflects many of the key qualities that are valuable in any interpretation of sustainability as our discussion on SFM showed. Firstly, a holistic understanding of urban forest values gives meaning to the concept of urban-forest sustainability in a deeper and broader way. Leading urban forest scholars remind us that the look, function and management of a sustainable urban forest depend on which ecological functions and social benefits are desired, who chooses them, and at what space and time scales these elements are to be sustained [56]. Exploring what it means to frame urban-forest sustainability as a values-based enterprise may require, as with SFM, constructing a comprehensive criteria-and-indicator framework. How this framework may be structured according to the values associated to the urban forest, and how it can be made operational, is a matter of future exploration. Secondly, because sustainability is a vision for the future within a spatial context, following short-term or space-limited conceptions of the urban forests could too easily end in urban forest unsustainability. The time-frame of 100 years chosen here echoes the discussion about SFM in general, which reflects both the long-term vision that managers should have and the far-reaching implications of deciding how to manage urban forests today with a values-based approach.

It is interesting to realize how giving meaning to urban-forest sustainability in such a broad way opens the door for many other considerations in urban forest management. For example, ecosystem values are defined in many ways by our contact with nature and the way people see the good in nature [38]. We hypothesize that people's values associated with urban trees is determined partly on tree-ownership patterns, and urban forest management must address these patterns more deeply. In some countries, urban trees are mainly owned privately, e.g., US [57], yet much is to be said about ownership patterns elsewhere in the world. As with SFM, sustainable urban forest management should accommodate ownership fragmentation, as this feature defines different management objectives. Moreover, this interpretation is open to address the integration of urban-forest sustainability with the wider concept of overall urban sustainability. This has been recognized as an issue for future research [58]. Indeed, many urban forest studies have focused on the technical backdrop to determine policy measures related to tree maintenance [59], but not on the inclusion of urban-forest sustainability in the wider urban planning and development context. Finally, this interpretation is open to addressing

climate change. Projected future climates across the globe may significantly affect and change urban forest structures and the ways we value them. Thus, actions associated with mitigation of and adaptation to climate change must be accommodated in urban forest management programs.

4. Conclusions

The concepts explored in the three conceptual domains in this paper provide a valuable backdrop to help interpret urban-forest sustainability more broadly and deeply than we have found evidence for so far. The applicability of this conceptual framework may have wider relevance than just in relation to urban forest systems. Moreover, the interpretation of urban-forest sustainability elucidated here reflects the myriad of values associated with the urban forest, helps engage people with interdisciplinary interests in the urban forest, and may provide the conceptual foundation for addressing key issues in urban forestry such as ownership patterns, integration and coordination with other management regimes, and climate change. How the interpretations of urban-forest sustainability found here may be framed and made operational in sustainable urban forest management is a matter for future thought. Enriched views of urban-forest sustainability are necessary for people to be able to care for their urban forests in a future characterized by growing human populations and a changing climate.

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