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Recreation services from ecosystems

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Contents

Introduction

This Discussion Paper covers a broad range of issues relevant to the definition, physical quantification of supply and use, and valuation of recreation services related to ecosystems. The initial intention of the discussion was to propose a limited and feasible set of metrics and methods for ecosystem accounting of recreation services. The scope widened as a result of discussions with co-authors and reviewers from different disciplines. The wider scope should provide a panorama of potential measurement methods, and outline the boundaries of ecosystem accounting for recreation.

Key Questions

The following questions are a combination of questions guiding the paper outline, and questions raised during the review process of the first draft. They are addressed throughout the text.

Extent, condition and recreation service

i. Should 'characteristics of the ecosystem enabling recreation' (CICES approach) be conceptualized as the recreation service, or as ecosystem condition for recreation?
ii. What is/should be the role of the abiotic characteristics in the supply of ecosystem services?
iii. Why are the concepts of recreation condition and capacity necessary to understand in connection with valuation methods ?
iv. How can we compute standardised accounting units of 'greenspace of good condition' for recreation accounting and valuation purposes?

Recreation use, benefits

i. Are there primary and secondary ecosystem services arising from a single interaction with an ecosystem and if so, how should this be treated? (e.g. leisure, recreation, pathways to health)
ii. Is the concept of information flows useful in describing and defining recreation services and other cultural services?
iii. The concepts of recreation services and benefits seem to have different definitions depending on the framing of the cause-effect chain linking ecosystem condition to recreation choice and health? Can they be better defined?

Valuation

i. What recreation valuation methods address the transaction price convention of value in national accounting?
ii. Can we sort pricing methods into tiers by consistency with current accounting contention, cost/complexity?
iv. How can we best use information on demand curves estimated with respect to benefits arising from ecosystem services?
v. How compatible do the institutional assumptions of simulated accounting price methods have to be with the current institutional context?
vi. How can we take advantage of the methodological triangulation of travel choice, simulated exchange value and hedonic property pricing to value recreation services while avoiding double counting?

1. Description of the ecosystem service

1.1 Describing the ecosystem service

This discussion paper spans outdoor recreation in landscapes ranging from urban built environments to wilderness. Attempting to cover the heterogeneity of recreation contexts that occur within a national accounting scope, calls for a distinction between recreation requiring natural capital/ecosystems (outdoors) and other recreation (indoors). Outdoor recreation services are part of leisure and a wider set of cultural practices of people interacting with environmental spaces. They are sometimes conceptualized as part of the general category of cultural ecosystem services[1].

Cultural ecosystem services is a catchall category which encompasses both direct final services from experiencing nature and 'household co-production' of health through recreation. The use of a single term to refer to these services would be a useful in discussions and accounting tables.

- 'Outdoor recreation services' [2] may also encompass urban open spaces without vegetation or wildlife, including air quality, perhaps making it too wide a term.
- 'Nature-based recreation services' may need qualification that it includes constructed vegetation and water bodies in urban areas.
- 'Green recreation services' is associated with greenspaces, but requires specification that they also include blue/water to avoid heavy terminology such as bluegreenspaces.

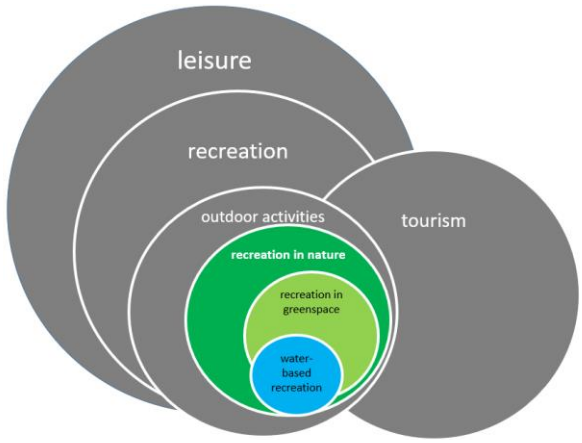


Figure 1 Overlapping concepts of recreation
Source: adapted from UK NEA(2011)

The proposal in this paper is to use the term 'recreation services' and allow the definition and measurement scope to clarify the intended boundaries.

The purpose of measurement in the context of this discussion paper is to quantify the contribution of the natural biotic and abiotic characteristics of outdoor spaces to recreation services, and value the benefits from recreation services to people. The main questions are:

[1] Fish, R., Church, A., Winter, M., 2016b. Conceptualising cultural ecosystem services: A novel framework for research and critical engagement. Ecosyst Serv 21, 208-217.

[2] UKNEA (2011). The UK National Ecosystem Assessment Assessment Technical Report. , UNEP_WCMC. Cambridge.

1) What are the appropriate biophysical units that describe the ecosystems' conditions that potentially enable recreation, and how practically should they be measured?
2) What are the appropriate biophysical units that describe recreation actual recreation services and their benefits, and how practically should they be measured?
3) At what accounting prices should biophysical units be valued, and how practically should they be measured?

To open discussion, we propose a definition similar to CICES[3] wherein 'recreation services are the biotic and abiotic **characteristics** of open space **that enable** health, recuperation and enjoyment through outdoor activities'. Thus, the point at which environmental structure and processes give rise to outputs that directly enter human preference functions (profit, utility, well-being) can be defined as an ecosystem service. In this context, 'enjoyment' is a synonym for utility and well-being.

While there is a direct link between ecosystem services and human welfare, it is challenging to identify separate metrics for "services", "benefits" and "value". Further, for accounting purposes a line needs to be drawn between the supply and use of ecosystem services. To provide an initial starting point for discussion of recreation services, we start from the position that they relate to the experiences of people occurring in a landscape. This starting point raises many questions from an accounting and measurement perspective, most importantly - which ecosystems, which people, which activities?

Proposals to answer these questions and associated issues are discussed in this section. Fitting with an accounting approach to ecosystem services the questions are considered in this paper in terms of supply side and demand side considerations. Questions of measurement in practice and valuation are considered later in the paper.

Supply side considerations

The role of the ecosystem in supplying recreation services can be framed in widely from a conceptual point of view, or narrowly based on quantifiable metrics. The conceptual framing described here fits within a comprehensive definition of cultural ecosystem services proposed by Fish et al and shown in the figure in Appendix 1[4].

The SEEA EEA Technical Recommendations[5] discussed cultural ecosystem services as arising from "ecosystems providing **opportunities** for people to engage in activities, learning experiences and the like" and specifically that cultural ecosystem services "**enable** nature based-recreation". However, the Technical Recommendations seem to confound this definition by also stating that "services and benefits can be measured in terms of people engaging in such **activities**". The 'opportunities' definition could be seen as a capitals framing, whereas the former definition is closer to a service flow.

[3] CICES v5.1 "characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active, immersive, passive or observational interactions". Haines-Young, R. and M.B. Potschin (2017): Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure.

[4] Fish et al. 2016 describe a number of cultural practices - playing and exercising, creating and expressing, producing and caring, gathering and consuming – which may all have aspects of physical and mental re-storation (Appendix 1).

[5] UN (2017) Technical Recommendations in support of the System of Environmental-Economic Accounting 2012. Experimental Ecosystem Accounting. White cover publication.

Havinga and Hein[6] propose to define and measure supply of cultural ecosystem services in terms of **information flow.** Based on earlier studies they argue that information is provided to human sensory organs by components, structure and dynamics of ecosystems[7]; there is a service flow when information is transferred to humans[8], e.g. from a landscape that is attractive and enjoyable for a recreation activity[9]. For recreation services, there is potential for this concept to be qualified in a number of ways that can then be used to determine the metrics to be chosen- the information flow framing is motivated by an interest in using social media data to quantify recreation services.

Note that appreciating the existence of national parks, cultural heritage sites or similar sites for their non-use existence value[10] is not within the scope of recreation services as we understand it here.

Ecosystems' space, structure and function enables opportunities for recreation - enjoyable and restortative environments, a refuge to escape from stresses of urban life, prospects for subsistence and related sports (e.g. gathering, fishing and hunting). Studies on ecosystem structure - complex versus simple - or biodiverse versus less diverse - run experiments to look at for example, prevalence of recreation activities and mental health responses[11]. Humans are attracted to other living beings and seek out living environments for the purposes of enhancing physical and mental well-being. Ecosystem size and shape in addition to other measures of ecosystem condition are important for habitat characteristics - patchiness and edge versus interior space are not only important for both flora and fauna, but for people as well. These combine with built structures such as parking spaces, picnic tables and paths to co-produce recreation. Locations that provide air and water quality, habitat for animals and wildlife viewing opportunities, landscape views, including biotic and abiotic features (rocks, mountains, water bodies etc) are also "habitats" for human recreation. Further, built infrastructure help access to locations (via roads, paths, transport options, etc) and enable activities onsite (paths, restrooms, drinking water, etc).

There are no a priori economic reasons to exclude or prioritise specific ecosystems types in a mapping of recreation services supply. Landscapes relevant for recreation services do not need to have salient vegetation and/or animal life for ecosystem services to be delivered. Abiotic features are important features of recreation sites (water, snow, sand, rock). Application of a minimum definition of an ecosystem for ecosystem accounting primarily concerns urban contexts. Urban green spaces of all sizes, including backyards and gardens, golf courses, and sporting fields, are important for recreation. Green and blue structures in an urban built environment - such as street tree canopy cover, green walls, green roofs, raingardens, vegetated drainage channels - provide regulating and habitat related services, but also contribute to recreation services through the multiple sensory stimuli of "soft edges"[12].

[6] Havinga, I. and L. Hein "Clarifying cultural ecosystem services" Research Note (22 November 2018).
[7] Braat, L.C., de Groot, R., 2012. The ecosystem services agenda:bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosyst Serv 1, 4-15.
[8] Schroter, M., Barton, D.N., Remme, R.P., Hein, L., 2014. Accounting for capacity and flow of ecosystem services: A conceptual model and a case study for Telemark, Norway. Ecol Indic 36, 539-551.
[9] Remme, R.P., Schroter, M., Hein, L., 2014. Developing spatial biophysical accounting for multiple ecosystem services. Ecosyst Serv 10, 6-18.
[10] Krutilla, 1967. Conservation reconsidered. Am. Econ. Rev. 57, 777–786.
[11] Pers. Com. Timon McPherson.
[12] Jan Gehls (2010) Cities For People.

Since few, if any, ecosystems are natural there is a continuum of management and ecosystem condition which will need to be assessed in ecosystem accounting. The issue of separately identifying ecosystem extent and condition is not unique to recreation services, but it is likely more challenging in urban areas given their mix of structures and land covers. Urban 'green structures' can also pose a measurement challenge when they supply characteristics that are experienced incidentally on a trip undertaken for other purposes (e.g. travel to and from work). In those trips green structures may represent small, spatially heterogeneous and distributed characteristics of a trip trajectory.

A related measurement challenge concerns the environmental quality - ecosystem condition more generally - that enables specific types of recreation[13], and how a change in condition impacts demand for recreation. Heavily modified or polluted water bodies in urban areas such as routed streams/rivers, ponds and reservoirs may offer recreation for walking and viewing, but not for swimming or boating. Air pollution may limit physical exercise outdoors. Vegetation and soil may also be degraded and eroded to the point where it no longer attracts visitors or is perceived as a recreational quality. The presence of invasive or alien species may affect the experience. Recreation use itself may lead to congestion[14] and impact negatively on the site[15]. In some contexts it will also be relevant to understand seasonal factors in the supply of services. For example, ski resorts, beaches and urban open spaces will have specific supply and demand profiles at different times of the year. Ownership and access rights also determine the value of the marginal experience. Contextual information[16] will be important in understanding the potential characteristics of recreation service supply and the capacity for different locations to supply services.

In understanding the supply of recreation services it will also be important to understand the presence or availability of facilties that enable people's access to and enjoyment of open spaces. Enabling factors would include

- the accessibility to the location in terms of travel and transport options.
- the presence of supporting businesses – hotels, restaurants, etc – that can provide goods and services to people.
- the provision of built infrastructures such as walking and cycling paths, sport facilities, viewing platforms, ornamental structures, toilets, at the locations taking into account the accessibility of these facilities for the mobility impaired.
- the types of regulations or norms that might apply to the access and use of the area.
- organized activities, maintenance, and safety could play important roles

In an accounting context, all of these aspects are relevant in understanding the flows of recreation services supplied by ecosystems.

[13] Pröbstl, U., Wirth, V., Elands, B., Bell, S., 2010. Management of Recreation and Nature Based Tourism in European Forests. Springer, Berlin, Heidelberg
https://link.springer.com/book/10.1007%2F978-3-642-03145-8#about

[14] Timmins, C., Murdock, J., 2007. A revealed preference approach to the measurement of congestion in travel cost models. J. Environ. Econ. Manag. 53, 230-249 or

[15] Marzano, M., Dandy, N., 2012. Recreationist behaviour in forests and the disturbance of wildlife. Biodivers Conserv 21, 2967-2986.

[16] Andersson, E., Tengo, M., McPhearson, T., Kremer, P., 2015. Cultural ecosystem services as a gateway for improving urban sustainability. Ecosyst Serv 12, 165-168.

Demand side considerations

Distinguishing benefits from ecosystem services is a key requirement from the demand perspective.

The comprehensive conceptual framing of Fish et al[17] defines cultural ecosystem benefits as dimensions of well-being associated with with cultural spaces and practices including identities (e.g. belonging, sense of place, rootedness, spirituality), experiences (e.g. tranquillity, inspiration, escape, discovery) and capabilities (e.g. knowledge, health, dexterity, judgement).

Havinga and Hein conceptualise cultural ecosystem services as **information flows** to humans[18]; **benefits** from cultural ecosystem services are realised when information flows are transfered to humans through the senses, thanks to some input of energy, effort, or labour[19]. In this framing, recreational **activities** are indicators of recreation benefit (number of trips and distance travelled). In an economic travel choice framing of recreation, travel time and expense, together with the recreation services, are the inputs required to realise benefits of recreation activity.

In an epidemiological framing by Markevych and coauthors[20], physical activity is one of several pathways mediating/moderating health and well-being. Their recent review distinguishes three pathways as mediators between greenspace and outcomes for individual health and well-being:

- Reducing harm (e.g. mitigation of exposure to air pollution, heat and noise)
- Restoring capacities (e.g. attention restoration and psychophysiological stress recovery)
- Building capacities (e.g. encouraging physical activity and facilitating social cohesion)

In this framing and individual’s mental and physical health are longer term benefits, while view enjoyment of a single visit could be seen - from an economic point of - as an input in a household’s production of health. The benefits of recreation are both short term (marginal) and long term (integral).

These different framings define recreation activity indicators as a metric for the recreation service or benefit, depending on whether the framework extends to health and well-being or not.

A further question on the demand side is determining who might use recreation services. Since all ecosystem types are potentially in scope, then it should be clear that potential users extend to include local residents and visitors travelling from their usual environment to other areas including people travelling internationally. Local, national and foreign visitor populations are accounted for in changes in the value of visits to a recreation site. The

[17] Fish, R., Church, A., Willis, C., Winter, M., Tratalos, J.A., Haines-Young, R., Potschin, M., 2016a. Making space for cultural ecosystem services: Insights from a study of the UK nature improvement initiative. Ibid. 21, 329-343.
[18] Havinga, I. and L. Hein “Clarifying cultural ecosystem services” Research Note (22 November 2018).
[19] Braat, L.C., de Groot, R., 2012. The ecosystem services agenda:bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosyst Serv 1, 4-15.
[20] Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A.M., de Vries, S., Triguero-Mas, M., Brauer, M., Nieuwenhuijsen, M.J., Lupp, G., Richardson, E.A., Astell-Burt, T., Dimitrova, D., Feng, X.Q., Sadeh, M., Standl, M., Heinrich, J., Fuertes, E., 2017. Exploring pathways linking greenspace to health: Theoretical and methodological guidance. Environ Res 158, 301-317.

distinction matters only in terms of practical challenges of modelling differences in their travel choices and costs.

Thus, urban open spaces should be measured as providing services to both local residents and those visiting from other parts of a country or other countries. National parks in remote areas should be measured as providing services to all visitors. Some measurement techniques tend to focus on understanding demand for particular groups of people (e.g. incidental, day trips, overnight trips), but the measurement of demand should not be limited in such a way from a conceptual perspective.

Policy issues, such as environmental justice, may justify compiling accounts which identify users with specific socio-economic status. For example, developing green spaces may be considered as a measure to reduce income-related inequality in health. Several studies show that the health benefits of green spaces are stronger among people from lower social-economic status[21].

Second, since the focus of this service is on people in the ecosystem/landscape, it is relevant to consider what type of activities are in scope and, associated with this, the purpose of those activities. The intention in recreation services is to consider situations in which people are in the landscape for recreation or leisure.

The types of activities will vary from location to location, but will include walking, walking the dog or other pets; physical exercise of different types,including jogging, hiking, biking, horse-riding, swimming, surfing, picnicing, hunting, fishing, gathering berries (excluding subsistence or professional activity of this type), wildlife and bird watching. We tend to list 'activities', but stationary pastimes of rest, study and camping in nature would also be in scope[22]. Both active and passive pastimes[23] in nature may have spiritual and cultural value such as shinrin-yoku (forest bathing). In an accounting framing, spiritual worship of a site, carried out on-site, would be in scope, while carried out off site would be considered a non-use and out of scope of recreation services.

Different metrics for ecosystem condition enabling recreation would be required for different types of activity:

- recreation services where the space for physical movement is key,
- passive aesthetic/appreciation type services where the quality of the 'view' is key,
- and possibly passive aesthetic/appreciation where views are not key, but other sensory qualities of the location are most important (sound, smell, temperature)

The classification above considers terrestrial recreation. Further thought is needed regarding qualities necessary for specialised water-based recreation (e.g. boating, diving).

The focus on recreation excludes from scope those in the landscape who are 'doing their job', such as farmers, foresters, guides, instructors, surveyors, transport etc. This is not to say that these people are not gaining an ecosystem service of some type from being in the landscape, but this is not included in the scope of measurement for this recreation service (see section below on related services).

[21] See ibid.

[22] requiring a metric that does not measure mobility

[23] The word "pastime" to describe both the physically active and passive enjoyment of nature suggests time as an intuitive metric.

This raises a measurement boundary issue. Recreation experienced incidentally as part of trips for other purposes – trips to and from work or in transport - might be excluded. However, the choice to walk or bike to work, and the choice of route, may be made – not incidentally - but partly for recreational purposes, due to environmental qualities enabled by vegetation and water. Some cities make large investments in providing connectivity through green infrastructure for walking and biking, for multiple purposes other than travel to and from recreation destinations. Weekday work-related travel time may exceed time allocated primarily for recreation on weekends. Excluding the restorative benefits of green infrastructure for work-related transportation would exclude a significant benefit of relevance for policy.

Also on the measurement boundary, hunting, fishing and gathering of berries and mushrooms for subsistence might be physical and mentally restorative, but the activity might not be considered primarily for recreation. Extending this logic further, community gardening in urban areas might be excluded if the primary purpose is considered subsistence, discounting health and social benefits because they are secondary. In high income countries the consumption benefits will often be incidental, and the activities considered for recreation.

Finally in terms of scope, there is a question of whether services arising from passive viewing of the environment may be excluded from scope of recreation services. The distinction between passive and active views may be relatively clear in the case of views of natural elements from the home[24], which may also be an important component in the overall value of a house. The distinction is not clear when people are in the outdoors outside their home, where qualities of views are experience in both passive and mobile recreation activities. Also, property pricing data captures both passive views and active recreation opportunities around the home. Further discussion on the boundary and the potential for measurement to distinguish between these aspects of generating benefits is needed. Note that passive views are not the same as 'non-use' values which arise without physical presence of a person.

Beyond direct health and well-being benefits from recreation services there would be broader benefits that may relate to economic and employment benefits that arise from people and business who support or earn income related to people's recreation in the environment. Community gardens are a special case, confering subsistence, social cohesion and some income, in addition to recreation.

It is evident from this scoping that significant recreational benefits may not be accounted for because they are secondary, incidental(but perhaps large in cumulative terms). A question for broader discussion is the appropriate treatment of what may be best termed *secondary production of ecosystem services* arising through single interactions between individuals and the environment.

In accounting for a recreation service, the issue is not the type of activity, but that greenspace is used as the setting. The following high level categorisation may be useful:

- **Nature-based recreation**, where the habitat or environment are essential to the recreation activity (bird-watching, kayaking, surfing, fishing etc). With nature-based recreation, the demand for those activities would fall to zero if the natural environments in which they took place were lost. Nature-based recreation may

[24] Kaplan, R., 2001. The Nature of the View from Home:Psychological Benefits. 33, 507-542.

take place in restored, constructed, and managed nature such as boating and fishing in stocked artificial reservoirs.

- **Nature-enhanced recreation**, where the habitat or environment make the experience better, but are not essential for the choice of e.g. jogging, walking, dog-walking, cycling in urban areas. With nature-enhanced recreation, loss of nature could be substituted by other non-natural settings (e.g. an indoor gym).
- **Incidental recreation** where the primary purpose for being outdoors is not recreation, but brings one incidentally into contact with nature recreation (a secondary production).

Summary

Recreation services are challenging to distinguish from their benefits and values. Recreation services are described in terms of different concepts, including opportunities, characteristics enabling recreation (such as accessibility), information flow and health. Recreation services supply is enabled by built infrastructure and maintenance. Recreation services use is enabled by amongst others norms and regulations, organized activities and provision of public safety. Different classifications of recreation service benefits serve different purposes, and articulate different aspects of value.

1.2 Similar and related ecosystem services

A listing of similar and related ecosystems is provided below in order to encourage thinking about possible data sharing and double-counting issues between recreation services and other ecosystem services. Recreation services as discussed above overlap with other types of cultural ecosystem services, and with provisioning and regulating services.In some cases, the overlap of definitions may not be evident or questioned until metrics are specified.

Key related ecosystem services are listed below.

Subsistence and own-consumption fishing and hunting, foraging and gathering of non-forest timber products such as berries and mushrooms are considered provisioning services, with market substitutes for the physical products.

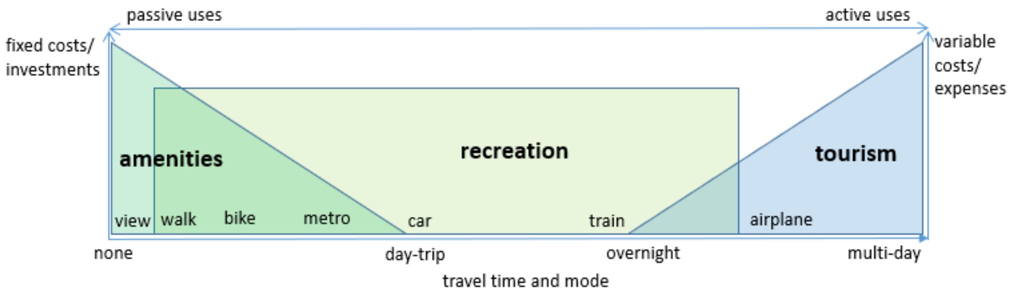
Knowledge and appreciation of the **existence** of a nature area without a physical presence of the person confers non-use value which may have restorative effects.

Habitat related services provide biodiversity, habitat and wildlife observation opportunities as characteristics of the recreation location.

Amenity services as observed through property prices may capture benefits of both passive views from the home and recreation opportunities close to the home.(Box 1)

Following the structure of Havinga and Hein's description of cultural ecosystem services, there will also be connections to amenities, as well as aesthetic and artistic services which are generated through peoples' more passive engagement with the landscape. As well, in terms of the scope of activities, engagement with the environment for scientific and educational purposes, and religious and spiritual purposes will also connect closely to activities for recreation and leisure.

Box 1 Potentially overlapping definitions of amenity, recreation and tourism services and double counting



'Amenity', 'recreation' and 'tourism' services can be defined on gradients from passive to active use, of travel time, and they also vary in terms of using fixed capital or variable expenditure costs to estimate values. When amenity, recreation and tourism services definitions are overlapping on these gradients, and different valuation methods are used on each type of service, there is a possibility of double counting. For example, property prices may internalise lower variable costs of travel to local recreation destinations. Valuation of attributes contributing to property values can be carried out using hedonic property pricing. Attributes of the properties neighbourhood (within walking, biking, public transport distance) often include recreation areas. Often values determined by hedonic property pricing are called 'amenity values'. In this definition, amenity values double count recreation values determined using travel cost and choice models. Similarly, holiday homes' property prices may internalise a tourist's expenses on accommodation that enable recreation in a local (natural/urban) park. Rental of sports equipment - e.g. sledges, skiis, boats, climbing equipment - enabling access to local outdoor recreation area may capture both use values from local residents and visiting tourist recreationers. If this local recreation is also valued using hedonic pricing and/or travel costs there may also be double counting.

A longer summary of links to other cultural ecosystem service types as described in Havinga & Hein (2018) is in Appendix 2. It is also noted that regulating services support air, water, sound, and thermal qualities which may be important characteristics of the recreation location. These would be referred to as amenities where they can be mapped as attributes of property.

1.3 Recreation services 'logic chain'

Figure 1 provide two alternative logic chains describing assets, service, benefits and enabling factors. The assets are open space composed of vegetation and surface water. The difference in interpretations of recreation service lies in whether the service is defined by (1.1.) characteristics enabling recreation or (1.2) perceived quality of the recreation experience or proxy indicators of quality such as time-spent or visitation frequency.

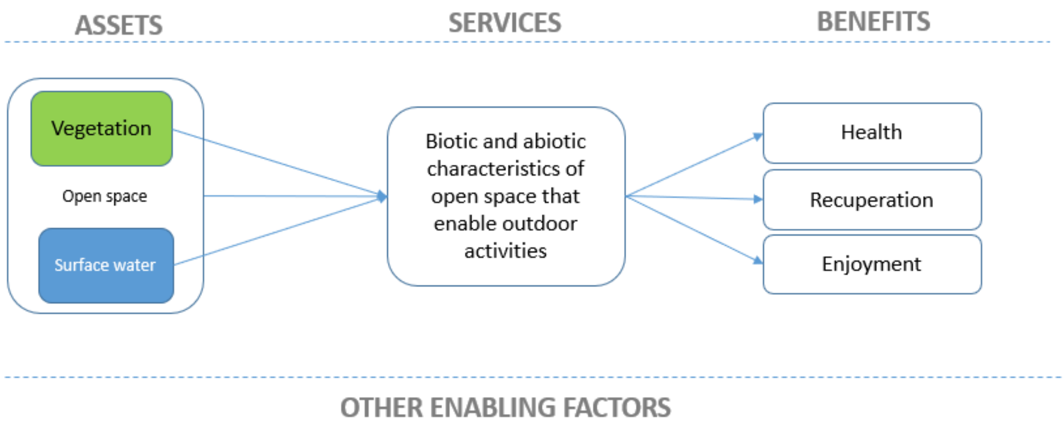


Figure 1.1 A 'logic chain' for outdoor recreation services and benefits defining enabling characteristics of open spaces as services (CICES approach)

Figure 1.1 uses our CICES-based definition of recreation service is 'biotic and abiotic **characteristics** of open space **that enable** health, recuperation and enjoyment **through outdoor activities**'. Note that the benefits in this definition are health, recuperation and enjoyment, with outdoor activities being a mediator of benefit. In other words, indicators of outdoor activities are proxy indicators of recreation benefits. The drawback of this definition of recreation services is that asset 'condition' and 'service' are not easily distinguished. Furthermore, the definition of recreation activities as a mediator/proxy of benefit, is unfamiliar to environmental economics, where visitation data have for long been equated with recreation benefit. Possibly, the relative ease in obtaining available visitation data has established this definition of recreation benefit in environmental economics, while other literatures define recreation benefits from a perception of well-being or health end-points.

Another conceptual problem is that enjoyment, recuperation and health are not mutually exclusive types of benefit, but nested. Enjoyment is in situ and immediate, recuperation may extend beyond the recreation experience on the short term, whereas health is integrative extending potentially to a person's lifetime.

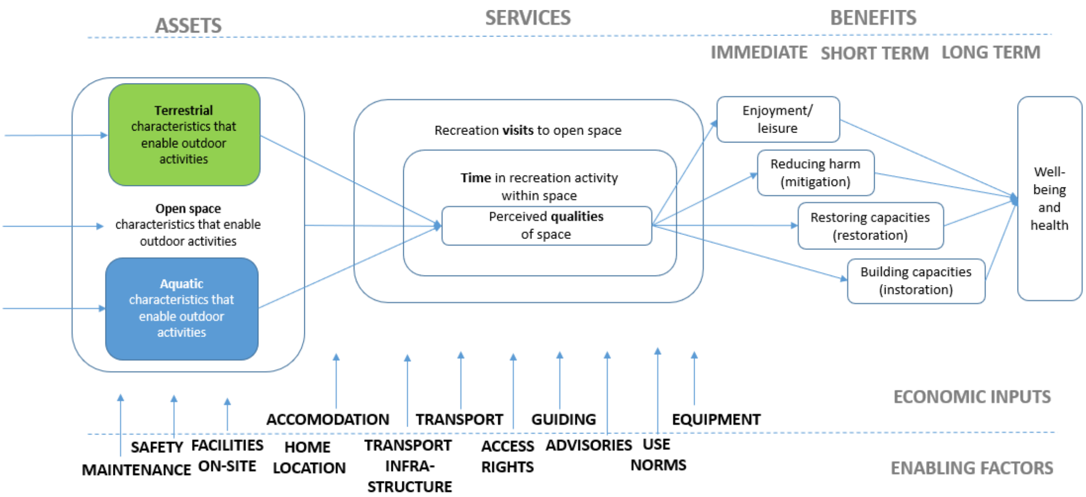


Figure 1.2 A 'logic chain' for outdoor recreation services and benefits. Perceived qualities of recreation site are identifies as services (or proxy indicators of recreation quality such as time spent and visitation frequency)

Figure 1.2 provides an alternative framing based on proxies of perceived recreation quality of the open space. In this approach ecosystem asset characteristics (condition) potentially enables recreation. The service is the subjective 'percieved qualities' of the recreation experience. The large environmental psychology literature on self-reported recreation experience provides many qualitative metrics, but does not provide accountants with guidance on whether to call these experiences "services" or "benefits". Since subjectively perceived recreation qualities cannot be observed directly, proxy indicators are used. Social media photos and tags provide indicators of site perception. A second best proxy of perceived quality of a site could be time spent in a specific recreational activity, assuming time spent is correlated with exposure to activity-specific site qualities. A third best proxy could be time spent in the recreation space without specifying the activity, assuming time spent is correlated with non-specific site qualities. A fourth best proxy of site qualities is the frequency of recreation visits, for specific or general activity purposes.

We note a duality in the use of time as an indicator of recreation services. Travel cost methods convention treats travel time as an opportunity cost. Applying the same convention to time on-site would also treat time as an indicator of opportunity cost. However, travel cost researchers will soemtimes take a fraction of travel time as opportunity cost, recognising that travel may have recreational benefits. Time on site could be recognised both as a proxy indicator for the quality of the recreation experience, and as an input from the household time budget to the production of leisure.

We also note that how far we extend the logic chain determines how we frame the production boundary of recreation, and whether time on site and visitation frequency are interpreted as as proxy indicators of service or a benefit. If we do not consider health as the end-point, then visitation frequency is more easily thought of as an indicators of final benefit.

Looking 'upstream' in the logic chain we can also note that a number of regulating ecosystem services are part of the ecological production function and intermediate to the recreation service (Figure 1.3).

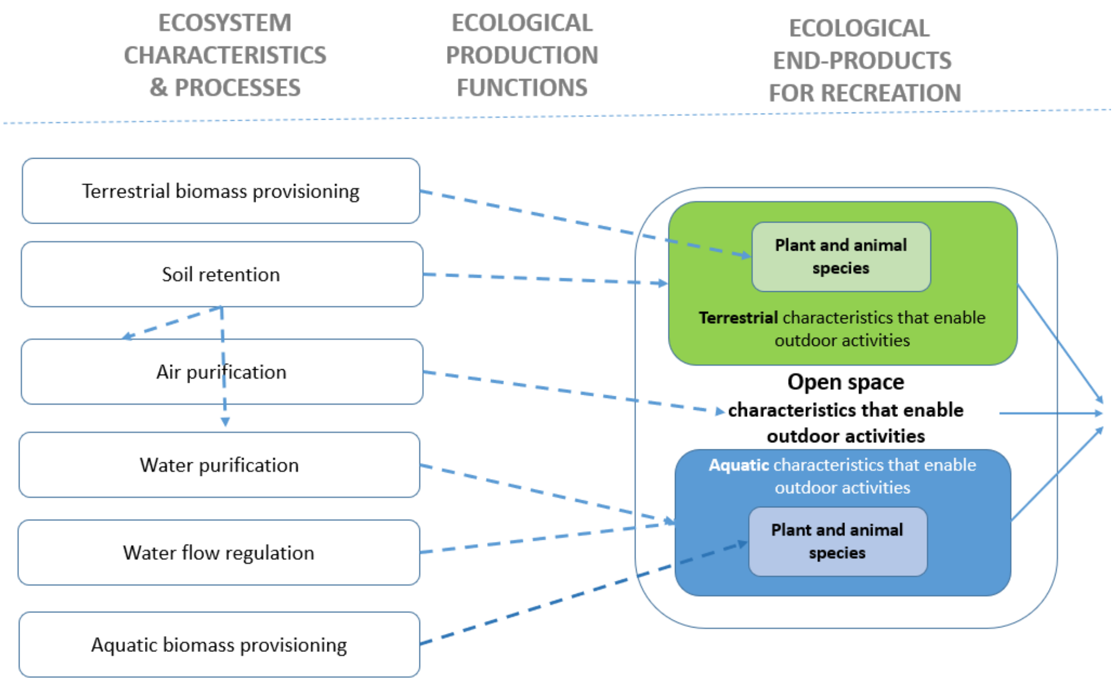


Figure 1.3 Regulating ecosystem services as intermediate in the ecological production functions providing recreation site qualities

Enabling factors specified in Figure 1.2 are artificial contextual characteristics that are additional to the natural biotic and abiotc characteristics provided by intermediate regulating ecosystem services. Man-made enabling factors are relevant for ecosystem accounting for predicting potential supply and actual use. When enabling factors are un-accounted for, they may be confounding factors in estimating and interpreting accounting data on recreation services and benefits.

Box 2 below further explains the different types of **enabling factors** and economic inputs from the large spatial scale to the lower scale with finer resolution. The purpose of discussing the complexity in enabling factors is to recognise that any chosen model of recreation services, benefits and values will apply a number of simplifying assumptions, although these are likely to be quite useful if they are accounting compatible and applied consistently over time.

Enabling factors can be also seen as economic inputs to recreation with observable and attributable fixed and costs. Rental of accomodation, transport, equipment and on-site facilities are intermediate and complementary business service inputs to recreation. Different levels of inputs and enabling factors distinguish amenity, recreation and tourism services. Tourism is associated with multi-day long distance travel, mobility, activities and higher expenses on business service inputs that facilitate recreation. At the other extreme, amenities are associated with close proximity to home - there are no marginal monetary expenses for passive recreation such as viewing, but high fixed costs for property location. Recreation is an overlapping concept in between these gradients, enabled with a variable mix of fixed (e.g. equipment) and variable (e.g. travel) costs (Box 1). The concept of a gradient of enabling factors is consistent with the establised 'recreational opportunity spectrum' framework in recreation literature.

Box 2: Types of enabling factors

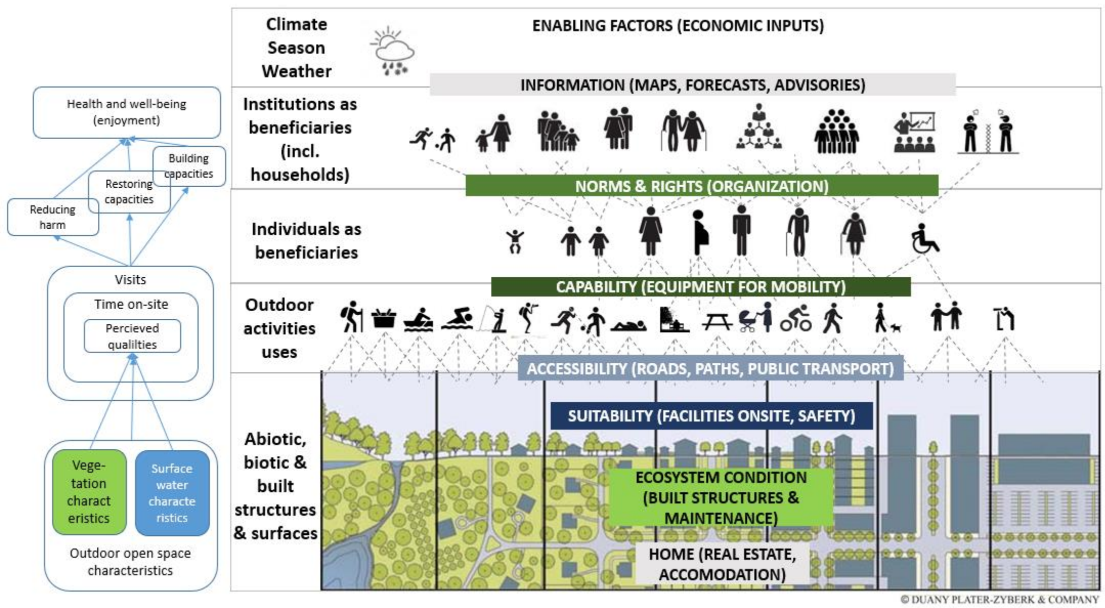


FIGURE 2. Enabling factors, spatial heterogeneity and urban-rural gradients of recreation services Source: adapted Barton (2016). Illustration transect: Duany Plater-Zyberk & Company. https://transect.org/ Icons Shutterstock Icons Shutterstock

Enabling factors are shown as levels (colour labels) and economic inputs that enable recreation are indicated in (parentheses). Enabling factors are organised roughly in a nested fashion with the highest spatial and conceptual scale at the top and lower spatial scale and higher resolution at the bottom.

Summarising the discussion above, Figure 2 builds on Figure 1.2, providing an overview of the enabling factors of outdoor recreation, and a visualization of characteristics defining spatial heterogeneity of recreation contexts. The "recreation services logic chain" seen here has a nested structure of enabling and mediating factors.

A standard enabling factor for recreation is a person's **home location**, providing access to local recreation opportunities. Home proximity to open spaces enables physical recreation activity at low marginal cost, as well as providing passive views and aesthetics on and from the home at no marginal cost. Real estate ownership or rental are the economic inputs enabling local recreation access, whether from home as primary domicile or for leisure. The neighbourhood area or 'home range' that is considered relevant for well-being by home buyers and sellers in a real estate market depends on their physical movement, often for the purpose of recreation[25]. In urban areas where car use is lower, home range is expected to be larger, and potential double counting of recreation values using visitation-based valuation and hedonic pricing methods is expected to be higher.

Access to recreation depends furthermore on individuals' **physical and mental capabilities**. Variations in capabilities by age, gender and physical or mental condition, as well as individual knowledge and skill sets, are predictors of recreation demand across a spectrum of activities.

Social economic capabilities. In some countries lower income households will have poorer access to transportation. Some greenspaces and neighbourhoods may have poorer perceived personal safety, discouraging mobility. Personal affinity to greenspace may be determined by life history (e.g. habits from childhood), rather than current proximity. These factors can introduce bias into recreation modelling if not taken into consideration (for example, first generation immigrants may have different greenspace preferences from established residents, and be less likely to participate in public surveys).

Recreation activities using outdoor/open space sort individuals across a **recreational opportunity spectrum** indentified by gradients of abiotic, biotic and built attributes of the landscape. **Multi-purpose trips** complicate attribution of ecosystem demand to specific recreation activities. Distinguishing recreation activities may be necessary if there is different willingness to pay for different activities. However, physical quantification of recreation demand can be indicated by visitation rates, travel effort and time-on-site where demand for specify specific activities or site quality requirements is 'baked into' (endogenous to) the overall decision to travel and allocate time to recreation.

Potential recreation supply is enabled by **artificial or built inputs** providing facilities for recreation:

- physical accessibility enabled by infrastructure such as roads, parking and public transport to the location, and paths on-site.
- the 'natural' suitability of an area for a particular recreation activity can be further enabled by recreation facilities on-site. Facilities such as rest-rooms, paths and sign posting are example of on-site enabling economic inputs.
- as noted above, ecosystem condition of a recreation area could be defined as the biotic and abiotic attributes such as vegetation cover, composition and complexity; wildlife visibility, water quality (lakes, rivers) and flow (rivers, streams).
- economic inputs to ecosystem condition include built structures providing regulating services for environmental quality (e.g. dams, water treatment plants), landscaping, maintenance of vegetation and wildlife management activities. Organizational inputs include planning, design and construction.

The planning, infrastructure and management costs of public greenspaces may be borne by the public sector or community stewardship. These inputs are relevant for accounting because they represent costs of supplying a recreation opportunity spectrum (ROS). Under public open access or common property/stewardship institutional regimes they are supplied at levels which are not the same as if access could be legally or physically restricted and charged for either by a public or private owner.

[25] Forman, R.T.T., 2008. The urban region: natural systems in our place, our nourishment, our home range, our future. Landscape Ecol 23, 251-253.

Formal **property and use rights** provide further information on access and permitted activities[26]. Social groups enable recreation by providing site knowledge, and information on informal norms of use. Institutions and social groups also enable individuals' capabilities by transmitting knowledge and skills required to engage in recreation requiring specialised equipment (e.g. skiing, climbing). Both training in the use of recreation equipment and the equipment itself are economic inputs to recreation service. Differences in access and use rights across greenspaces is usually proxied in recreational modelling using formal management designations (urban parks, national parks, nature reserves etc.). In some countries informal access and use rights might not be visible in the mapping of ecosystems. There may be differences in accessibility between greenspaces due to hunting and harvesting rights which have an unobserved and indicental effect on recreation. Differences between countries may mean that recreation service valuation methods that work for a given ecosystem in one country are institutionally incompatible in another. For example, there may be constitutionally guaranteed public access rights to private unmanaged nature in one country, while being only de facto permitted, but not legally protected in another. Where access prices cannot be charged, valuation methods assuming that they can may be computable, but not credible nor consequential for policy.

Climate, season and daily **weather** can determine access to recreation locations and enjoyment on site over larger areas. Economic inputs facilitating and improving the recreation experience include information on accessibility, weather and site conditions (precipitation and temperature) such as adverts, promotions, visitor maps, trip advisories and weather forecasts. Forecasting and advisories **information** is particular important for boating generally and sailing specifically. Temperature, snow depth and ice thickness forecasts and advisories are key informational inputs to winter sports in particular cross-country skiing and ice skating on lakes and coastlines. For winter sports activities open "white space" is a characteristic of the asset. If seasonal factors occur unequally across an accounting area, within an accounting period, they may affect visitation rates in ways that introduce noise into recreation modelling.

[26] Biernacka, M., Kronenberg, J., 2018. Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces. Urban for Urban Gree 36, 22-33.

2. Measuring the ecosystem service

This section discusses physical metrics used in measuring recreation service flows and recreation benefits. Following the logic chain above, it would seem reasonable to proceed by selecting accurate and reliable metrics for assets, then services related to those assets, and finally benefits associated with services (i.e. from left to right in Figure 1).

However, in applied studies, the selection of metrics and methods often does not follow such a step-by-step logic chain. In most of the examples the data available, the metrics, the statistical methods and the definition/partitioning of the ecosystem service are defined collectively. This makes it challenging to separately identify metrics and methods for physical measurement of recreation services without also discussing the valuation of benefits.

Photo: David N. Barton

Photo: Axel Heymann

What types of vegetation and what types of activities are within scope for recreation services in ecosystem accounting?

2.1 Ecosystem service modeling approaches to describing ecosystem characteristics

As indicated in Figure 2, recreation activities can take place across a urban-rural gradient. At one extreme, in wilderness with no man-made modification or infrastructure, and at the other extreme in a completely built environment. The first thing to note is that the distinction between ecosystem extent and ecosystem condition is fuzzy as one moves across a gradient of unbuilt-to-built land. Ecosystem classification is often based on break points in land cover and land use - for example the building density at which a mapping unit switches from a rural landuse to urban/built land – or the tree canopy density at which an area ceases to be classified as forest.

Modelling approaches deal with continuums of ecosystem characteristics slightly differently, combining some of the same metrics as "landscape gradients", "destination choice attributes" or "property amenities":

- **Landscape gradients.** Recreation supply mapping methods such as ESTIMAP [27] construct composite indicators of a gradient of recreation potential, by combining

[27] Zulian, G., Paracchini, M.L., Maes, J., Liquete, C., 2013. ESTIMAP: Ecosystem services mapping at European scale. JRC Technical Report EUR 26474 EN
Paracchini, M.L., Zulian, G., Kopperoinen, L., Maes, J., Schagner, J.P., Termansen, M., Zandersen, M., Perez-Soba, M., Scholefield, P.A., Bidoglio, G., 2014. Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecol Indic 45, 371-385.

many map layers of biotic, abiotic and built features, including access and on-site infrastructure[28] referred to in Figure 1, as enabling factors.

- **Destination attributes.** Recreation choice modelling such as ORVal[29] are based on destinations for recreation day trips which each have clearly designated boundaries and are used to measure travel distances (municipal parks, cemeteries, woods, allotments, nature, country, path access points, beaches). Greenspace attributes for each destination include management designation categories, the proportion of different landcovers within the site, and points of interest (e.g. viewpoint, playground). Transport costs to sites they have visited are used to compute marginal willingness to pay for a visit.
- **Property amenities.** Hedonic property pricing models use a combination of gradients (such as air pollution, noise, green density), views (greenview, viewshed) and distances to recreation destinations to describe amenities of a property for the owner.

2.2 Measuring ecosystem condition enabling recreation services

Whether they are ultimately used in valuation methods or not, metrics of ecosystem condition enabling recreation services can have a high information value for policy as stand-alone biophysical indicators. In the following we briefly explain a number of metrics that have been used in the literature to indicate enabling conditions for recreation. In the framework in Figure 1.2 they are potentially perceived recreation qualities. They represent a list of hypothetical variables which may or may not impact the probability that someone selects recreation at a site over some other site and activity.

Insolation and temperature. Insolation time is an important service at certain times of the year and in certain climates, indicating both access to light and thermal comfort of a location/property. Often, but not exclusively, associated with living space and/or passive recreation.

Visibility and viewshed. Visibility measures at their simplest indicate the arc degrees, or percentage of a 360 degree viewshed with open vista, and/or containing qualities of interest, such as view of vegetation. The further away a landscape attribute of interest is in the line-of-sight, the lower the percentage of the viewshed it will occupy. Viewsheds are thus a combined measure of the distance to, and amount of the amenity, that is "viewable". Information about the beneficiary's location choice (and characteristics) is implicit in the viewshed perspective, making it hard to distinguish the recreational services and benefit.

A possible approach to modelling a "beneficiary neutral" viewshed could be to compute public visibility of landscape features known to be important for recreation. This is relevant in an urban context where vegetation and water may be on private land and blocked from public view. Here visibility analysis can compute the proportion of the attribute that is

[28] Zulian, G., Stange, E., Woods, H., Carvalho, L., Dick, J., Andrews, C., Baró, F., Vizcaino, P., Barton, D.N., Nowel, M., Rusch, G.M., Autunes, P., Fernandes, J., Ferraz, D., Ferreira dos Santos, R., Aszalós, R., Arany, I., Czúcz, B., Priess, J.A., Hoyer, C., Bürger-Patricio, G., Lapola, D., Mederly, P., Halabuk, A., Bezak, P., Kopperoinen, L., Viinikka, A., 2017. Practical application of spatial ecosystem service models to aid decision support. Ecosyst Serv.

[29] Day, B., Smith, G., 2018a. Outdoor Recreation Valuation (ORVal) User Guide: Version 2.0, Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter. , Day, B.H., Smith, G., 2018b. Outdoor Recreation Valuation (ORVal) User Guide: Version 2.0, Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter.

privately/publicly visible, without specifying any specific use or beneficiary (this is however computationally very intensive to do for all objects of interest in an accounting area).

A GIS based modelling of viewable features is distinct from perceived views (what qualities are subjectively experienced).

Air quality, water quality, smell. Air and water pollution can be measured using objective biophysical indicators. Air and water quality are mediated by dispersion and dilution as a function of the volume of the recipient airshed or water body and mediated by biota (vegetation, algae). Biota's mediating effect on air and water quality can also be classified as a regulating ecosystem service. Air and water *quality* and smell can be assessed using perceptible visual qualities (smoke, smog, water opacity, algae) and smells as nuisances. Exposure, conditioning and existing pollution/health standards condition subjective perception of objectively measured air and water pollution metrics. Vegetation also has natural smells (e.g. terpenes) for which there are some evidence showing health benefits[30].

Sound. Absence of sound measured in dB can be defined as an ecosystem condition generated by landform and vegetation absorbing soundwaves that potentially enables recreation. The absence of sounds that are perceived as nuisances – noise – can be defined as a recreation service (perceived quality). Above a threshold certain sounds can become a nuisance, while others are perceived restorative, depending on the subject. Natural soundscapes including sound of water, wind, vegetation, wildlife and other people can provide sound qualities to a location. Silence may not be perceived as a quality of the location if there is no spatial variation/gradient in noise levels. Exposure and conditioning changes subjective perception of objectively measured sound. Noise mitigation and sound qualities (e.g. birdsong) mediated by vegetation and as wildlife habitat can be interpreted as both supporting and regulating ecosystem services. Sensory maps of natural noise and smell perception based on social media tags may be used as an indicator of recreational ecosystem services[31]. (The definitions of ecosystem condition, service and benefit are easily entangled. The distinction between recreation service as perception of nuisance sound, and recreation benefit as on-site enjoyment of its absence, is unclear, but perhaps unnecessary for valuation for accounting purposes. On the other hand making a distinction between immediate on-site enjoyment and health benefits on the long term of stress reduction is significant.)

Structural diversity. Recreation areas can be characterised by the diversity of abiotic, biotic and built structural features present, as a proxy for functional diversity[32]. Some structural complexity may enable recreational use, or the opposite may be true as well. For example, dense forest structure can prohibit some forms of recreation (e.g. running) or invite others (e.g. bird watching). Visual physical characteristics of recreation areas are interpreted by people in terms of composite recreation experiences[33]. Composite and subjective concepts

[30] Pacifico, F., Harrison, S.P., Jones, C.D., Sitch, S., 2009. Isoprene emissions and climate. Atmos Environ 43, 6121-6135.

[31]Quercia, D., Schifanella, R., Aiello, L.M., McLean, K., 2015. Smelly Maps: The Digital Life of Urban Smellscapes. In Proc. of the 9th International AAAI Conference on Web and Social Media (ICWSM), 2015, Aiello, L.M., Schifanella, R., Quercia, D., Aletta, F., 2016. Chatty maps: constructing sound maps of urban areas from social media data. Roy Soc Open Sci 3.

[32] Soy Massoni, E., Rusch, G., Barton, D.N., Gundersen, V., 2018. Bigger, more diverse and better? Mapping structural diversity and its recreational value in urban green spaces. Ecosyst Serv https://doi.org/10.1016/j.ecoser.2018.02.013.

[33] Experiential qualities of outdoor recreation areas in environmental psychology studies use a more composite typology , e.g. "Serene, Space, Nature, Rich in Species, Refuge, Culture, Prospect and Social". Grahn, P., Stigsdotter, U.K., 2010. The relation between perceived sensory dimensions of urban green space and stress restoration. Landscape Urban Plan 94, 264-275.

of landscape experience such as “coherence, legibility, complexity, mystery” can be statistically significant predictors of preferences for landscapes[34], while individual physical attributes of recreation areas may not be significant[35]. Given this complexity, aggregate classifications of recreation areas in terms of functional types for different observed multiple use profiles - also called sociotopes[36] - may be more feasible than attempts to quantify specific structural characteristics of ecosystem condition that enable recreation.

Species visibility. Likelihood of observing fauna and flora species within a defined recreation area such as a private garden, city street, public park, public wood, and conservation area could be interpreted as an ecosystem condition enabling recreation. Information about species that are perceived as qualities and species perceived as nuisances/disservices, is needed to determine the recreation service.

Greenspace walkability. Walking distance in a street network weighted by vegetation coverage along the route, can be measured by e.g. satellite-based Normalized Difference vegetation Index (NDVI). These are conditions that potentially enable recreation. The perception of walkability of different surfaces) and landscape and streetscape forms (with/without vegetation) is required to identify the recreation service.

Proximity to amenities. Euclidean/walking distance/proximity to amenities from home are used as access time indicators in hedonic property pricing to infer the capital value of the amenities. Proximity and access time enables recreation, but it is not normally an ecosystem condition (e.g. absence of vegetation on paths is a service, but not of the ecosystem). Access time can be used to infer qualities of the amenities in hedonic pricing when they are not measured directly. For example, differences in the marginal price effect of proximity to different city parks of the same size and at the same distance could reflect unobserved recreational qualities - amenities - of the park. A common challenge in hedonic property pricing is choosing a priori which GIS observable neighbourhood characteristics to include in a model. Characteristics are potentially enabling for recreation, but only the significant variables will be amenity services (or proxies for recreation services). The benefits of proximity to amenities are unobservable in property price studies, so service and benefit are easily conflated in the discussion (and we can ask whether the distinction is necessary for accounting purposes).

Actual and perceived safety. Absence of rubbish, vegetation maintenance providing visibility and actual incidence of crime are potentially enabling conditions of a greenspace for recreation. In urban green space up to 50% of a total maintenance budget may be dedicated to cleaning[37]. In areas where funding for public green spaces has been drastically diminished, cleaning and general upkeep has been neglected and use has fallen. An areas’ cleanliness can be a predictor of users’ sense of safety and of visitation. Sense of safety is a subjectively measured quality and as such would be defined as a recreation service. While absence of vegetation may explain sense of safety, it is not a service, but an input to the recreation service of a greenspace, conceptually similar to perceived safety through policing.

[34] Kaplan, R., Kaplan, S., 1989. The experience of nature: A psychological perspective. Cambridge University Press, New York.
[35] Kaplan, R., Kaplan, S., Brown, T., 1989. Environmental Preference:A Comparison of Four Domains of Predictors. 21, 509-530.
[36] Ståhle, A., 2006. Sociotope mapping – exploring public open space and its multiple use values in urban and landscape planning practice. Nordic Journal of Architectural Research 19, 59-71.
[37] Pers.com. Thomas Randrup

2.3 Measuring recreation services in quantitative and qualitative terms

In the following we try to explain metrics for recreation services in light of the framework in Figure 1.2 where perceived ecosystem quality is the targeted concept for recreation services. The following metrics are largely proxies for perceived quality *in situ* and in the short term.

Potential visitation of a local recreation site in its simplest form is estimated based on a definition of a population within a "service area" – an estimated maximum distance for walking – to a recreation areaLarger recreation sites with more attractions have been observed to have higher willingness to walk, but no site or individual information about the beneficiary is used in this simplest of approaches. Because it is simple the approach is often used in GIS based modelling of recreation absent onsite use or preference data. Potential visitation is second or third best service proxy because the service area is a stock, and the magnitude of potential recreation demand is driven only by population[38]. It is not sensitive to changes in recreation preferences other than at a macro level through change in population.

Predicted visitation uses characteristics of the location and respondents to predict visitation rates. A more targeted indicator of enjoyment/benefits would predict return visits, rather than all visits. A trip-distance-decay function / trip generation function shows the percentage of the population that would access a site for recreation purposes at different distances from a green space. Increasingly sophisticated travel choice models identify site qualities (e.g. size) and individual capabilities (e.g. age, mode of transport) to identify underlying preference parameters and predict visits within a service area. The data is obtained froma sample of the population providing recall/diary data about trip modes, lengths and destinations. Predicted visitation is necessary to predict future service flows needed to estimate asset values.

Actual visitation is distinct from potential and predicted visits in that it is based on actual visitation frequency using e.g. trail counters, registration of admission (tickets) and overnight stays in accommodation. Measurement of actual visitation is needed for use accounts of recreation. Measurement needs to be accurate enough to observe marginal changes in actual visitation due to changes in ecosystem extent and condition. Visitation can be counted using counters, entry-exit logs**,** or tracking using GPS-based apps, and GSM/mobile network tracking of visitors' mobile phones. Privacy laws may hinder tracking of individuals, with mobile network operators offering data aggregated to a minimum (e.g. in Norway aggregation of data from 5 users, and positions within 50 meters). This should be sufficient to account for aggregate visitation.

Time on-site has until recently[39]. not been measurable across a visitor population in any practical way. We hypothesise that it may be a better proxy indicator of recreational service (perceived quality) than visitation rate. To our knowledge there is as yet no economic evidence to support this claim.. Time-on site can be measured using entry-exit logs**,** or tracking using GPS-based apps, and GSM/mobile network tracking of visitors' mobile phones. Privacy laws and data aggregation mean that this data may be sufficient for

[38] Fenichel, E.P., Abbott, J.K., 2014. Heterogeneity and the fragility of the first best: Putting the "micro" in bioeconomic models of recreational resources. Res Energy Econ 36, 351-369.
[39] De Nadai, M., Staiano, J., Larcher, R., Sebe, N., Quercia, D., Lepri, B., 2016. The Death and Life of Great Italian Cities: A Mobile Phone Data Perspective. arXiv:1603.04012v1 [cs.CY] 13 Mar 2016.

estimating total time on-site, but not for calibrating travel choice models (which need individual choice data).

The density of social media posts such as Flickr have been used as a proxy for visitation frequency[40]. Social media posts and tags could furthermore be classified using dictionaries of activities and positive and negative affect words[41].

Subjective metrics of recreation experiences include stated levels of enjoyment for example on a qualitative Liekert scale[42], or stated likelihood of a return visit. Metrics of particular usefulness for ecosystem accounting are ones that can be applied in surveys that are representative of populations and specific to physical recreation sites and their qualities[43]. Because they are stated levels of enjoyment these are qualitative metrics of benefits.

Perceived quality of views. The definition of a viewshed depends on the location of a person. For the purposes of accounting, the supply of viewsheds cannot be computed without defining specific locations of recreation (e.g. from homes, tourisk accommodation or paths and trails). The arc degrees of physical sightlines available are a proxy for the perceived quality of the view. The quality of the view depends on the persons vision and cognitive perception, which are in part determined by speed of movement(type of recreation activity). Photos posted on social media (Flickr, Instagram) can be analysed for composition to determine what characteristics of views people wish to share with others. Photos may not be geolocated exactly enough for locations with poor cellphone or GPS coverage, and may represent only segments of the population. If a GIS computed viewshed is not based on any use data, the notions of condition, service and benefit are proxied by one and the same metric. These metrics are of most relevance in describing urban ecosystem services for incidental recreation.

If activity, time-on site or perceived qualities are assigned the label of ecosystem services as in Figure 1.2, then benefit of recreation pertain to more integrative concepts of perceived **well-being** and **health.** We recognise that we cannot cover the vast literature[44] on the links between greenspace exposure through recreation and health[45] in this discussion paper. A brief reference to some relevant literature here serves as a placeholder for considering the question about how *benefits are layered,* and what is within scope in relation to recreation.

- Access to local, safe and natural green spaces can help motivate individuals to exercise. Available evidence, although rather inconsistently, suggest that people living in close proximity to green space might have a higher **propensity to exercise**. Individuals

[40] Wood, S.A., Guerry, A.D., Silver, J.M., Lacayo, M., 2013. Using social media to quantify nature-based tourism and recreation. Sci Rep-Uk 3.
[41] Aiello, L.M., Schifanella, R., Quercia, D., Aletta, F., 2016. Chatty maps: constructing sound maps of urban areas from social media data. Roy Soc Open Sci 3.
[42] Soy Massoni, E., Rusch, G., Barton, D.N., Gundersen, V., 2018. Bigger, more diverse and better? Mapping structural diversity and its recreational value in urban green spaces. Ecosyst Serv https://doi.org/10.1016/j.ecoser.2018.02.013..
[43] Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A.M., de Vries, S., Triguero-Mas, M., Brauer, M., Nieuwenhuijsen, M.J., Lupp, G., Richardson, E.A., Astell-Burt, T., Dimitrova, D., Feng, X.Q., Sadeh, M., Standl, M., Heinrich, J., Fuertes, E., 2017. Exploring pathways linking greenspace to health: Theoretical and methodological guidance. Environ Res 158, 301-317.
[44] WHO-CBD, 2015. Connecting Global Priorities: Biodiversity and Human Health. A State of Knowledge Review, WHO, 2016. Urban green spaces and health. A review of evidence. Copenhagen: World Health Organization (WHO) Regional Office for Europe.
[45] Markevych et al. 2017

exercising in the natural environment are more likely to have **sustained and intense physical activity.** Available studies quantifying the mediation role of physical activity in health effects of green spaces have shown that phsycial activity is a less important mediator compared to other mechanisms such as mental restoration and social cohesion[46].

- Subjective **self-rated health perception** has been found to be related to morbidity and mortality rates and a predictor of health status and outcomes[47]. Moreover, contact with green spaces has been associated with enhanced cognitive development and lower risk of behavioural and psychiatric problems in children[48], improved cognitive function and reduced risk of psychiatric problems such as anxiety and depression[49] in adults, and decelerated cognitive ageing in elderly[50].

Summary of data sources and models linking greenspace characteristics, recreation services and benefits

This section was aimed at listing input data used to identify blue-green extent and condition variables, and modulating/confounding variables for the links between greenspace and recreation services and benefits. The scope of work for this discussion paper has been too limited to conduct a representative review with global coverage. Except for global satellite data, data sources on recreation use are national or local and highly study specific. For example, the Orval model[51] uses over 150 factors used to explain individuals' decisions over recreation in England and Wales (see model description in the next section).

In a recent review of the epidemiological literature Markevych *et al.* (2017) defined different pathways linking spatial measures of greenspace characteristics - through individual behavioural and perceptual mediators and moderators – to health and well-being (Table 1 and Appendix 2).

This 'biopsychosocial pathways' approach is interesting for ecosystem accounting because what environmental psychologists regard as 'individual perceptual mediators', ecosystem accountants would call 'recreation services' from the perspective of sensory information enabling recreation; and what epidemiologists see as 'individual behavioural mediators' ecosystem accountants might call metrics for recreation benefit (revealed behaviour).

[46] Dadvand, P., Bartoll, X., Basagana, X., Dalmau-Bueno, A., Martinez, D., Ambros, A., Cirach, M., Triguero-Mas, M., Gascon, M., Borrell, C., Nieuwenhuijsen, M.J., 2016. Green spaces and General Health: Roles of mental health status, social support, and physical activity. Environ Int 91, 161-167.
de Vries, S., van Dillen, S., Groenewegen, P., P., S., 2013. Streetscape greenery and health: stress, social cohesion and physical activity as mediators. Soc Sci Med. 94, 26-33.

[47] Kardan, O., Gozdyra, P., Misic, B., Moola, F., Palmer, L.J., Paus, T., Berman, M.G., 2015. Neighborhood greenspace and health in a large urban center. Sci Rep-Uk 5.

[48] Dadvand, P., Nieuwenhuijsen, M.J., Esnaola, M., Forns, J., Basagana, X., Alvarez-Pedrerol, M., Rivas, I., Lopez-Vicente, M., Pascual, M.D., Su, J., Jerrett, M., Querol, X., Sunyer, J., 2015. Green spaces and cognitive development in primary schoolchildren. P Natl Acad Sci USA 112, 7937-7942.
McCormick, R., 2017. Does Access to Green Space Impact the Mental Well-being of Children: A Systematic Review. J Pediatr Nurs 37, 3-7.

[49] Gascon, M., Triguero-Mas, M., Martinez, D., Dadvand, P., Forns, J., Plasencia, A., Nieuwenhuijsen, M.J., 2015. Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. Int J Env Res Pub He 12, 4354-4379.
de Keijzer, C., Gascon, M., Nieuwenhuijsen, M.J., Dadvand, P., 2016. Long-Term Green Space Exposure and Cognition Across the Life Course: a Systematic Review. Curr Environ Health Rep. 3, 468-477.

[50]de Keijzer, C., Tonne, C., Basagaña, X., Valentín, A., Singh-Manoux, A., Alonso, J., Antó, J., Nieuwenhuijsen, M., J., S., Dadvand, P., 2018. Residential Surrounding Greenness and Cognitive Decline: A 10-Year Follow-up of the Whitehall II Cohort. Environ Health Perspect. 2018 Jul 12;126(127):077003.

Is the biophysical pathways approach relevant for recreation choice modelling? The 'Biopsychosocial' pathways provides hypotheses for greenplace conditions which can further predict visitation frequency and time onsite in discrete choice travel choice models. The potential for multiple pathways of influence also provides a broader understanding of the complexity of predicting site choice based on marginal changes in recreation site quality (see section 4 on data requirements of discrete choic).

Table 1 Metrics for different pathways greenspace characteristics, health and well-being

Pathway	Individual behavioural/perceptual metrics (enjoyment)	Spatial metrics	Data sources
Reducing Harm (mitigation)			
Air pollution	Individual behaviour does not change the mitigating effect of greenspace on environmental exposures	Tree cover Greenness indices Area covered by greenspace Eye-level panorama imagery	Lidar(cm), Sentinel-2(10m) NDVI, GRVI, SAVI, EVI LANDSAT(30m),MODIS(0.25-1km), CORINE(25ha), Google Earth Engine Google Streetview
Noise		Tree cover Greenness Eye-level panorama imagery	(as above)
Heat		Tree cover Greenness Area covered by greenspace	(as above)
Restoring capacities (restoration)			
Attention restoration and physiological strees recovery	Green view from a window Percieved greenness Percieved access and attractiveness Percieved restorative quality (psychological distance, positive engagement) Amount of time spent in greenspace Perceived safety of greenspace	Greenness Tree cover Eye-level panorama imagery Type, size, physical activity facilities, maintenance and other qualities of greenspace	(as above) Municipal land use and management maps GPS, GSM, user diaries
Building capacities (instoration)			
Encouraging physical activity	Amount of time spent in greenspace conducting physical activity Perceived access and attractiveness of greenspace for physical activity Perceived safety of greenspace	Greenness Distance to green spaces Type, size, physical activity facilities, maintenance and other qualities of greenspace	Land use and GIS network analysis (as above)
Improving social cohesion	Amount of time spent in greenspace in social activities Perceived social cohesion Perceived safety of greenspace	Greenness Distance to green spaces Type, size, social facilities (e.g. benches), maintenance and other qualities of greenspace	(as above)

Source: adapted from Markevych *et al.* (2017)

3. Predicting future flows of ecosystem services

This section provides examples of models linking ecosystem condition and the capacity to supply recreation services. The purpose of predicting future flows of ecosystem services is to estimate changes in asset values due to changes in quality[52].

Models should ideally:

- predict recreation choices (visitation site, frequency, time on-site) across all open spaces used for recreation in an accounting area.
- be sensitive to marginal changes in predicted site characteristics that enable recreation (size, biotic, built and abiotic structural features)
- account for interaction effects between sites (substitution, scarcity)

The models presented is not an exhaustive overview. Nor is it an ideal selection that meets the above criteria. It is limited to examples of models predicting recreation activities and amenities at regional or national levels, familiar to the ecosystem services research community in Europe. For an overview of recreation modelling from mainly US studies see a review by Phaneuf and Smith (2005)[53].

The examples are nevertheless illustrative of different challenges faced by different starting points with regards to available data. The models also illustrate challenges in separately identifying recreation services and benefits.

Modeling recreation potential

The ESTIMAP recreation model by the JRC[54] illustrates the use of a GIS layer overlays and population proximity to define potential use. The methodology was developed in 2012[55]

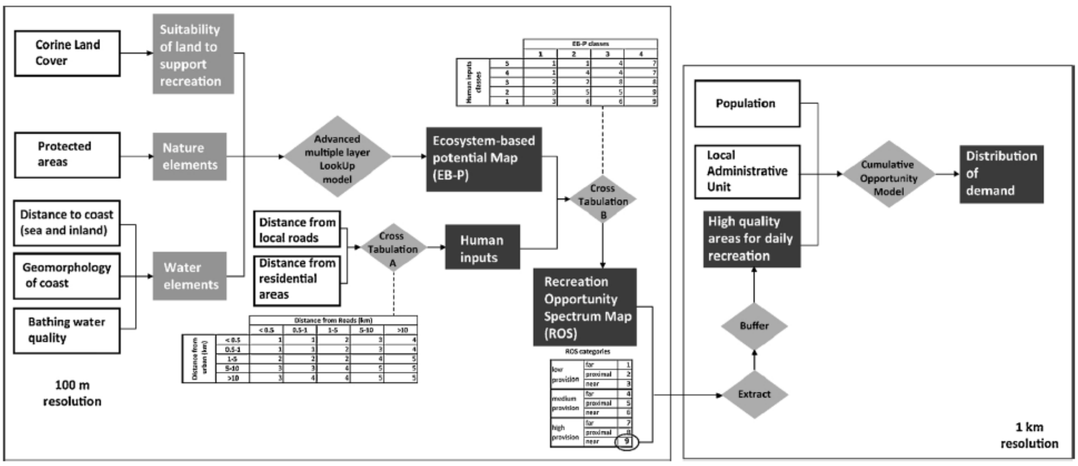


Figure 4 Structure of the ESTIMAP model for nature-based recreation. Source: Vallecillo et al. 2019

[52] Fenichel, E.P., Hashida, Y., 2019. Choices and the value of natural capital. Oxf Rev Econ Pol 35, 120-137.
[53] Phaneuf, D.J., Smith, V.K., 2005. Chapter 15 Recreation Demand Models. Handb. Environ. Econ. https://doi.org/10.1016/S1574-0099(05)02015-2
[54] Vallecillo S, La Notte A, Polce C, Zulian G, Alexandris N, Ferrini S, J., M., 2018. Ecosystem services accounting: Part I - Outdoor recreation and crop pollination, EUR 29024 EN; Publications Office of the European Union, Luxembourg, doi:10.2760/619793, JRC110321. , Vallecillo, S., La Notte, A., Zulian, G., Ferrini, S., Maes, J., 2019. Ecosystem services accounts: Valuing the actual flow of nature-based recreation from ecosystems to people. Ecological Modelling 392, 196–211.
[55] Paracchini, M.L., Zulian, G., Kopperoinen, L., Maes, J., Schagner, J.P., Termansen, M., Zandersen, M., Perez-Soba, M., Scholefield, P.A., Bidoglio, G., 2014. Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecol Indic 45, 371-385.

and applied for different purposes[56] and at multiple scales[57]. It can be adapted to fit multiple needs (urban recreation, nature based recreation in natural parks) and the parameters can be adjusted with local data when they are available.

"Recreation potential" - also called "recreation opportunity spectrum" - consists of combinations of classes of ecosystem suitability mapping and accessibility. Recreation suitability is compiled using recreation suitability scoring of landcover classes based on expert assessment of their recreation characteristics[58]. A probability of recreational visits is calculated as the ratio between weekly total visits from a recreation survey and population in local area administrative units. A trip generation function to predict potential users is estimated by regressing ROS classes on visitation likelihood. Visitation likelihood data should come from a random sample of the population providing recreation recall information on frequency and destinations during a defined time period prior to the survey (week, month, year). However, because demand is aggregated there is no recovery of individual preference data. The final metric is a predicted number of visits for all combinations of recreational opportunity spectrum (ROS) classes. A predicted visitation rate for all land with recreational potential can in principle be computed with this approach.

A number of assumptions are made in GIS cross-tabulations and in classifying recreational opportunity spectrum which determine potential number of users. The method predicts average potential use per ROS class, and so does not predict visitation for particular sites within a ROS class. The ESTIMAP prediction of potential use for a particular ROS class will be sensitive to changes in landuses with different recreation suitability scores. It is not sensitive to other characteristics of recreation sites, as discussed above. In other words, ESTIMAP wil only predict a change in potential visitation if landuse - and hence the expert-determined suitability score – changes at the recreation site.

In a first ecosystem accounting application of ESTIMAP Recreation[59] the model predicted low recreation visits for the UK when compared to national survey data[60]. Two possible explanations for underestimation are:

- only daily trips within 4 km <u>not</u> using a car were estimated.
- the log-logistic function predicting mobility within 4 km as a proportion of the population is not an accurate functional form.
- Because demand is aggregated over a population with heterogeneous spatial preferences, and over a large spatial area with heterogeneous recreation

[56] Liquete C, Piroddi C, Macías D, Druon J-N, Zulian G (2016) Ecosystem services sustainability in the Mediterranean Sea: Assessment of status and trends using multiple modelling approaches. Sci Rep. doi: 10.1038/srep34162
[57] Baró F, Palomo I, Zulian G, Vizcaino P, Haase D, Gómez-Baggethun E (2016) Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region. Land use policy. doi: 10.1016/j.landusepol.2016.06.006;
Zulian, G., Stange, E., Woods, H., Carvalho, L., Dick, J., Andrews, C., Baro, F., Vizcaino, P., Barton, D.N., Nowel, M., Rusch, G.M., Autunes, P., Fernandes, J., Ferraz, D., dos Santos, R.F., Aszalos, R., Arany, I., Czucz, B., Priess, J.A., Hoyer, C., Burger-Patriciom, G., Lapola, D., Mederly, P., Halabuk, A., Bezak, P., Kopperoinen, L., Viinikka, A., 2018. Practical application of spatial ecosystem service models to aid decision support. Ecosyst Serv 29, 465-480.
[58] "Experts" may be recreation researchers, local managers and local user representatives. Norway's municipalities are currently conducting a national mapping and valuation of outdoor recreation areas' suitability using a national guidance. Suitability scoring is based on municipal evaluation of their recreation areas, using 'valuation groups' consisting of local residents and recreation organization representatives. Miljødirektoratet, 2014. Kartlegging og verdsetting av friluftslivsområder. Rapport M98-2013 (Mapping and valuation of recreation areas). Norwegian Environment Agency
[59] Vallecillo et al. (2018)
[60] Pers. com. Rocky Harris, DEFRA

destination characteristics the method is expected to underestimate demand relative to a spatially disaggregated approach[61].

A further limitation is the lacking availability of data to calculate a mobility function at the national level. The EU study used UK national recreation survey data.

Modeling predicted visitation.

Random utility models (RUM) of recreation choice can be used to predict the number of visits across a set of sites with different qualities, for a population of recreation users with different socio-demographic characteristics, located at different distances from the recreation sites. The example discussed here concerns the ORVal model[62]. ORVal recreation demand model is capable of predicting the number and destination of recreational day trips for the adult population in England and Wales. Covering all forms of outdoor recreation locations from urban parks, through to countryside pathways, woodlands, mountains and beaches, the model is uniquely comprehensive in applying such detailed coverage of recreation activity across an entire nation. Given its foundation in economic theory the ORVal model is relevant for the purposes of recreation valuation and accounting. While directly dealing with many complex facets of recreation choice including the choice of transport mode and the substitution possibilities that exist across different recreation sites, the model only examines day trip recreation and does not address the complicating issue of multi-site trips. It does not address very small greenspace such as amenity grass and trees around buildings. Figure 2 provides a schematic of the data used.

The model is based on a weekly random sample of the adult population who record their recreational day trips to greenspace during the week preceding the survey. The survey has been conducted each year since 2009 with a sample that currently exceeds 350,000 observations. Recreation destinations across the accounting area are broadly divided into parks, beaches and paths described in terms of their extent, landcover composition and diversity, management conservation, and points of interest (including archaeology, historic

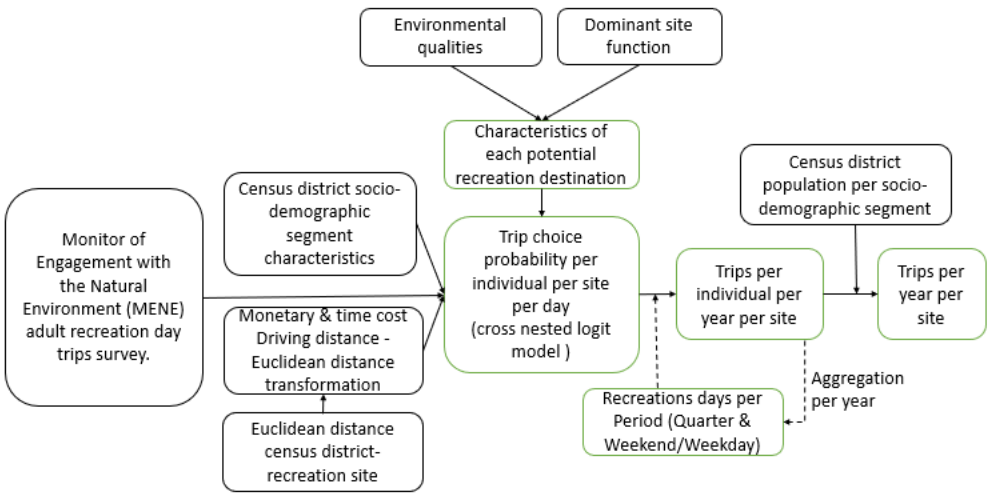


Figure 2. ORval recreation demand model recreation.
Source: own elaboration based on Day and Smith(2017)

61 Addicot, E.T., Fenichel, E.P., n.d. Spatial Aggregation and the Value of Natural Capital. J. Environ. Eonomics Manag

62 Day, B.H., Smith, G., 2018b. Outdoor Recreation Valuation (ORVal) User Guide: Version 2.0, Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter.

building, scenic feature,playground, viewpoint). The model is sensitive to changes in any quality attribute of any of the 138,000 sites across England and Wales. That includes changes in landcovers, river water quality, bathing water quality, built features like playgrounds, woodland types. The model predicts visitation from all segments within a census district to a given recreation site, and aggregates predicted visitation for all sites over all census districts. Predicted visitation per census district, is sensitive to change in the distance to the site. Predicted visitation rates in the model are also sensitive to changes in the seasonal distribution of an individual's recreation activity which could be sensitive to weather and weather dependent site characteristics (e.g. ice and snow cover)[63].

A more direct approach has been used in Caparrós et al. (2017), where the information of a survey to a representative sample of the population was used to estimate recreational visits to the forest ecosystems of Andalusia (the largest region in Spain). Face-to-face interviews were conducted to a sample of 3214 adults from Andalusian households and 836 adults from households of the rest of Spain. These surveys included a question where respondents were asked to indicate the Andalusian recreational areas that they had visited in the last 12 months, followed-up by a question where they had to state the duration of each visit. The respondents where given a list of iconic recreational areas, and the option to indicate other recreational areas visited. The advantage of this approach is that no modelling effort is needed to determine the number of visitors, as the result for the population is obtained directly using inferential statistics. The disadavantage it that it would require annual surveys. In addition, the method is arguably more adequate to estimate visits to iconic recreational areas, as it may not capture adequately visits to small recreational areas.

[63] Since the ORVal model predicts transport mode to sites and we can use data from elsewhere to estimate physical activity on site, it can be used to look at the physical activity levels associated with recreation activity across England & Wales (pers.com. Brett Day).

4. Pricing of changes in ecosystem value measured through changes in recreation

As described above, the direct challenge for measurement of recreation services is to estimate the number of people, from all places, visiting each target ecosystem for recreation and leisure and determine the contribution of the ecosystem to the benefits they receive in undertaking that activity. For the purpose of valuation in accounting, the aim is to determine an appropriate price for the change in recreation in response to a change in ecosystem extent and condition.

To frame the discussion of valuation, three types of transactions in recreation services can be identified:

- Recreation activity at no monetary cost, but with opportunity cost of time (e.g. walking to the local park)
- Recreation activity with travel costs and/or entrance fees (e.g. driving to the beach)
- Recreation activity through transactions with business (e.g. a tour operator)

Generally speaking, methods for estimating prices in the cases where there are revealed transactions are well established and are summarised later in this section under the heading primary valuation options. More challenging are cases for valuing recreation activity where no monetary exchanges take place. To tackle this situation, we discuss here the estimation of prices for accounting purposes (i.e. exchange values) that are based on alternative institutional contexts. We list the different contexts first and then discuss the estimation of context specific accounting prices.

A further comparison of valuation methods could use selection criteria such as those listed in Appendix 3.

4.1 Accounting prices for recreation and valuation of welfare changes

Accounting prices for recreation should be estimated at the marginal value with respect to a change in the ecosystem (extent, condition)[64]. The accounting price so determined is relevant for the observed change in the accounting period. In any real world application to spatially heterogeneous ecosystems and recreation demand, the marginal value accounting price only represents the range of change in the accounting period for which it was estimated. As a marginal value it should not be extrapolated to estimate the aggregate value of all visits across all conditions of the ecosystem[65].

[64] Fenichel, E.P., Abbott, J.K., Yun, S. Do, 2018. The nature of natural capital and ecosystem income ✶. Handb. Environ. Econ. https://doi.org/10.1016/bs.hesenv.2018.02.002

[65] Johnston, R.J., Boyle, K.J., Adamowicz, W. (Vic), Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., Vossler, C.A., 2017. Contemporary Guidance for Stated Preference Studies. J. Assoc. Environ. Resour. Econ. 4, 319–405. https://doi.org/10.1086/691697

Box 3 Spatial variation in implicit accounting prices for recreation areas

The following is a stylized example of why ecosystem accounting for recreation has to address spatial heterogeneity – why accounting prices for recreation vary with location. The horizontal axes in Figs. 1-2 represent the distance between two lakes (a , b), and lake condition in a first (dt=1-0)(Fig.1), and second accounting period (dt=2-1).(Fig.2). Between the accounting periods there is an improvement in lake *b* which takes it from unsuitable(red) for recreation to a maximumrecreation quality(blue) surpassing the condition of neighbouring lake *a* (green).

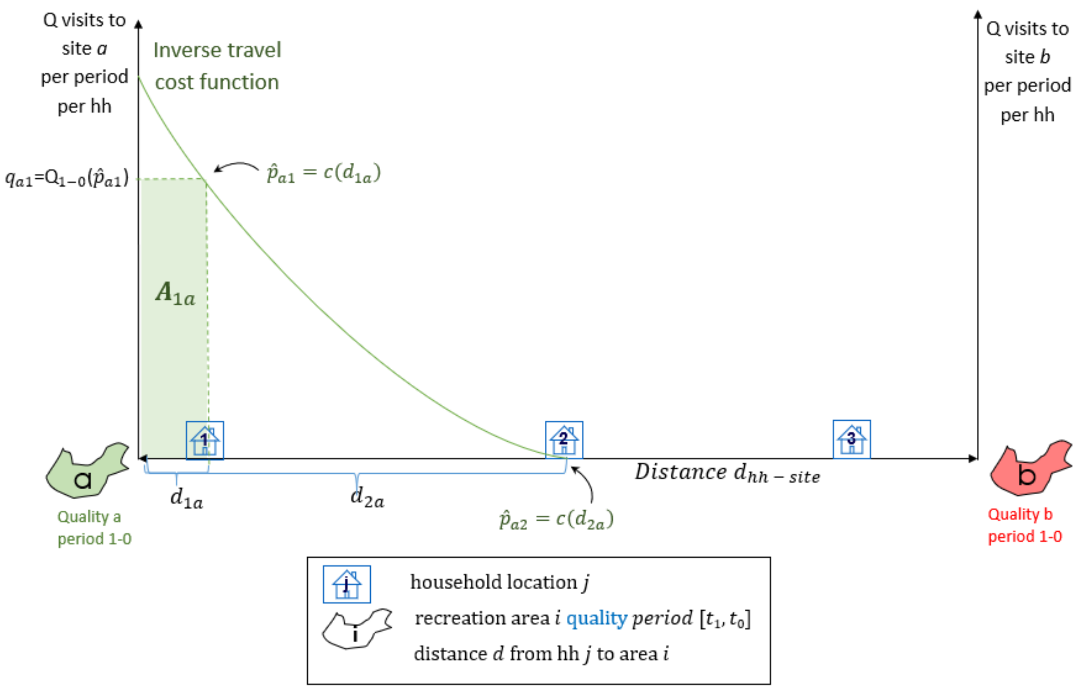


Figure 1. Synthetic accounting area with two lakes during the first accounting period [t=1, t=0,]

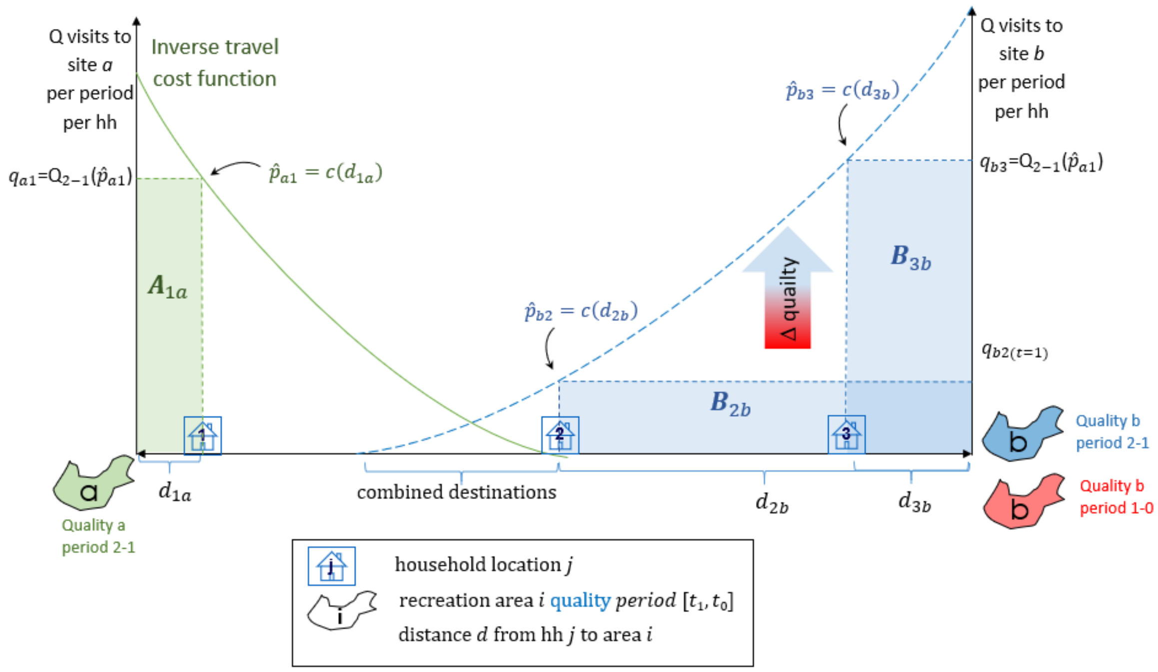


Figure 2. Synthetic accounting area with two lakes during the second accounting period [t=2, t=1]

Box 3 (cont.)

The population near the lakes is composed of households 1-3. For simplicity all households have the same same preferences for recreation identified by the same inverse travel cost function for access to lake *a*. Household vary only in their location. The lakes are identical in all attributes except recreation suitability(condition) and distance.

Household 1 travels to lake *a* revealing a positive marginal willingness-to-pay (MWTP) and an implicit price p_{a1} for each trip. Households 2 makes a marginal visit to lake *a*, but it is so far that marginal willingness to pay is zero (MWTP = $\hat{p}_{a2} - c(d_{2a}) = 0$). The flow of recreation service benefits (W) in the accounting area for period [t=1,t=0] is due to household 1 and valued at:

$$\boldsymbol{W_{1-0}} = \boldsymbol{A}_{1a} = \hat{p}_{a1}\ \mathrm{Q}_{1-0}(\hat{p}_{a1}) \quad (1)$$

By the second accounting period [t=2,t=1] ecosystem condition accounts record that water quality in lake *b* has been improved by pollution control measures to excellent quality (Fig. 2). Household 1 is too far from lake b to be affected by its improvement, and has the same use of lake *a* as the previous period. Households 2 and 3 start traveling to lake *b* with different frequency (Q_b) revealing a new inverse travel cost function with higher MWTP than lake *a* , due to its better quality. Household 2 substitutes to recreation at lake *b*. The implicit exchange value of household 2's recreation during the second accounting period in is $\boldsymbol{B}_{2b} = \hat{p}_{b2}\ \mathrm{Q}_{2-1}(\hat{p}_{b2})$. With the water quality improvement, the previously unobserved household 3 has joined the population of recreationers with MWTP_{b3}>0 and a positive implicit price p_{b3} . The implicit exchange value of household 3's recreation is $\boldsymbol{B}_{3b} = \hat{p}_{b3}\ \mathrm{Q}_{2-1}(\hat{p}_{b3})$. The flow of recreation service benefits (W) in the accounting area for period [t=2,t=1] is now due to all three households and valued at:

$$\boldsymbol{W_{2-1}} = \boldsymbol{A}_{1a} + \boldsymbol{B}_{2b} + \boldsymbol{B}_{3b} = \hat{p}_{a1}\ \mathrm{Q}_{2-1}(\hat{p}_{a1}) + \hat{p}_{b2}\ \mathrm{Q}_{2-1}(\hat{p}_{b2}) + \hat{p}_{b3}\ \mathrm{Q}_{2-1}(\hat{p}_{b3}) \quad (2)$$

In a monetary supply and use table in ecosystem accounts, $\boldsymbol{A}_{1a}$ would be allocated to ecosystem asset *a*, and $\boldsymbol{B}_{2b} + \boldsymbol{B}_{3b}$ would be allocated to ecosystem asset *b* in period [t=2,t=1].

While the implicit price for the open access lakes may be zero for the last visit of the marginal household living at the distance limit of its MWTP, other households reveal positive implicit prices. Note that there is a range where households would visit both lakes *a* and *b*. Lakes are potential and actual substitutes depending on household location. This is a complication for empirical estimation which can be addressed by discrete travel choice models with travel choice data covering a spatially representative sample of households and all their recreation destinations.

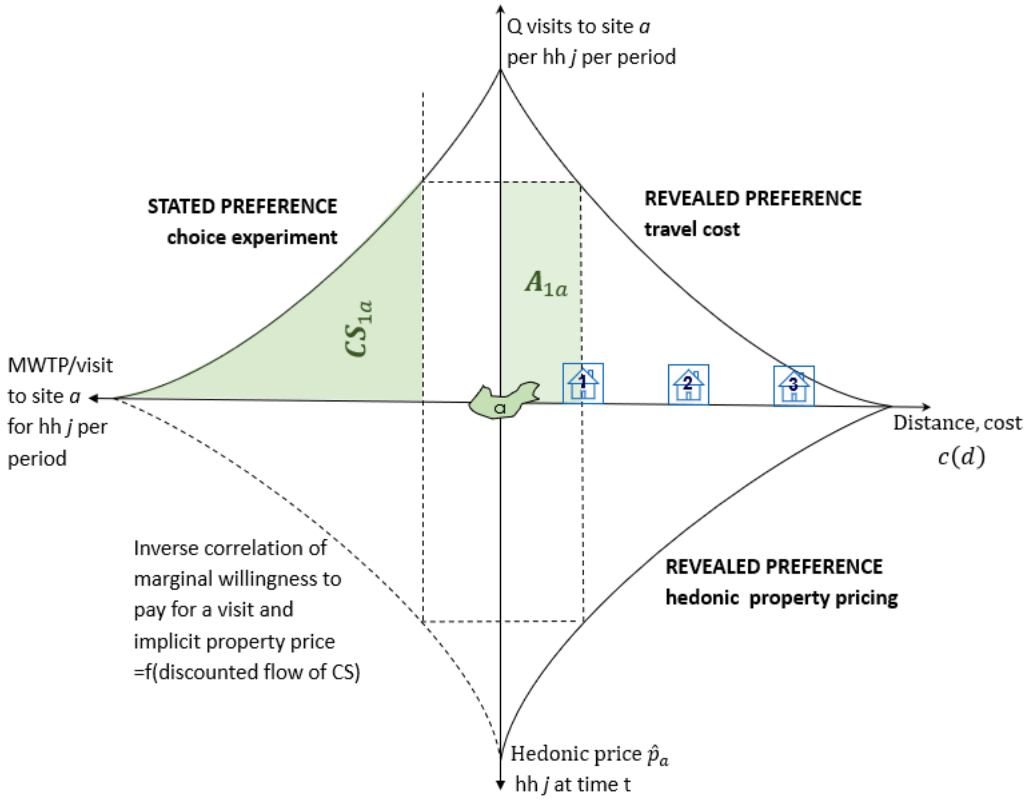
All implicit prices are unique for combinations of specific households and lake destinations. Note that the resulting average value per hectare of lakes *a* and *b* would be different even if they were of identical in every way, due to the different spatial configuration of the user population. This has implications for the use of benefits transfer in ecosystem accounting.

With (i) perfect knowledge of households' spatial recreation preferences, (ii) the technological ability and (iii) right to levy a charge on each household visit, there would be a basis for accounting for W. This represents a stylized example of the perfect price discriminating institution. With these assumptions there is no theoretical difference between revealed preference methods such as discrete travel choice method, and stated preference method eliciting marginal willingness to pay for visits. There are empirical differences in reliability and accuracy which are discussed in the following.

The challenge faced is finding accounting prices that apply to the change in recreation areas in the accounting period. With each household in a unique location, each recreation choice set is unique, there is no single market, no single accounting price to apply across all visits (or visitor hours). In a open access recreation area, the marginal willingness to pay of each visitor is zero. We don't directly observe any price for visits. However, non-market demand curves are summed vertically so there are infra-marginal rents across households to a change in the ecosystem condition of a potential recreation site. While the price of recreation is zero for the marginal household at a given point in time, a change in ecosystem condition during an accounting period produces benefits across the population. Box 3 provide a stylized example.

The implicit price and consumer surplus measures from the different valuation methods are correlated when measured correctly (see a stylized example in Box 4).

Box 4. Comparability of revealed and stated preference methods in determining accounting prices – potential for double counting benefits in revealed and stated preferences for recreation



The upper right panel is the same starting point as Fig.1 Box 3, representing the valuation data obtained from a travel cost. The lower right hand panel represents distance decay in the hedonic property price for lake *a* relative to household distance. The upper left hand panel shows declining marginal willingness to pay for increasing visits by a given household that might be recovered from a choice experiment. The consumer surplus for household 1 across all visits in the accounting period could be estimated as $\boldsymbol{CS}_{1a}$ (MWTP net of travel costs $\boldsymbol{A}_{1a}$). If demand curves uncovered in the different revealed and stated preference valuation methods are 'well behaved' downward sloping we would expect marginal willingness to pay for visits and the implicit property price of a given household to be inversely correlated. The revealed hedonic property price would be a function of the discounted consumer surplus of visits to lake *a* derived from the choice experiment. In this case there would be potential double counting in valuing recreation across the travel distance gradient starting at the home location, and valuing the property amenity of proximity to lake *a*.

The exchange price curves and welfare price curves are the same when measured correctly[66]. The change in exchange value is equal to the change in producer and consumer surplus from a change in ecosystem condition[67].

This anticipates the discussion on valuation methods - the choice of valuation method should be determined more by the reliability and accuracy of measurement and modelling of the change in ecosystem condition, than by the method being revealed or stated preference.

While the approach to accounting prices has been clarified conceptually there number of empirical challenges[68]:

- Due to data recreation choice models are most often estimated over a few sites of the same recreation type for a limited geographical area, with limited observation variation in condition and substitute sites and activities.

- Studies draw on sample frames of existing users, while accounting for asset value needs to consider future changes in recreation area condition and resulting changes in users (some of whom may currently not be recreating. In accounting we need to consider all the households that would potentially visit the site with the best ecosystem condition, holding the quality of substitute sites constant (even if they don't currently visit under current lower than optimal conditions)(see Box 3 for a stylized example).

In conclusion, it is possible to identify changes in welfare of recreation due to changes in ecosystem condition. However, the implicit prices revealed by changing patterns of recreation due to the change in quality of a recreation area, and its substitutes, does not apply to all possible non-marginal changes in condition of the ecosystem. They do not apply to loss of an ecosystem type in the accounting area (e.g. all lakes), although the prices do apply to incremental loss of use benefits from particular ecosystem assets (individual lakes in Box 3). Total monetary asset value in the face of ecosystem loss is not useful to evaluate changes due to environment management decisions[69]. The high spatial variation in ecosystem condition, localion of users with different preferences, and the resulting spatial distribution of implicit prices, is a large empirical challenge for ecosystem accounting, if not in theory, then empirically.

4.2 Common institutional contexts for valuation of recreation

In addition to spatial variation in ecosystem recreation qualities and demand, there may be institutional differences in management and use rights across the accounting which further differentiate accounting prices[70]. Institutional context is therefore directly relevant for the choice of valuation method. The following aspects are relevant in considering the institutional context for recreation services.

Formal property rights are a basic institutional characteristic of land which determine which valuation methods are appropriate. Exchange-based valuation methods such as hedonic pricing are based on information on sales of private residential property, but commonly used to derive the implicit value of access to public amenities. Conversely, trees and vegetation on private property may have public values through visibility and regulating ecosystem services.

[66] Fenichel, E.P., Abbott, J.K., Yun, S. Do, 2018. The nature of natural capital and ecosystem income ✶, Handbook of Environmental Economics. Elsevier B.V. https://doi.org/10.1016/bs.hesenv.2018.02.002

[67] Harberger, A.C., 1971. Three Basic Postulates for Applied Welfare Econo. J. Econ. Lit. 9, 785–797.

[68] Fenichel, E.P., Abbott, J.K., Yun, S. Do, 2018. And
Fenichel, E.P., Abbott, J.K., 2014. Natural Capital: From Metaphor to Measurement. J. Assoc. Environ. Resour. Econ. https://doi.org/10.1086/676034

[69] Fenichel, E.P., Abbott, J.K., 2014.

[70] Addicot, E.T., Fenichel, E.P., n.d. Spatial Aggregation and the Value of Natural Capital. J. Environ. Eonomics Manag.

Formal use / access rights determine whether entry fees are charged for areas used for recreation. Restricted access make it possible to record entry/exit and time use on- site. Assumptions about the feasibility of excluding access need to be made in order to use simulated exchange value method (more below).

Public and community management of a recreation site and its current maintenance level determine whether management scenarios are found credible in stated preference surveys and can be used to identify a demand function of recreation site quality.

Informal use norms such as stewardship responsibility may determine whether respondents in stated preference surveys will find public management scenarios necessary or credible.

Similarly, replacement and restoration costs make assumptions about the effectiveness of formal and informal institutions in controlling future ecosystem degradation.

Labour market regulations and contracts determine the extent to which it is reasonable to use foregone costs of labour income as a marginal value of recreation time.

Real estate market regulation determines the extent to which hedonic property pricing reflects the marginal willingness to pay for property attributes.

Institutional context specific accounting prices

The fundamental valuation problem for ecosystem accounting of recreation services is in the pricing of open-access public goods. There is no market formation and hence no price to attach to the visits to outdoor recreation areas. To progress, it is necessary to assume an appropriate institutional context about the recreation area[71]. In the following we work through this using the simple partial equlibrium model of a recreation area in Figure 3 to discuss the effect of different local institutions..

If the greenspace really is open access, partial equilibrium micro-economic theory predicts that the recreationists will increase their use until the marginal value of visits is zero (point *o* in Figure 3). In this theory, in the absence of institutions governing use of the recreation area, the only logical accounting price is zero[72] (*Po* , Figure 3). This would be the accounting price of a location with no governance and no carrying-capacity limits on the quality of the visit. Methods based on greenspace characteristics, generic information on willingness-to-travel, but no site-specific information on visitation choices will estimate an upper bound for the potential demand for that recreation areas under these assumptions.

At the other extreme, an ecologically sensitive recreation area might have an identified visitor carrying capacity which - if auctioned to the highest bidders - would reveal a price at *Pu.* We could note that this price could only be revealed in the presence of highly site specific information (long term monitoring of ecosystem response to visitors, information about access control, on-site management of visitors, and design of an auction pricing institution).

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[71] Barton, D.N., Grimsrud, K., Greaker, M., Heyman, A., Chen, X., Garnåsjordet, P.A., Aslaksen, I., 2017. Monetary valuation methods in urban ecosystem accounting - examples of their relevance for municipal policy and planning in the Oslo metropolitan area. Presentation at London Group meeting, "Methodology of SEEA CF and the Ecosystem Accounts", 17-20 October 2017, Costa Rica. .

[72] noting that the value of a change in the ecosystem is not zero (as discussed above)

Between accounting prices *Po* and *Pu* a number of other accounting prices are possible, each of which would be consistent with different institutional contexts. Accounting price *Pm* could be consistent with a **local urban open access recreation area** where fixed cost infrastructure (e.g. public metro line access) and variable cost management (e.g. public trail maintenance) enable a visitor carrying capacity to expand to *m*[73]. The recreation area contribution to the economy would be the area under the fixed and variable costs curve up to visitation rate *m*. Travel cost studies would reveal a marginal willingness to pay/travel at *Pc* which would be an accounting price achieving the same level of visitation as the public open access regime *if no travel costs existed and access to the recreation area could be restricted and charged for*. While *Pc* could be computed, an entry-fee would not be consistent with the governance regime where open access is constitutionally guaranteed[74].

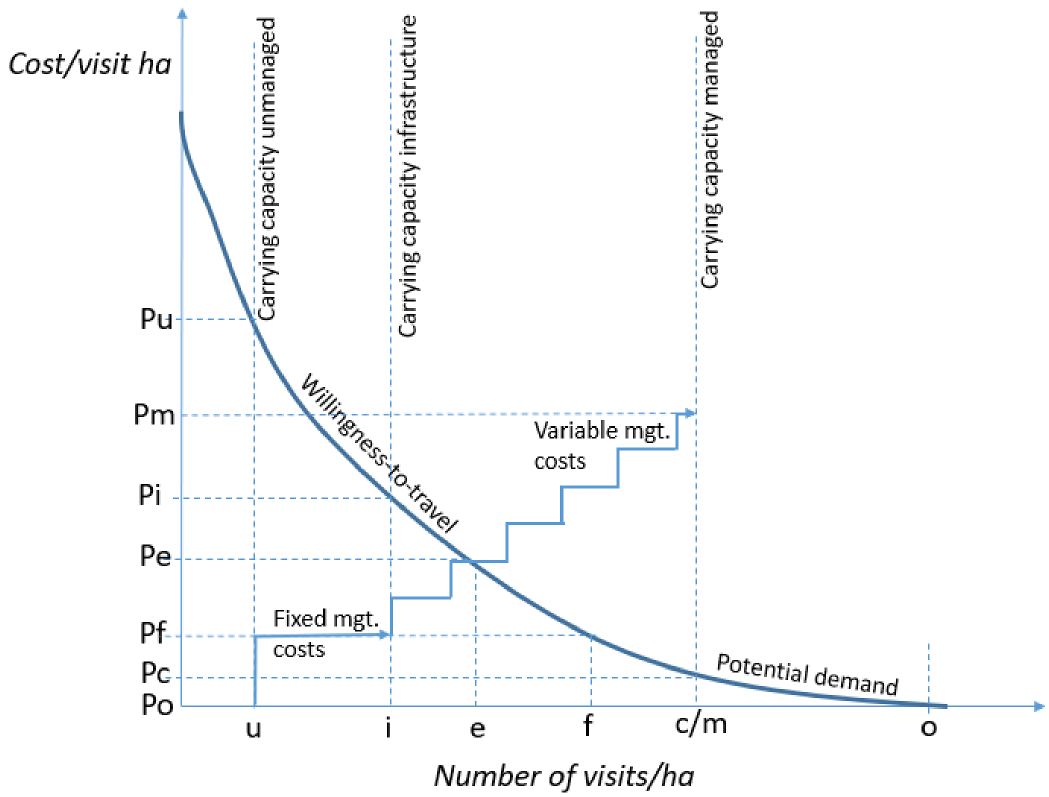

Figure 3 Theoretical alternatives for a recreation service accounting price under different institutional assumptions.

Several different accounting prices are consistent with different institutional assumptions of access rights, and different levels of management determining different carrying capacities.

An accounting price of *Pf* could be consistent with a governance regime where open access to private property is *de facto*, but owners could legally charge for entry if they could physically restrict access, and substitute recreation sites were similar and also restricted access[75]. Stated preference studies could determine willingness-to-pay - potential demand - if access were restricted. If access-fees were implemented there might be some fixed infrastructure and management costs for controlling entry,

[73] An example could be the Oslo peri-urban forest Marka which is co-owned and managed between the municipal government, not-for-profit recreation organizations (DNT, Skiforreningen) and private forest owners.
[74] The accounting price would be consistent with the marginal cost of public transportation to the recreation area, but the total accounting value would be lower than the supply cost and consumer surplus.
[75] An assumption of how recreation areas compete would have to be made. See Caparros et al (2017) for an example of monopolistic competition assumption.

but possibly no variable costs of management of use within the recreation area. A revenue optimizing owner would charge entry fee of *Pf* , with a predicted visitation of *f*. The accounting price *Pf* is computable and potentially *de jure* consistent with existing governance. There is uncertainty about whether the simulated visitation with fixed costs only is compatible with the carrying capacity of the recreation area. Another accounting price *Pi* might be assumed such that the predicted vistiation *i* was compatible with the sites carrying capacity, taking into consideration that there was no (information about) variable management costs on-site.

A highly managed public botanical garden with fixed costs for visitor infrastructure, and variable management costs, would charge an entrance fee of *Pe* if it wished to maximize revenue, admitting a number of visitors (*e*). Accounting for variable management costs there would be less uncertainty than in the example above regarding whether the accounting price was consistent with the garden's carrying capacity. If it were a public institution this pricing may or may not be consistent with its public mandate.

All the approaches using information about supply costs attach a higher price to greenspaces where there is a higher input of produced capital.

An entirely different approach would estimate marginal value of additional green space for individuals along the willingness-to-travel demand curve. The willingness-to-travel curve in Figure 3 is for a single site, conditional on the accessibility of other recreation sites to the population in its vicinity. Different accounting prices for different populations (e.g. by census district) could be estimated depending on their local access to green spaces, without information about management on-site. Institutions such as access restrictions, are adapted to the impact caused by recreation. The institutional, management and biophysical site characteristics of accessible green spaces would be taking as given - 'endogenous' - to the visitation choices of the population. This is the general approach followed by Orval presented earlier. The accounting prices could be further differentiated for biophysical qualities of the recreation area and its governance context where available. A flexible general approach is of course more data intensive than the partial equilibrium approaches illustrated in Figure 3.

4.3 First and second best valuation methods

The purpose of the following two sections is to describe available approaches to the valuation of recreation services. We also discuss what assumptions about baselines and counterfactuals are required, and whether the method identifies marginal or non-marginal changes. If properly implemented, the valuation methods described below provide an adequate estimation of the value of a change in the recreation service, due to a change in recreation sites' quality and availability.

First and second best valuation methods are close to estimating marginal changes in the recreation service metric (perceived recreation quality), or a reliable proxy of perceived quality as data permits (e.g. time on-site or site choice/visits). Additional valuation methods do not reveal the value of recreation choices on the margin, do not use revealed preference data (e.g. cost based methods), or use directly stated preferences estimating consumer surplus of poorly defined changes in ecosystem condition.

Direct market price based approaches. A tour operator could make a profit margin thanks to a concession to provide guiding and transport services in a national park. A hotel operator may turn a profit from having a concession to offer accommodation within or bordering a protected area. In both cases commercial access is limited by operating permits or concessions, which bar entry to other operators. Som of the rent is captured by the consumer and some by the producer. The net operating surplus (i.e. after deducting costs of produced and human capital) will reflect a lower bound on the resource rent that is attributable to the recreation service.

The challenge in applying this method is to be able to isolate the payment made such that it reflects as closely as possible a payment for recreation benefits. In some cases this might be relatively straightforward as for payments to skiing operators or for safari tours. However, in cases where the payment relates to a range of items – e.g. travel, accommodation, food – in addition to the recreation service and benefit estimation will be more complex.

The challenge in adopting this approach is well described in the Australia Bureau of Statistics (ABS) work on estimating tourism related ecosystem services for its ecosystem accounts for the Great Barrier Reef.[76] The ABS method used national level factors for tourism related revenue and costs and applied them to regional level estimates of tourism expenditure to derive a residual estimate of rent associated with tourism activity. However, without a more detailed understanding of the precise experiences that each tourist had in the region (for example some tourist may visit the reef while others just stay in a resort), it was not possible to more accurately isolate the ecosystem service value using this approach.

A resource rent based approach was also applied in the work of Remme et al (2015)[77] in developing values for nature tourism for Limburgh province in the Netherlands. In this application an adjustment was made to the regional tourism expenditures to narrow down the focus by using information on the proportion of tourists who visited Limburg for nature tourism. The estimated total nature based tourism rent for Limburg was then spatially allocated to relevant locations in Limburg based on measured patterns of visitation to various nature areas in the province, taking account of variations in expenditure in different parts of the province and finally focussing on expenditures within a 15km radius of nature areas. These additional steps beyond the approach of the ABS clearly work towards better identification of the ecosystem services contribution to tourism expenditure, but also highlight the complexities to be considered.

Indirect market price based approaches. In many situations it will be possible to observe purchases of goods and services that may be directly related to the recreation activity but do not represent the direct purchase of the recreation benefit. In these cases it is possible to impute the utility obtained from visiting a location by understanding the demand for the associated goods and services. The more people use equipment to undertake the activities (hiking and camping gear, fishing gear, etc) and the more people expend time and energy to travel to a recreation location, the higher the utility of the recreation service of that location.

Certain types of equipment provide exclusive access to inaccessible recreation sites with qualities associated with hazard and skill (e.g. diving, boating, climbing, offroad biking, off-piste skiing, base jumping). Where equipment is a necessary condition for access to recreation sites, cost of equipment may reflect hedonic qualities of a set of sites. However, the equipments' value may not easily be ascribed to any site in particular, as is the case of the hedonic value of property. However, when such equipment is provided for rent locally this may support use of a more direct market price based approach.

In travel cost and random utility modelling of recreation it is assumed that travel expenses are weak complements to greenspace in delivering recreation services. This assumption is used to estimate the implicit demand curve for visitors to recreation destinations . See Box 3 and the discussion in further detail below.

Access and entrance fees. Often fees are paid to enter parks and this may reflect a direct estimate of the exchange value of the recreation service, but it is important to consider whether the fee being charged also covers the cost of park maintenance, facilities and other operational costs. These should be deducted in obtaining an estimate of the value of the ecosystem service, and in many cases, it is likely that the resulting residual reflects a very low or zero value for ecosystem services. Although entry fees are transactions for a service, they are often regulated and not determined through a market clearing process.

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[76] See http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4680.0Main+Features12017?OpenDocument

[77] Remme et al (2015) Monetary accounting of ecosystem services: A test case for Limburg province, the Netherlands, *Ecological Economics*, 112, pp 116-128

Earmarked contributions. Membership fees, or voluntary contributions, are paid to conservation organisations or recreation special interests for management of a greenspace, often a protected area. To the extent that these contributions are cost recovery and earmarked for maintaining recreation infrastructure they represent an exchange value.

Hedonic property pricing is used to estimate the marginal effect of attributes of a property - environmental quality, views of and proximity to vegetation and water - in the value of real estate. The seeming advantage of hedonic property pricing in an accounting context is the direct estimation of a monetary asset value of amenities. However, what is usually reported in hedonic property pricing is a % of the real estate price due to the property being within the 'service area' of the natural asset. Some studies differentiate the marginal value contribution to the property of greenspace by type and at different spatial scales[78]. However, hedonic property pricing studies have not been used for accounting purposes. With some exceptions, hedonic pricing studies have not conducted a second step of attributing and aggregating the marginal values from all properties within the 'service area' back to specific greenspaces[79] or ecosystem spatial units such as tree cover[80]. A challenge for hedonic property pricing is the requirement to precisely define and map on-property, street, neighbourhood vegetation and water attributes and define relevant green space types. A further challenge is to control for spatial correlation between environmental quality, greenspace cultural amenities[81], requiring a number of modelling assumptions and advanced spatial econometrics techniques.

A particular challenge for accounting is to obtain property sales data for the whole accounting area, and GIS-data of similar resolution for the whole property market. This can be challenging as properties are likely to be sensitive to smaller greenspace features (e.g. individual trees) the more dense the built environment. Property market effects are highly localised and specific to types of homes (e.g. with and without gardens). Hedonic property pricing results from one market are not easily transferred nor scaled across different sizes of recreation area without large benefit transfer errors.

Interestingly for accounting, there is no need for modelling actual recreational use to underpin hedonic property pricing, as the methods directly use data on recreation area's extent, proximity and condition attributes to estimate capitalised exchange value. In principle, hedonic price functions that control for air quality, noise and urban heat island effects could identify the separate effect of access to recreation, but in practice ecosystem services are bundled into a few composite greenspace variables[82]. A final accounting method choice of choosing a specific discount rate for recreation services is needed in order to annualize the exchange value capitalized in the home price.

Simulated exchange value is a hypothetical price that would be charged for visitor access to optimize the revenues of an otherwise open access greenspace[83]. The simulated optimal revenue visitation accounts for fixed infrastructure and variable per visitor management costs. Recreation demand is representing willingness-to-travel, estimated from a stated or revealled preference survey. The simulated exchange value identifies a recreation demand curve from a stated preference survey of willingness-to-pay entry fees to the site that is currently open access.

[78] Abbott, J.K., Klaiber, H.A., 2010. Is all space created equal? Uncovering the relationship between competing land uses in subdivisions. Ecol. Econ. 70, 296–307. https://doi.org/10.1016/j.ecolecon.2010.09.001
[79] Panduro, T.E., Jensen, C.U., Lundhede, T.L., Thorsen, B.J., 2016. Estimating demand schedules in hedonic analysis: The case of urban parks. IFRO Work. 6.
[80] Mei, Y., Hite, D., Sohngen, B., 2017. Demand for urban tree cover: A two-stage hedonic price analysis in California. For. Policy Econ. https://doi.org/10.1016/j.forpol.2017.05.009
[81] Heyman, A.V., Chen, X., Manum, B., Nowell, M., Barton, D.N., 2017. Attributes of location and housing prices in Oslo: A monetary valuation with spatial configuration in mind. Proceedings of the 11th Space Syntax Symposium pp. 68.61-68.15.
[82] Czembrowski, P., Kronenberg, J., 2016. Hedonic pricing and different urban green space types and sizes: Insights into the discussion on valuing ecosystem services. Landsc. Urban Plan. 11–19.
[83] Caparros, A., Oviedo, J.L., Alvarez, A., Campos, P., 2017. Simulated exchange values and ecosystem accounting: Theory and application to free access recreation. Ecol. Econ. 139, 140–149.

The method requires an assumption about the market structure that is most appropriate for each recreational area considered. For iconic recreational areas the most reasonable assumption is that they are sufficiently unique to assume monopolistic competition, as the recreational services offered are similar but can be differentiated. In general, it is also reasonable to assume that there is a given number of iconic recreational areas and that new entries would need a considerable amount of time (if possible at all). Thus, in the short run, the number of recreational areas is fixed. With these assumptions, in the short run, the equilibrium is given by the intersection between the site-specific marginal revenue function and the site-specific marginal cost function. Simulated exchange value has been used with contingent valuation techniques to estimate site-specific demands for the main recreational areas in Andalusia[84]. The results were based on face-to-face interviews to a sample of 4030 free access visitors to recreational sites in Andalusian forest ecosystems.

If the site-specific demand is estimated using a contingent valuation study based on a hypothetical entrance fee, the scenario needs to be credible for the respondents. However, even if establishing an entrance fee is not feasible or credible, the site-specific demand could still be estimated using the travel cost-method, or a contingent valuation study based on hypothetical increases in travel costs, as long as travel costs are sufficiently relevant. However, it is true that the method is more appropriate for public conservation areas with evident management costs and limited access. It would assume a redistribution of access rights which may not be credible for highly accessible public recreation areas, such as local public parks in urban areas with no travel expenses.

The main advantage of the SEV method is that it yields exchange values that can be integrated with other monetary values in an ecosystem accounting framework. Campos et al. [85] present an application where recreational values are integrated with 15 other private and public activities in spatially-explicit accounts for Andalusian forest ecosystems

In anything but perfect competition, there are strategic rents that should in theory not be accredited to the ecosystem, but are hard to identify empirically[86]. The institutional assumption of monopolistic competition is not necessary, as one could assume that perfect competition would prevail in the market if there are a very large number of similar recreational areas. However, the implication would be that the simulated price would just cover costs. This would be a special case of simulated exchange pricing that approaches the marginal value pricing method discussed below.

To obtain an estimation of the recreation service itself, understood as the "contribution of the ecosystem", only part of the value should be considered. In other words, the value of human inputs to the service needs to be taken into account[87], as shown in Caparrós et al. (2017) and Campos et al. (forthcoming). Only a fraction of the free access recreational value (estimated using simulated exchange value) estimated for Andalusian forests can be considered an ecosystem service in monetary terms. Approaches to estimating the ecosystem service component, beyond resource rent and production function type approaches need further consideration.

Marginal Value Pricing[88] using random utility models of travel choice The starting point for Marginal Value Pricing (MVP) is to note that according to economic theory the exchange price of a good is identical to the marginal value placed on that good by society. Of course, as a result of the open access

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[84] Caparros et al. 2017 op.cit

[85] Campos, P., Caparros, A., Oviedo, J.L., Ovando, P., Alvarez-Farizoa, B., Diaz-Balteiro, L., Carranza, J., Begueria, S., Diaz, M., Herruzo, C. Martinez-Peña, F., Soliño, M., Alvarez, A., Martinez-Jauregui, M., Pasalodos-Tato, M., de Frutos, P., Aldea, J., Almazan, E., Concepcion, E.D., Mesa, B., Romero, C., Serrano-Notivoli, R., Fernandez, C., Torres-Porras, J., Montero, G., 2019. Bridging the Gap Between National and Ecosystem Accounting Application in Andalusian Forests, Spain. Ecological Economics 157: 218–236.

[86] Strategic rents might be identified by testing for the assumptions behind monopolistic competition: by varying the payment scenario in a stated preference survey where respondents are reminded of competing substitute sites in one scenario, while they are reminded of the uniqueness of the experience in another.

[87] Caparros et al. 2017 (op.cit) and

[88] MVP method proposed by Brett Day (pers. comm.)

nature of greenspace, thinking about the good as number of trips runs into immediate problems since people expand their visits until their marginal valuation is zero. Since trip quantities are unconstrained the implicit exchange price of te last trip is zero. When the recreation good is conceptualised as access to greenspace things are different. The supply of greenspace accessible to people is necessarily constrained (often significantly so given its open access properties), such that the value of a unit expansion in supply will be positive and hence the implicit exchange price of this constrained supply will also be positive. The MVP approach proposes using this marginal valuation of greenspace to calculate accounting entries for the flow of services provided by the open access greenspace currently supplied to housholds. See Box 3 for additional illustration.

With regards to practical application, the MVP approach would require a standard measure of access to greenspace that would quantify levels of current supply. Since the supply of access to greenspace is spatially specific, the measure would necessarily differ across the accounting area, such that implementation would require separate greenspace supply statistics to be calculated over some reasonably fine resolution statistical unit of population. From accounting period to accounting period, measured changes in the supply of greenspace would be reflected in changing greenspace supply statistics. Exchange prices would then be calculated for the measured supply in each unit through identification of marginal values for greenspace in that unit. The accouting entry for recreation would be taken as this local marginal value multiplied by the local marginal supply summed over all local units.

As shown in Figure 4, a tool like the ORVal model would be well suited to calculating marginal valuations for the implementation of the MVP approach[89]. Indeed with that model the approach could be taken further so as to dissagregate marginal values by different types of greenspace or different qualities of greenspace following the same MVP logic. Equiped with a standardised index of the accessibility of (a particular type of) greenspace for each local statistical unit, ORVal could be run before and after adding a standard spatial unit of greenspace, and computing the marginal value of the resulting change in utility[90] experienced by the population in the statistical unit. The approach can draw on experience from linking recreation behaviour to site characteristics (water quality, congestion, fish catch, tree canopy cover)[91].

In principle the advantages of the proposed marginal value pricing method would be:

- it identifies theoretically coherent measures of quantity and price with which to account for recreation service flows.
- the units of quantity used in the approach are direct assessments of the quantities of natural capital stocks supplied to communities.
- the approach naturally handles disaggregation into different forms of natural capital stock.
- the approach explicitly identifies heterogeneity in the supply of greenspace across the accounting area.
- assuming use of a utility-theoretic modelling method like the random utility model that underpins the ORVal model, the approach naturally incorporates the substitution possibilities that exist across greenspace. All else equal, the marginal value (price) of greenspace in a community more greatly endowed with accessible greenspace will be lower than in a community less well endowed[92].

[89] Pers.comm. Brett Day
[90] Based on the marginal utility of individuals' income
[91] Phaneuf, D.J., Smith, V.K., 2005. Chapter 15 Recreation Demand Models. Handb. Environ. Econ. 2, 671–761. https://doi.org/10.1016/S1574-0099(05)02015-2
[92] Other approaches addressing income effects include Phaneuf, D. J., C. L. Kling, and J. A. Herriges. 2000. Estimation and welfare calculations in a generalized corner solution model with an application to recreation demand. The Review of Economics and Statistics **82**:83-92.

Potential challenges of marginal value pricing include:

- the cost of conducting an annual and nationwide recreation survey
- evaluating the sensitivity of the econometric model (as per ORVal) to specification assumptions and data sampling
- the present ORVal model is calibrated on visitation statistics for a number of years (2009-2015). If the model is to capture inter-annual changes in the quality and composition of recreation areas, trip values should ideally be calculated on an annually calibrated model, using only data from that year. The dilemma from an econometric perspective is that this would reduce the power of the individual annual models. Annual updating of a model that has been calibrated on data from before the accounting period in question would be a second best option.
- the greenspace supply statistics requires a standardisation of discrete greenspace sites. This requires additional preference information on the relative importance(weights) of different environmental qualities for different recreation activities within each greenspace functional type. This weighting challenge is also faced by the ESTIMAP approach where expert judgement is used. Preference weightings could be derived from running ORVal simulations across a large number of quality combinations.

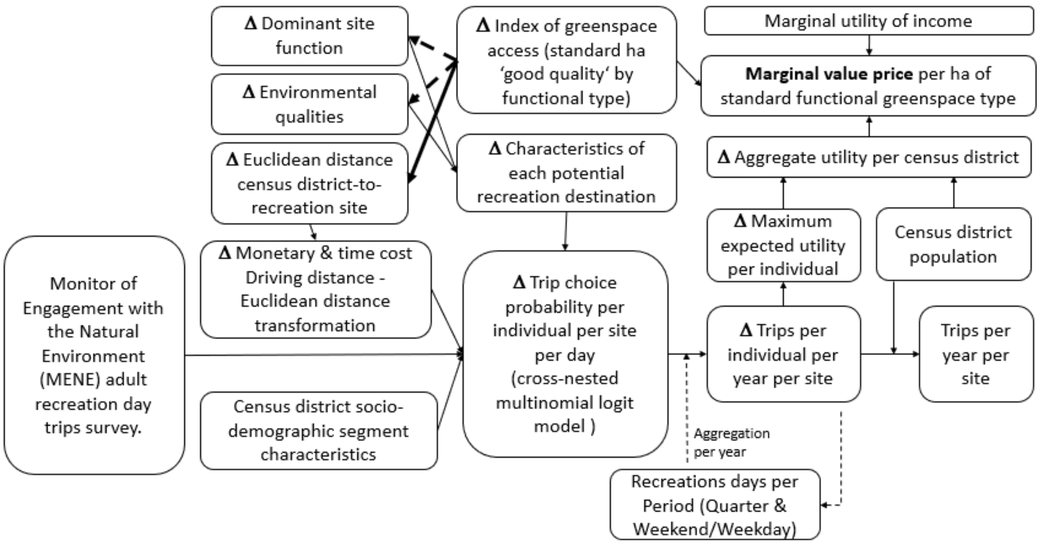


Figure 4. Marginal value pricing of a standardised accounting unit of greenspace using a discrete recreational travel choice model

Box 2. Similarities and differences of Simulated exchange (SEV) , hedonic property pricing (HPP) and Marginal Value Pricing (MVP)

A key contrast between the SEV approach and the hedonic property price approach is that they have somewhat different conceptualisations of how to define the good of 'outdoor recreation', and in practice have used different stated and revealed preferences data to identify the exchange price. The HPP method *reveals willingness to pay* for the *opportunity of access* to attributes of accessible greenspace. In the SEV approach, the exchange price is found at the point where *willingness to pay* for visits to greenspace is equal to costs of current recreation management, under assumptions about rights of access, type of market clearing competition between greenspaces. SEV can in principle use both stated willingness to pay from a survey or revealed through travel cost.

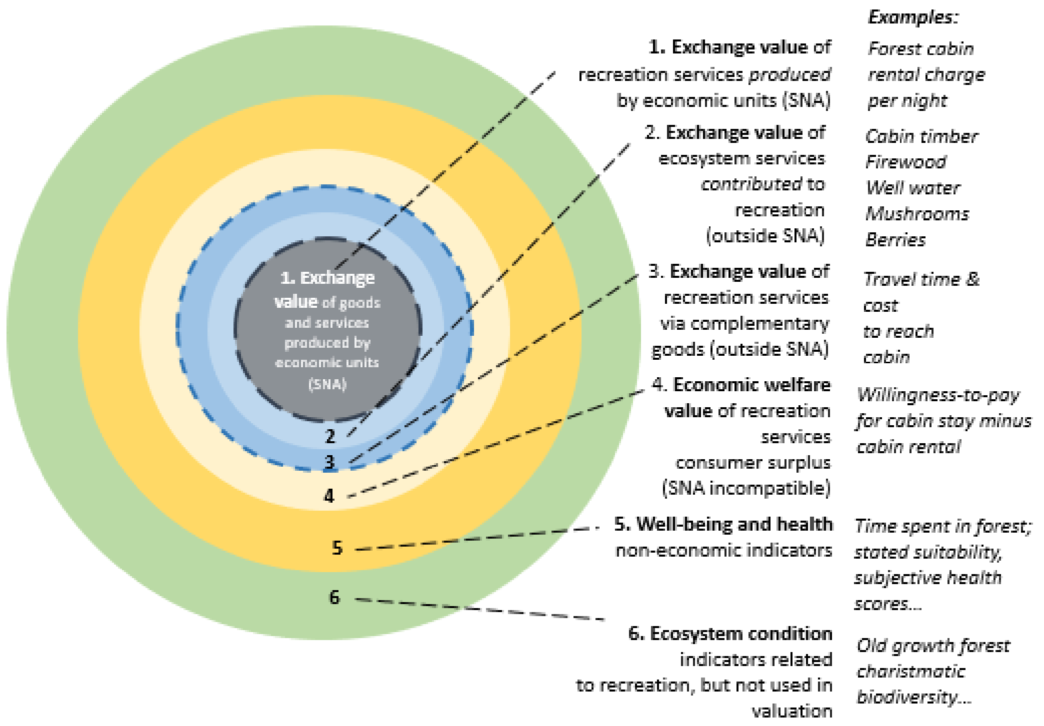
MVP (below) applies the hedonic conceptualisation of attributes of a greenspace good – measured by proximity and on-site characteristics - and uses data on preferences revealed through travel choice.

Under what assumptions could exchange prices from MVP, HPP and SEV be expected to converge? Assuming i) that home purchasers have full information about recreation opportunities in the neighbourhood in HPP, (ii) that we can estimate an attribution function for marginal capitalized property values back to individual greenspaces in HPP, (iii) that we can find an appropriate discount rate for recreation benefits with which to annualize capitalized greenspace values in HPP, (iv) that methods are applied at the same spatial scale, (v) that SEV uses revealed choice data, (vi) that the same metrics for greenspace attributes are available to each method, then we might expect the methods to reveal similar marginal annual exchange values for greenspace. Further clarification of the theoretical, data collection and computational similarities and differences between methods would be useful in order to clarify how the methods could complement oneanother from different valuation perspectives in ecosystem accounting and policy analysis.

4.4 Additional valuation options

The primary valuation options discussed above are data intensive. They may currently lack time series and data covering the whole accounting area and take time to implement. Exchange-value accounting prices cover just one of dimension of well-being. Additional valuation methods may therefore be useful in order to support multi-criteria policy analysis[93]. Recreation services contribution to the economy recorded in the system of national accounts (SNA) seen in combination with other indicators will provide a more complete picture of the societal importance of ecosystems for recreation (Box 4).

Box 4. Multiple indicators of the contribution of ecosystems to recreation



Currently only a small portion of the information available on ecosystems contribution to recreation is used in the system of national accounts (SNA)(1 - illustrated by the inner dotted line). Ecosystem service mapping and valuation using the exchange-based valuation methods discussed above will make it possible to expand the scope of national accounts to cover flows not currently recorded, such as nature's contributions to recreation (2) and complementary goods and services to recreation(3) (illustrated by the outer dotted line). Economic welfare measured by consumer surplus from recreation(4) is not accounting compatible, but could be recorded in parallel, along with non-economic indicators of health and well-being (5), and indicators of ecosystem condition (6) likely to be important for recreation, but not currently used by recreation demand models.

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[93]Jacobs, S., Dendoncker, N., Martin-Lopez, B., Barton, D.N., Gomez-Baggethun, E., Boeraeve, F., McGrath, F.L., Vierikkoh, K., Geneletti, D., Sevecke, K.J., Pipart, N., Primmer, E., Mederly, P., Schmidt, S., Aragao, A., Baral, H., Bark, R.H., Briceno, T., Brogna, D., Cabral, P., De Vreese, R., Liquete, C., Mueller, H., Peh, K.S.H., Phelan, A., Rincon, A.R., Rogers, S.H., Turkelboom, F., Van Reeth, W., van Zanten, B.T., Wam, H.K., Washbourne, C.L., 2016. A new valuation school: Integrating diverse values of nature in resource and land use decisions. Ecosyst Serv 22, 213-220.

Stated preference methods[94]**.** Beyond approaches which measure exchange values, there are a range of techniques that are used to estimate consumer surplus for benefit-cost analysis. We have already looked at applications to accounting of travel choice models and stated preference for simulated exchange valuation. As stated previously, the change in exchange value can be a good approximation of the change in producer and consumer surplus from a change in ecosystem condition[95]. The criterion for considering stated preference methods for accounting should be the quality of the study to measure change in ecosystem condition, rather than the large body of academic SP studies which have been focused on method development, rather than designed for policy support[96] .

Contingent valuation and choice experiments are based on the Random Utility Model, but differ from the methods discussed above in that they construct a hypothetical market. Contingent valuation is less hypothetical when focused on a familiar project area, specifying credible policy alternatives for supplying recreation services to a well defined potential population of users. The proposition here is that the more credible stated preference studies (i) identify site specific changes in measurable ecosystem condition indicators, and consequently (ii) are not scalable to regional or national accounts across sites without benefit transfer error[97]. Contingent valuation includes often just two or few scenarios in order to check that willingness-to-pay is sensitive to scope of improvements. Choice experiments offer more flexibility to estimate multiple points on a demand curve to changing site quality, and potentially transfer demand functions across sites with different qualities.

Replacement cost. Replacement cost refers to the replacement of a specific recreation service (restoration cost referred to below is defined in relation to the ecosystem asset.) The assumption about whether the replacement is a least-cost alternative and whether there are available substitutes are determinant of whether replacement cost is an over or under-valuation. For example, time spent in nature-based recreation could be valued at replacement cost of time in a similar non-nature based activity, for example indoor exercise in a gym. This assumes that the substitute for nature-based outdoor recreation is indoor exercise – thus discounting any potential additional benefits of outdoor recreation and hence generating a conservative valuation.

Restoration cost. Urban open spaces may be landscaped, replanted and recreational infrastructure such as paths, benches, lighting installed. Enclosed streams can be re-opened and landscaped with riparian vegetation. Costs of blue and green infrastructure must be distinguished from costs of other built recreational infrastructure in areas designed for urban recreation. Restoration would also have to be primarily for recreation. This seems more applicable in urban areas where land is zoned for specific uses, and where the counter-factual baseline is not recovery to a natural state (in which case man-made restoration does not represent a least cost option). In rural areas, it could be argued that artificial restoration is not a least cost option because natural restoration will take place.

Careful consideration about whether restoration is a least-cost alternative and whether there are available substitutes are important considerations in whether restoration cost is a credible accounting price for recreation services of a green space. The alternative use of the land without artificial

[94] Johnston, R.J., Boyle, K.J., Adamowicz, W. (Vic), Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., Vossler, C.A., 2017. Contemporary Guidance for Stated Preference Studies. J. Assoc. Environ. Resour. Econ. 4, 319–405. https://doi.org/10.1086/691697

[95] Harberger, A.C., 1971. Three Basic Postulates for Applied Welfare Econo. J. Econ. Lit. 9, 785–797.

[96] Johnston, R.J., Rolfe, J., Zawojska, E., 2018. Benefit Transfer of Environmental and Resource Values: Progress, Prospects and Challenges. Int. Rev. Environ. Resour. Econ. https://doi.org/10.1561/101.00000102

Laurans, Y., Rankovic, A., Billé, R., Pirard, R., Mermet, L., 2013. Use of ecosystem services economic valuation for decision making: Questioning a literature blindspot. J. Environ. Manage. 119, 208–219. https://doi.org/10.1016/j.jenvman.2013.01.008

[97] Johnston et al. 2018

restoration, and whether restoration is primarily for recreation are further criteria. Restoration may be legally mandated, in which case it represents a social demand, and a transaction is recorded. However, each greenspace restoration scenario and counterfactual is unique[98] and it seems difficult to apply this a general method and at national level.

Value of time spent in a greenspace would seem to be a measurable and intuitive indicator of enjoyment and a straightforward indicator of recreation benefit. Time spent in an activity is also a physical indicator of benefit. It is common practice in transport research tio value leisure time at 1/3 of the wage rate[99]. Time spent traveling to a recreation site is usually treated as a cost. The monetary value of recreation time onsite is however highly context specific. In transport literature the Value of Travel Times (VTTs) differentiates between different types of trip of different lengths at different times under different conditions and different modes of transport[100]. If foregone disposable income is used as a metric for recreation benefit of time onsite, it assumes that the alternative to recreation is work paid by the hour. It assumes that the recreationer has a flexible labour contract and that there is no unemployment. Despite an intuitive understanding of "quality time", measurement is highly subjective and context specific. The travel cost method uses a (weakly) complementary good to the time onsite and use demand for that good to infer the value that must be attached to the time on site. Recently, national level data sets from household time use surveys have been used to quantify the trade-offs between indoor leisure and outdoor recreation in forests[101], demonstrating the potential for using time on-site as a valuation index for national recreation accounting.

Health-related cost avoided. This valuation approach interprets trip specific recreational enjoyment and leisure as intermediate inputs to reducing longer term health risks/improving health relative to a population wide health expectation. Risk assessment "*is a systematic approach to quantify the burden of disease/injury resulting from risk factors*" [102] . In the case of greenspaces, risk assessment can be applied to quantify the avoided health-related burden attributable to the availability of green spaces in a certain setting and population (e.g. avoided mortality due to cardiovascular conditions or outpatient visits/hospitalization for psychiatric problems). Health studies have shown that the exercise that occurs in nature is more beneficial for health compared to the exercise carried out in indoor environments[103]. There may be exceptions in the case of risk of ecosystem-borne diseases[104]. The information generated by risk assessment is used to quantify the avoided healthcare burden in monetary terms and compare it with counterfactual scenarios[105].

Accounting studies may use medical costs of treating health conditions, assuming they can be associated with physical inactivity due to the counterfactual absence of greenspace [106]. The effects of greenspace on health are also The assumption is that physical activity is the main/sole mechanism

[98] Pers. com. Brett Day. Say there was a little woodland near to me that was used by my community for walks … then in a terrible storm all the trees were blown down. We could restore that woodland, but it would be hugely expensive needing us to truck in mature trees and re-establish them. It might be that for my community this is the only greenspace we have and as such that expense is tiny compared to our value. It might be that there is a field over the road which serves pretty much as well for recreation as the woodland, in which case the loss of the woodland is of little consequence. How much it costs to replace or restore something (if it can be replaced or restored) tells us nothing about how much that thing is valued.

[99] Cesario, F.J., 2006. Value of Time in Recreation Benefit Studies. Land Econ. https://doi.org/10.2307

[101] Berry, K., Bayham, J., Meyer, S.R., Fenichel, E.P., 2017. The Allocation of Time and Risk of Lyme: A Case of Ecosystem Service Income and Substitution Effects. Environ. Resour. Econ. 70, 1–20. https://doi.org/10.1007/s10640-017-0142-7

[102] World Health Organization, http://www.who.int/hia/tools/xtra_tools/en

[103] Pavam Dadvand reference

[104] Berry et al. 2017

[105] Kardan, O., Gozdyra, P., Misic, B., Moola, F., Palmer, L.J., Paus, T., Berman, M.G., 2015. Neighborhood greenspace and health in a large urban center. Sci Rep-Uk 5.

[106] eftec, 2017. A Study to scope and develop urban natural capital accounts for the UK. Final Report for Defra. June 2017.

underlying the health effects of greenspaces[107]. As described earlier the evidence for this is poor. Ascribing all treatment costs to the condition also ignores whether there are other possible causes than physical inactivity, as well as whether physical inactivity is only due to lacking accessibility to recreational areas, or to other causes.

Income foregone due to reduction in **quality adjusted life years** (QALYs) is also an exchange based valuation. Well-established dose-response functions are available for the impacts on QALYs of physical activity. The valuation methods work best for impacts of an incremental change in physical activity level within activity levels that are normal for a population. This assumes that there is no adaptation behaviour among users, where they replace exercise in green spaces with exercise in open or indoor spaces without green. Finally, health effects of greenspace are mediated by individual access to and effectiveness of different parts of a country's health care system/market.

4.5 Valuation method screening criteria

Further method screening criteria could be applied which are not particular to the valuation of recreation:

Conceptual consistency

   a. **Sensitivity to scarcity**? Is the method sensitive to changes in ES supply and use?
   b. **Institutional compatibility?** Are the institutional assumptions of the valuation method compatible with current institutions governing ecosystem use?
   c. **Close to market?** Does the method measure exchange values? This is a national accounting convention, which is difficult to follow in the case of public goods. All other things equal it should be subordinate to methods that value ecosystem change in a way that is most compatible with existing institutions.
   d. **Individual services? Double counting?** Is the method able to identify the ecosystem service individually? Does this identification reduce the likelihood of double counting.

2. **Practical considerations for application (to policy analysis)**
   a. **Significance?** Is the method likely to zero or low monetary values? (relative to level of biophysical flows). While disappointing for "big numbers" arguments, low values as an indication of poor management is useful for policy analysis.
   b. **Robustness?** Is the valuation method complex, subject to a large number of data transformations and modelling assumptions? (methods with few data transformation steps and assumptions are more robust)
   c. **Accuracy?** Can valuation method variance/uncertainty be quantified? Is the method sensitive to spatial and temporal variation in the accounting area and period?
3. **Institutional capacity to conduct valuation**
   a. **Technical complexity?** Does the method require a specialist in a particular software?
   b. **Information cost?** Is the method costly to implement (time to completion)
4. **Other policy applications?** Are the input data or results of the method applicable to other policy analysis purposes, than those of accounting?

[107] Pers. Com. Brett Day. Using a structural model of choice like ORVal it is possible to see whether removing the availablilty of one particular greenspace leads to people no longer taking trips to greenspace or simply substituting to an alternative site National travel surveys do not (yet) provide data on alternative activities to outdoor recreation.

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Appendix 1 - Examples of conceptual models of recreation benefits of greenspace

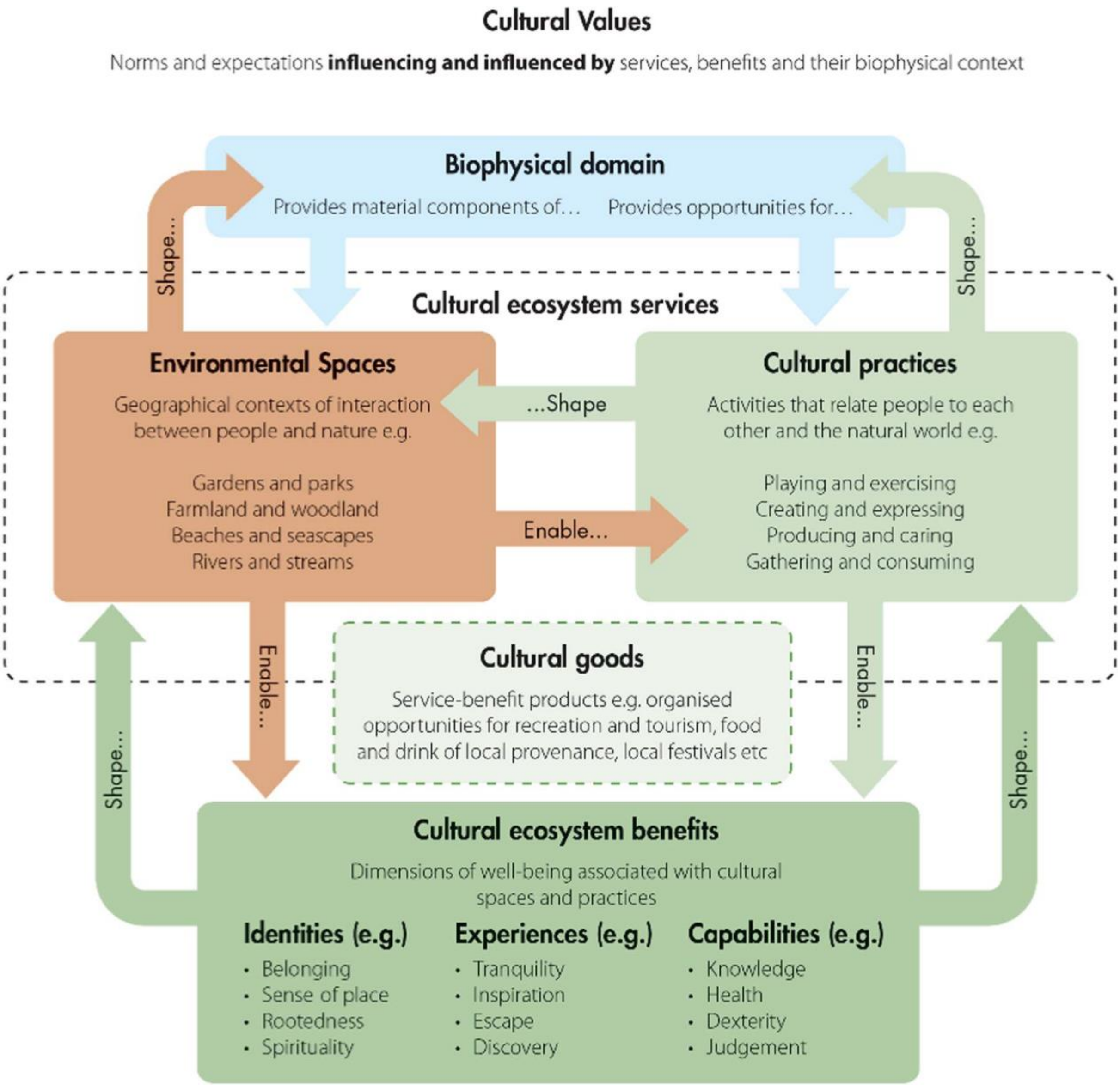

Fig. 1. A conceptual framework for cultural ecosystem services. Source: Fisher et al. (2016) Ecosystem Services 21 (2016) 208–217

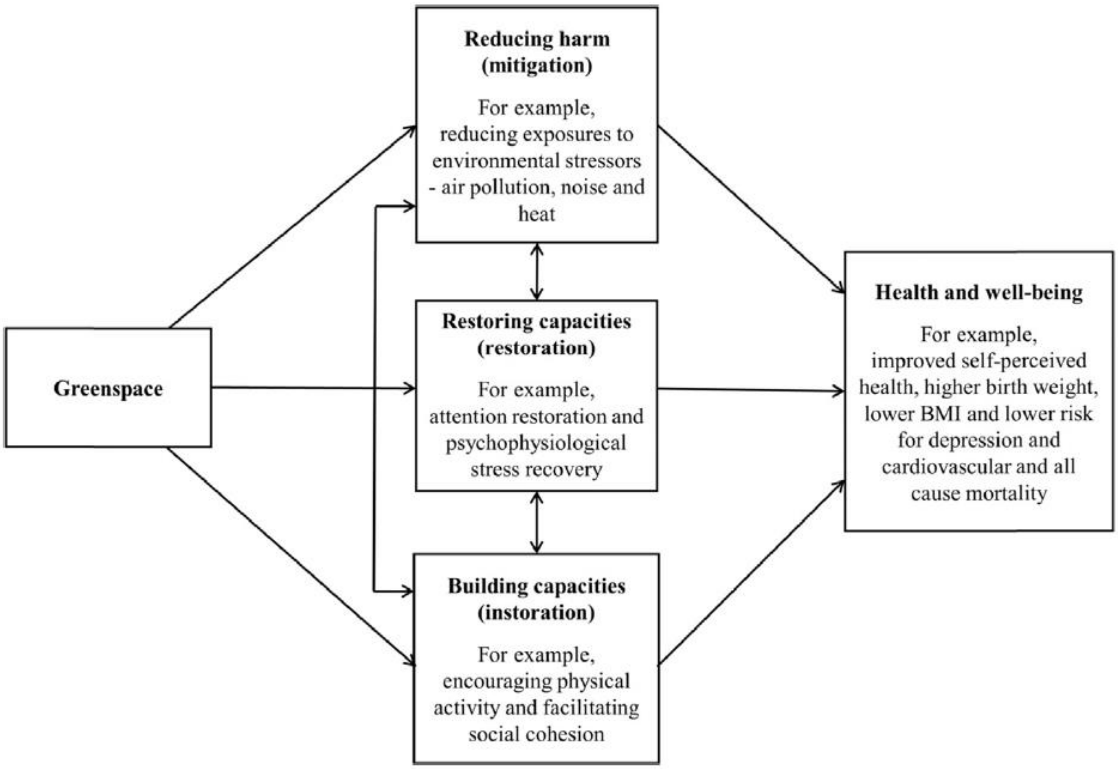

Figure 2. Three domains of pathways linking greenspace to positive health outcomes.
Source: Markeyvich et al. 2017 http://dx.doi.org/10.1016/j.envres.2017.06.028

Appendix 2: Cultural ecosystem services based on Havinga and Hein[108]

The following cultural services were proposed by Havinga and Hein[109]. Several of the services defined are related to recreation services as discussed above.

Habitat services* have been defined as conferring a sense of ecological importance (example metric: citizen science species records per hectare). The metric proposed is similar to **Scientific and educational services*** defined as contributing to the development of knowledge (example metric: (empirical) species records /ha). Recreational species observation is associated with "habitat services" as defined here, but not scientific and education services. Because species observations reported by amateurs are often quality controlled and then submitted to Biodiversity databases on a par with research funded species observations the service definitions are nested.

Activity services* have been defined as information transfer providing an attractive environment for recreation (metric example: meters hiked / m2 of viewshed). Meters of paths/hiking trail available per unit of ecosystem area is a metric of opportunity(a service), rather than of activity(a benefit). Activity services here refer to infrastructure that allows for physical mobility (walking, jogging, biking). A narrow definition of 'recreation services' could be limited to opportunities for physical /mobile activities.

Amenity services* have been defined as information transfer contributing to the desirability of a place or building (metric example: €/ha). Amenity services as such are a proxy for recreation in and near the home, observed through property prices. Regulating and supporting services are intermediate services to amenity services, providing environmental quality and wildlife viewing opportunities near the home. Marginal values of amenity attributes are associated with the property - there is an unresolved spatial modelling challenge in allocating marginal values of amenities distributed in the proxmity of a property, from a number of properties, to individual greenspaces in the neighbourhood. There is potential double counting with recreational valuation computed using visitation and travel cost data.

Aesthetic services* have been defined as information transfer generating a sensory configuration of beauty (metric example: Photo-User-Day-Viewshed/ha). Social media have also been used to describe aesthetics for other senses. For example, 'sensory maps' for smell and sound words in social media posts have been used to map non-visual sensory qualities of street segments (see other metrics further on in the Discussion paper).

Religious and spiritual services* have been defined as conferring a sense of spiritual importance (metric example: tweets/ha). The metric suggest that social media posts could be analysed for their content using a dictionary of spiritual and religious words. Similary, social media posts could be classified in terms of sensory, aesthetic, artistic and habitat observation experiences.

Artistic services* have been defined as the role (of nature) in the realisation of art (metric example: poem references/ha)[110]. A related metric for the density of place names per unit area of an ecosystem has been proposed as an indicator of 'symbolic value' in recreation area mapping and valuation in Oslo, Norway

[108] * Havinga, I. and L. Hein "Clarifying cultural ecosystem services" Research Note (22 November 2018).
[109] * Havinga, I. and L. Hein "Clarifying cultural ecosystem services" Research Note (22 November 2018).
[110] (pers. Com. David N. Barton,NINA).