www.nina.no

1115

NINA Report

Materials and methods appendix for valuation of ecosystem services of green infrastructure in Oslo

David N. Barton
Nora Vågnes Traaholt
Stefan Blumentrath

OSLOpenNESS

NINA

Norwegian Institute for Nature Research

NINA Publications

NINA Report (NINA Rapport)
This is a electronic series beginning in 2005, which replaces the earlier series NINA commissioned reports and NINA project reports. This will be NINA's usual form of reporting completed research, monitoring or review work to clients. In addition, the series will include much of the institute's other reporting, for example from seminars and conferences, results of internal research and review work and literature studies, etc. NINA report may also be issued in a second language where appropriate.

NINA Special Report (NINA Temahefte)
As the name suggests, special reports deal with special subjects. Special reports are produced as required and the series ranges widely: from systematic identification keys to information on important problem areas in society. NINA special reports are usually given a popular scientific form with more weight on illustrations than a NINA report.

NINA Factsheet (NINA Fakta)
Factsheets have as their goal to make NINA's research results quickly and easily accessible to the general public. The are sent to the press, civil society organisations, nature management at all levels, politicians, and other special interests. Fact sheets give a short presentation of some of our most important research themes.

Other publishing
In addition to reporting in NINA's own series, the institute's employees publish a large proportion of their scientific results in international journals, popular science books and magazines.

Materials and methods appendix for valuation of ecosystem services of green infrastructure in Oslo

David N. Barton
Nora Vågnes Traaholt
Stefan Blumentrath

Norwegian Institute for Nature Research

Barton, D.N. , N. Vågnes Traaholt, S. Blumentrath (2015) Materials and methods appendix for valuation of ecosystem services of green infrastructure in Oslo.– NINA Rapport [1115. 65 pp.]

Oslo, February 2015

ISSN: 1504-3312
ISBN :978-82-426-2737-7

AVAILABILITY
[Open]

PUBLICATION TYPE
Digital document (pdf)

EDITION
[xx]

QUALITY CONTROLLED BY
Henrik Lindhjem

SIGNATURE OF RESPONSIBLE PERSON
Erik Framstad (sign)

CLIENT(S)/SUBSCRIBER(S)
OpenNESS EU FP7

CLIENTS/SUBSCRIBER CONTACT PERSON(S)
Eeva Furman, SYKE (OpenNESS)

COVER PICTURE
Oslo Case study OpenNESS Logo

KEY WORDS
- Norway, Oslo
- Urban ecosystem services
- Green infrastructure
- Economic valuation

NØKKELORD
- Norge, Oslo
- Urbane økosystemtjenester
- Grønnstruktur
- Økonomisk verdsetting

CONTACT DETAILS

NINA head office
Postboks 5685 Sluppen
NO-7485 Trondheim
Norway
Phone: +47 73 80 14 00

NINA Oslo
Gaustadalléen 21
NO-0349 Oslo
Norway
Phone: +47 73 80 14 00

NINA Tromsø
Framsenteret
NO-9296 Tromsø
Norway
Phone: +47 77 75 04 00

NINA Lillehammer
Fakkelgården
NO-2624 Lillehammer
Norway
Phone: +47 73 80 14 00

www.nina.no

Foreword

Barton, D.N. , N. Vågnes Traaholt, S. Blumentrath (2015) Materials and methods appendix for valuation of ecosystem services of green infrastructure in Oslo – NINA Rapport 1115. 65 pp.

The material in this report constitutes a Methods and Materials appendix for two reports disseminating the results to a wider audience in English and Norwegian. We recommend that readers start with one of the cited reports below, using the appendix as a companion report to look up specifics:

Barton, D.N. , N. Vågnes Traaholt, S. Blumentrath (2015) Naturen i Oslo verdt milliarder. Verdsetting av urbane økosystem-tjenester fra grønn infrastruktur. NINA Report 1113.

Barton, D.N., E. Stange, S. Blumentrath, N. Vågnes Traaholt (2015) Economic valuation of ecosystem services for policy. A pilot study on green infrastructure in Oslo. NINA Report 1114.

The work has been carried out in the EU FP7 financed project OpenNESS as part of WP5 Case study activities. (http://www.openness-project.eu/). The OpenNESS case study in Oslo is a collaboration between NINA, VISTA Analyse A/S and Oslo Municipality. We gratefully acknowledge the collaboration with Oslo Municipality's Urban Environment Agency (BYM), Planning and Building Agency (PBE) and Water and Sewage Agency (VAV) in making this study possible, both through the contribution of data bases and for discussions with their experts at regular meetings regarding the role of economic valuation of ecosystem services in Oslo Municipality. In particular we acknowledge the coordination of Future Cities Project at BYM who has been the OpenNESS project's main facilitator of contacts with other colleagues within Oslo Municipality.

The contents and evaluations in this report are entirely the responsibility of the authors.

February 2015

David N. Barton
NINA
Gaustadalleen 21, 0349 Oslo
david.barton@nina.no

Contents

1 Introduction

The material in this report constitutes a methods and materials appendix for two reports disseminating the results to a wider audience in English and Norwegian.

We recommend that readers start with one of the cited reports below, using the report you are now reading as a companion report to look up specifics:

- Barton, D.N. , N. Vågnes Traaholt, S. Blumentrath (2015) Naturen i Oslo verdt milliarder. Verdsetting av urbane økosystem-tjenester fra grønn infrastruktur. NINA Report 1113. (in Norwegian)

- Barton, D.N., E. Stange, S. Blumentrath, N. Vågnes Traaholt (2015) Economic valuation of ecosystem services for policy. A pilot study on green infrastructure in Oslo. NINA Report 1114. (in English)

Readers looking for specifics will want to skip to particular sections of this report. The report is structured as follows:

Chapter 2 provides further illustrations of the framework for decision contexts of valuation. It illustrates different spatial scales and resolutions at which economic valuation of ecosystem services might take place. It discusses some hypothetical policy questions that might arise at the different scales as possible contexts for economic valuation.

Chapter 3 briefly discusses alternative frameworks that discuss when and economic valuation is relevant for decision-making. Readers can get a sense of the many ways in which 'policy relevance' of economic valuation can be explained.

Chapter 4 provides brief introductions to what we mean by economic value and monetary valuation methods. We also discuss what is meant by 'value transfer' versus doing original valuation studies.

Chapter 5-9 constitute the main body of the report with the valuation examples. Readers interested in further discussions of the assumptions behind the monetary valuation examples are encourage to go here.

Chapter 5 Willingness to pay for recreation in urban parks

Chapter 6 Capital value of blue-green areas in property prices

Chapter 7 Recreational value of peri-urban forest

Chapter 8 Liability value of city trees

2 Framework for decision-contexts of economic valuation

Gómez-Baggethun and Barton (2013) proposed a framework for decision-relevant valuation of ecosystem services adapted to the urban context . The framework brings together the notions that economic valuation is specific to particular spatial scale and resolution, and to different decision context requirements for accuracy and reliability of economic valuation.

The framework identifies the purpose of ecosystem service valuation in different decision-support contexts. Different use of ecosystem service valuation estimates will have different reliability and accuracy requirements (***Figure 2.1***). The reliability and accuracy that is achievable depends on the information available. Information demands increase with increasing geographical scale and resolution of the decision-support context. Information costs increase accordingly.

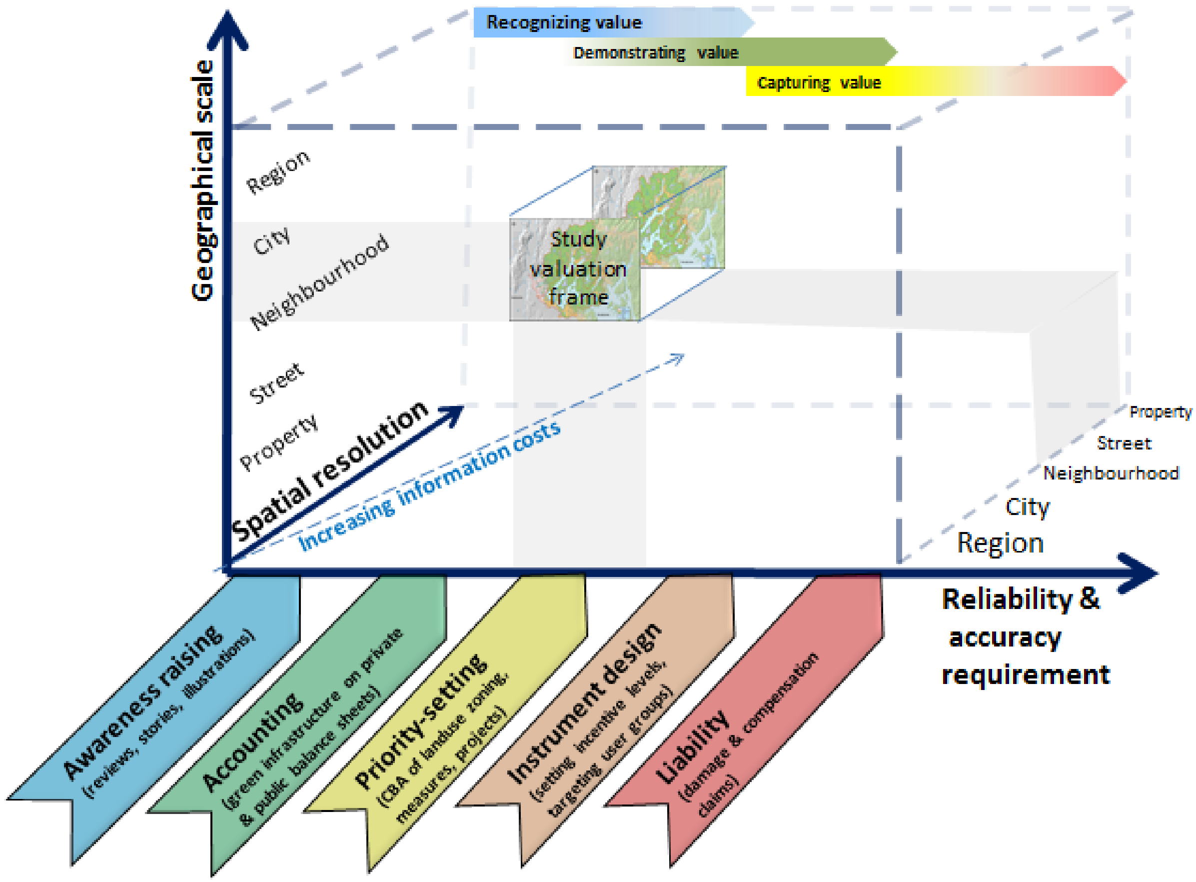


Figure 2.1 *A Framework for policy-relevant valuation of ecosystem services at different scales Source:adapted from Gómez-Baggethun and Barton (2013)*

Information costs also increase with the demand for accuracy and reliability of valuation methods. Study costs increase successively when moving from a policy setting requiring simply awareness raising (e.g. regarding costs of ecosystem service loss), to including ecological infrastructure in accounting of municipal assets, to priority-setting (e.g. for location of new neighbourhoods), to instrument design (e.g. user fees to finance public utilities), or finally to calculation of claims for damage compensation in a litigation (e.g. siting of a road).

Ecosystem service value estimates differ substantially between the fine and coarse resolution analyses (Grêt-Regamey et al., 2014). Below we provide illustrations of the different spatial scales and resolutions of hypothetical policy questions for ecosystem services, with Oslo as an example. The scales and resolutions are those referred to in vertical and inward axes of the "policy relevant valuation framework" in ***Figure 2.1***. This examples below are meant to highlight how policy contexts of ecosystem services can span a wide range of spatial scales, with potentially different requirements for economic valuation methods.

2.1 Property scale

At property scale individual blue and green structures can be identified (***Figure 2.2***). Examples of hypothetical policy questions of relevance for valuation include:

(i) what blue green structures are preferred by property owners ?
(ii) what blue green structures generate most value-added for developers?
(iii) what is a minimum blue green factor score structures that should be required of new property development in different parts of the city ? (Dronnningalandskap et al., 2014)
(iv) should property taxes or other private incentives be adjusted for the level of positive externalities generated by privately held green infrastructure?

Figure 2.2 *Blue-green factor example at property and street level*

Source:Dronnningalandskap et al. (2014)

2.2 Streetscape scale

At the streetscape scale we still focus on individual structures such as street trees and small green spaces such as pocket parks (***Figure 2.3***). Examples of hypothetical policy questions include:

- what blue green structures in public spaces are preferred by users?
- what blue green structures public spaces generate most value-added for developers, private home owners, commercial interests and?
- what is a minimum blue green factor score structures that should be required of new public infrastructure projects ?
- should public utilities fees be charged private property owners to cover costs of maintaining public green infrastructure in their neighbourhood?
- What is the economic liability facing private interests that damage public blue green structures? (e.g. street trees)

Figure 2.3 *Blue-green factor example at street level*

Source: Dronnningalandskap et al. (2014)

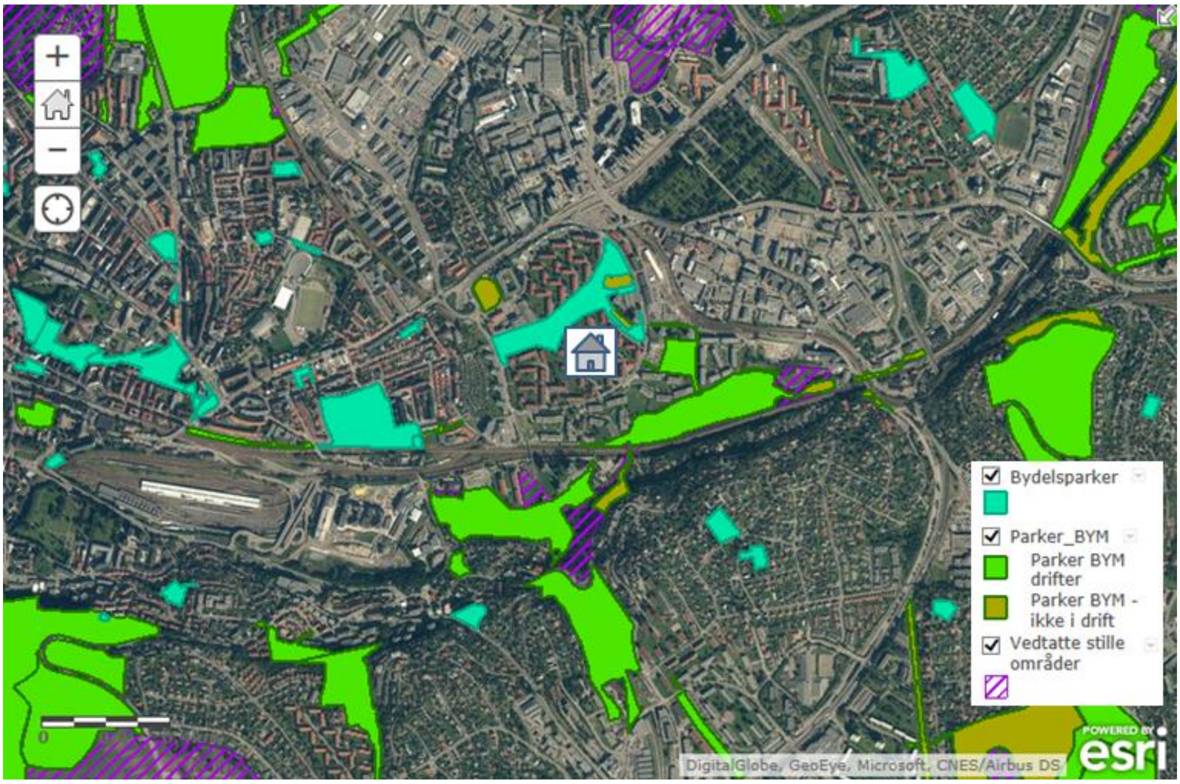
From a valuation perspective we have shifted from a particular property owner to municipal land. The same potential valuation methods apply as at property level, but valuation now concerns providing public goods, which is likely to lead to different values for otherwise similar structures.

2.3 Neighbourhood scale mapping of blue and green spaces

At neighbourhood scale it is less feasible to map individual blue green structures (***Figure 2.4***). Ecosystem service mapping at this resolution deals with blue and green spaces or areas. The neighbourhood scale is difficult to define for policy and ecosystem service mapping purposes because a neighbourhood depends on the type of resident (young/old, family/single etc.) and the type of activity related to blue and green structures. A neighbourhood is defined by local accessibility. Examples of hypothetical policy questions related to ecosystem services could be:

(i) What open spaces are important for recreation and should be protected and structurally upgraded?
(ii) What characteristics of blue and green structures increase recreation use?
(iii) What open spaces are in critical locations for regulating services?
(iv) What are minimum requirements for connectivity to promote recreational use ?

Figure 2.4 *Blue and green structures at park - neighbourhood level*



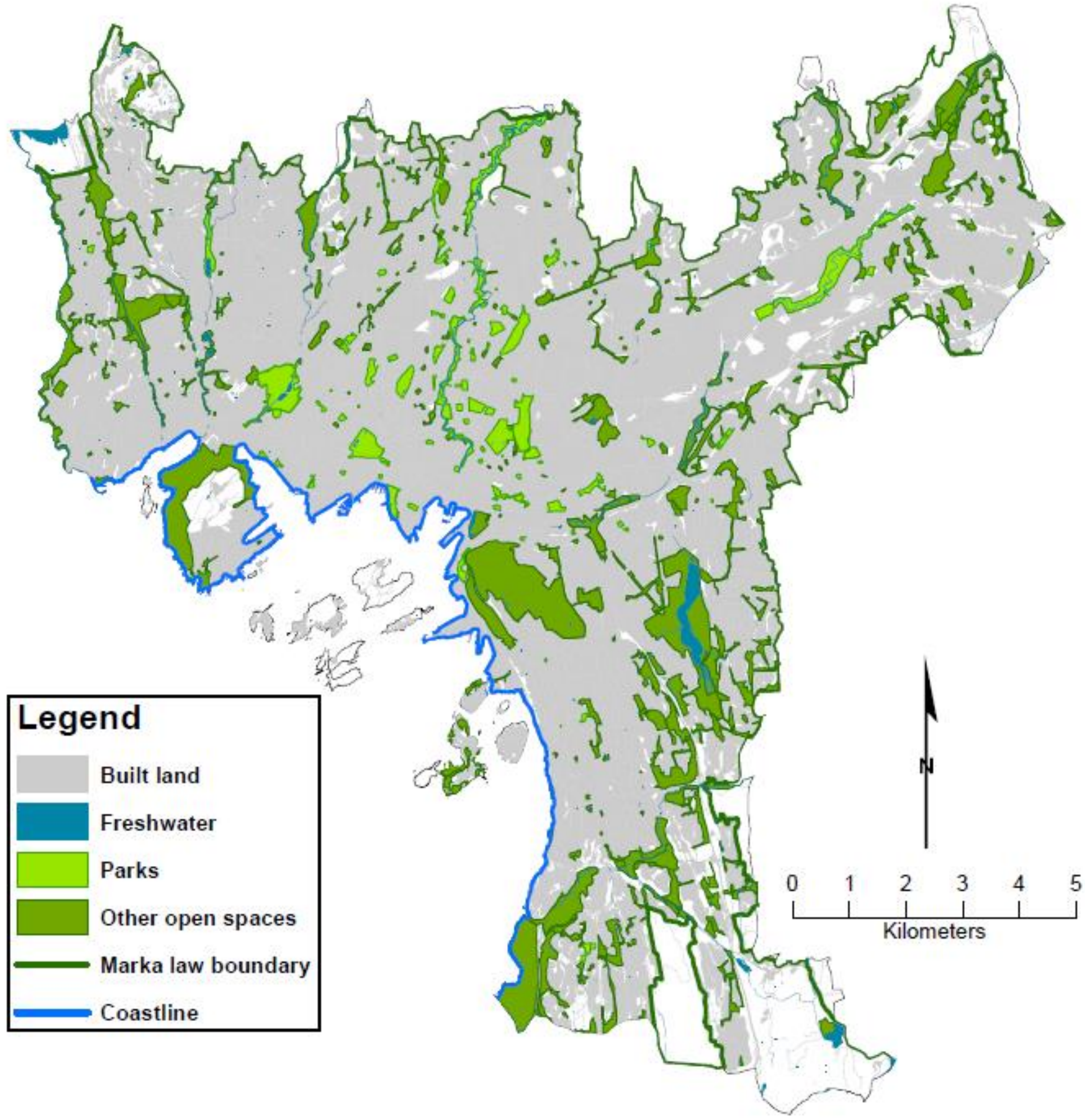
Source: Bymiljøetaten, Oslo Kommune

2.4 City scale mapping of green infrastructure

At the city scale individual structures such as city trees and small blue and green spaces such as pocket parks cannot be identified (***Figure 2.5***). Examples of hypothetical policy questions of relevance for valuation could include:

(i) What is coverage per inhabitant of blue and green spaces across city districts?
(ii) Are there gaps between recreational capacity of blue-green areas in city districts and population demand?
(iii) Is accessibility to urban ecosystem services for the city as a whole comparable to other cities in the region(in terms of attracting labour)?
(iv) Is accessibility to green infrastructure across the population above minimum levels required for mental and physical health?
(v) Can loss of green infrastructure in parts of the city by offset in terms of ecosystem services by restoration of green infrastructure in other parts of the city?

Figure 2.5 *The green infrastructure of Oslo City's built zone bounded by the Marka-forest limit and the Oslofjord*



Source: Bymiljøetaten, Oslo Kommune

2.5 Municipal scale mapping of green infrastructure and ecosystems

The municipal scale (***Figure 2.6***) includes the built area and the peri-urban greenbelt within municipal boundaries. At this scale the spatial configuration of green infrastructure within the built area is less important than the relative area under different types of landuse within and outside the city. Hypothetical policy questions could include:

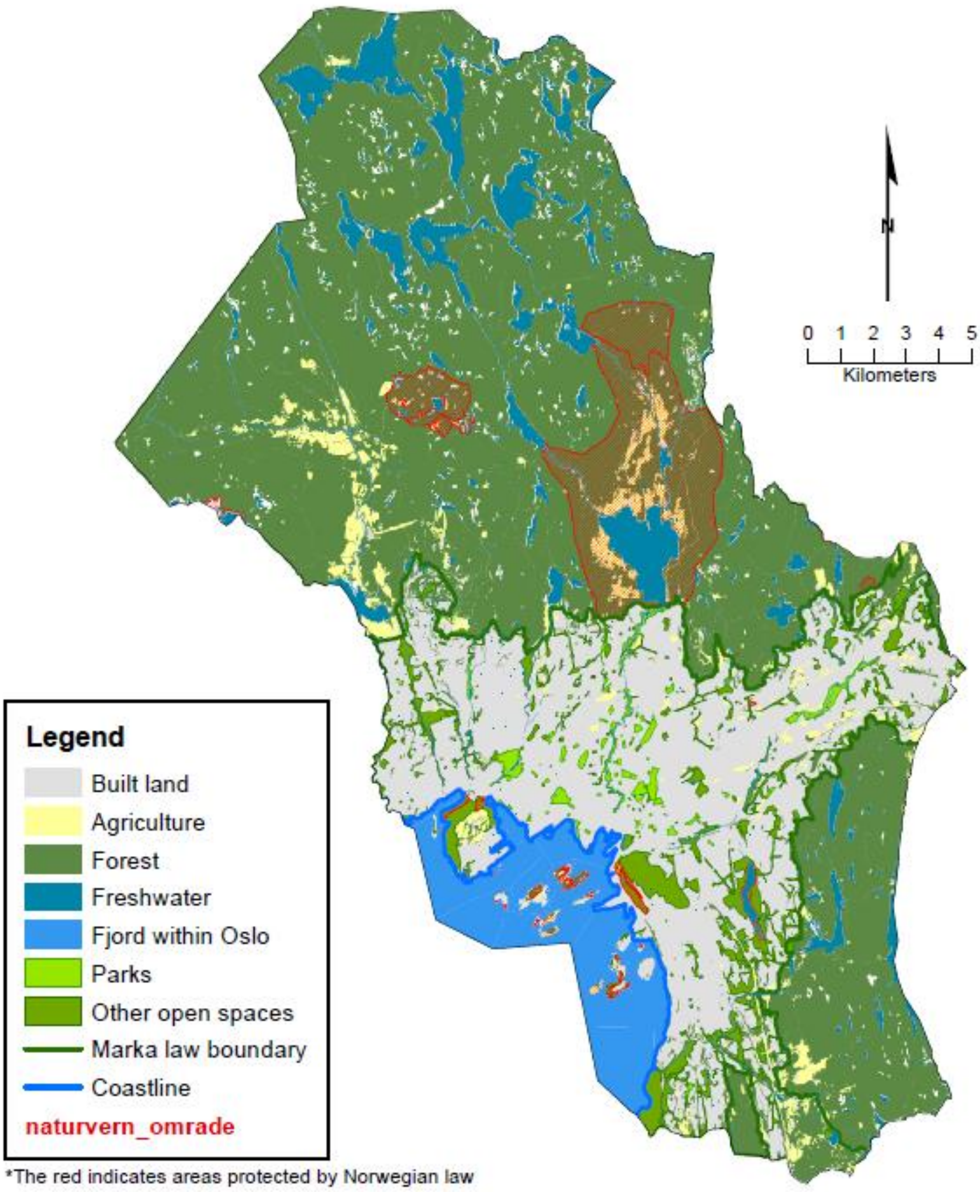
(i) Is it preferable from an ecosystem services point of view to densify the city on existing built area, on open space within the built area or extend the built area into the peri-urban forest?

(ii) Can regulating services such as water supply from the peri-urban watershed meet demands from projected increase in population and commerce?

(iii) To what extent can carbon sequestration and storage in peri-urban forests offset city CO2 emissions?

(iv) Can Oslofjord treatment of sewage overflow offset the need for increased stormwater capacity in the drainage system?

Figure 2.6 *Green infrastructure of the Municipality of Oslo*



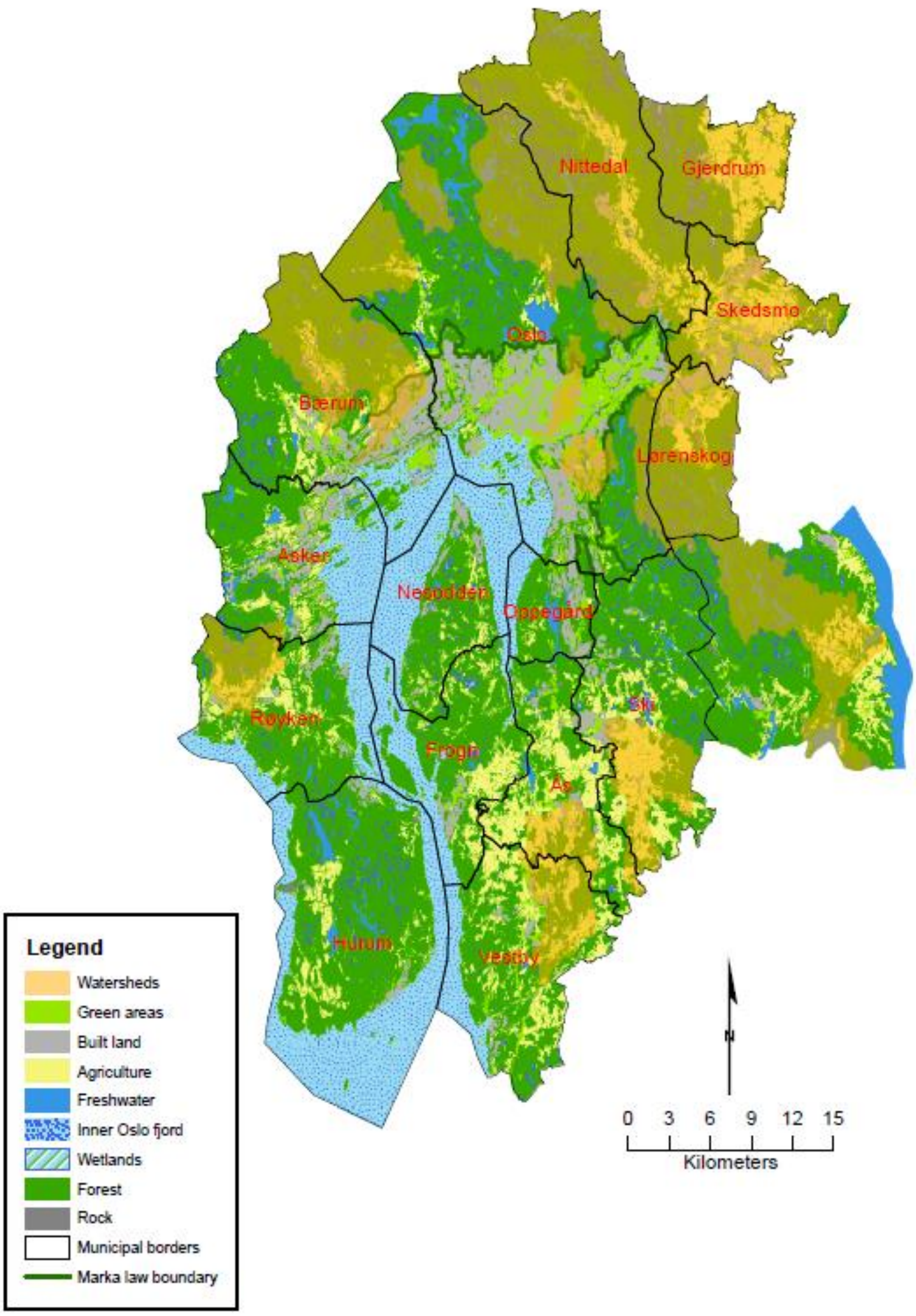
Source: BYM, Oslo Kommune

2.6 Regional scale mapping of ecosystems

At a regional scale the distribution of ecosystems and land use across neighbouring municipalities is evident (***Figure 2.7***). Hypothetical policy questions could include:

- To what extent do ecosystems within Oslo Municipality provide services to neighbouring municipalities and vice versa?
- Are ecosystem service spillovers between municipalities and costs of ecosystem management so large that they justify ecological fiscal transfers - adjustments to state-municipal fiscal transfers (also know as the ‘kommunenøkkel’)?

Figure 2.7 *Green infrastructure of the Municipality of Oslo*

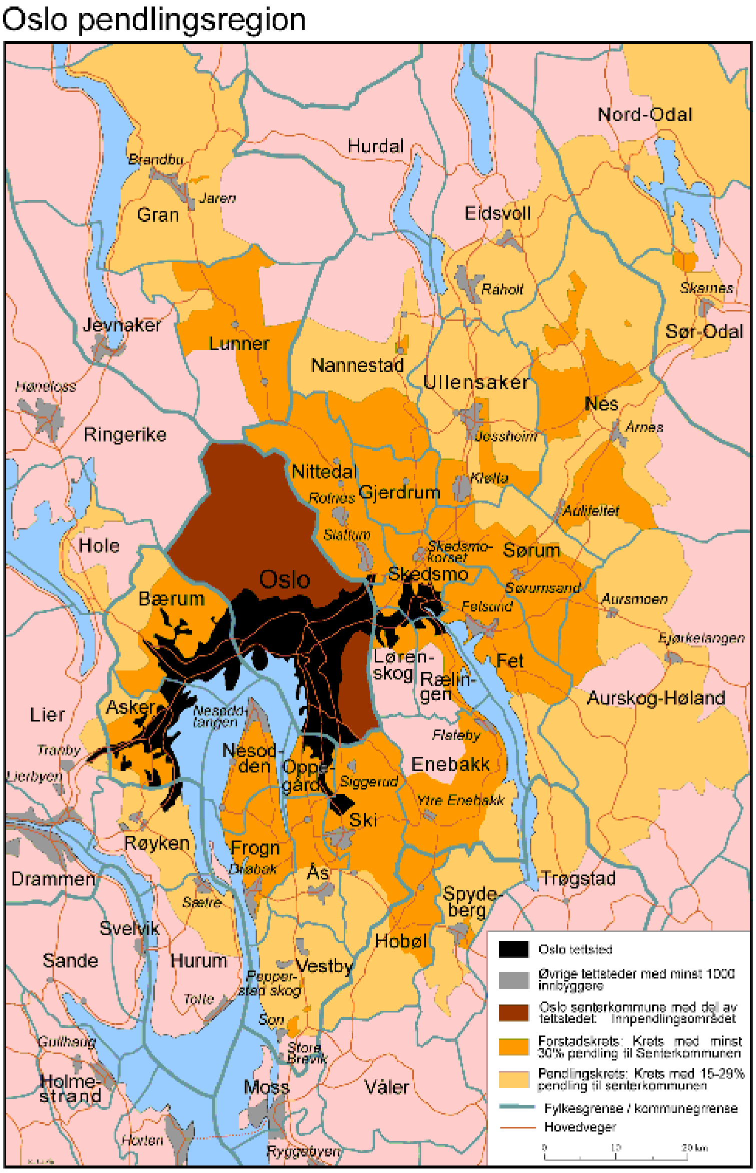


Source: AR5 and Bymiljøetaten, Oslo Kommune

Demand for ecosystem services from green infrastructure also comes from a large commuting population living outside Oslo's municipal borders (***Figure 2.8***). Hypothetical policy questions could include:

- To what extent does the Marka law restriction on building into Oslo's peri-urban forest, shift demand for land for housing to other municipalities of the region?
- To what extent does Oslo import virtual cultural and regulating ecosystem services from neighbouring municipalities through commuters' demand for housing?
- What is Oslo's ecosystem service footprint in Norwegian rural landscapes in terms of land required to produce inputs embodied in imports of goods and services to the capital city?

Figure 2.8 *Greater Oslo's area of "commuter influence"*



Kartet viser pendling til Oslo senterkommune i 1990 fra grunnkretser i omlandskommunene.

Prosent av de yrkesaktive i kretsene med arbeid i Oslo (pendlingsfrekvensen) er beregnet på grunnlag av krets-data fra Folke- og boligtellingen 1990, kontrollert og justert ved hjelp av tall fra Folke- og boligtellingen 1980.

Datagrunnlag: Statistisk sentralbyrå. Databearbeiding og kartfremstilling: M. Helvig, Institutt for geografi, Universitetet i Bergen.

Source: http://www.regjeringen.no/se/dep/kmd/Dokumeanttat/NA-at/1997/nou-1997-12/6/3/2.html?id=344824

3 Decision context of ecosystem services valuation – other frameworks

Below we briefly compare the framework by Gómez-Baggethun and Barton (2013) to other frameworks for the decision context of ecosystem services valuation.

3.1 Use of ecosystem service valuation (UESV)

Laurans et al. (2013) conducted a review of the use og 313 ecosystem services valuation studies and found that the use of ecosystem service valuation (UESV) had rarely been documented. They proposed a more detailed classification of valuation use contexts than Figure 4 above. Laurens et al. did not focus on comparing information demands of valuation contexts. Below we have re-ordered Laurans et al. (2013) 'use context' list in what we would roughly regard as increasing requirements for accuracy and reliability:

Informative
- for awareness-raising
- for justification and support for a given course of action a priori or a posteriori (net benefits of single alternative)
- for accounting indicators

Decisive
- as a 'negotiation language' to encourage participation
- for trade-offs and optimization (ranking several alternatives on net benefits)
- as a criterion for environmental management (spatial targeting)

Technical
- for price-setting (after a choice of instrument has been made)
- for establishing levels of damage compensation

Laurans et al. (2013) suggest a number of reasons why few ecosystem service valuation studies specify the context in which estimates will be used. Generally speaking, lacking research interest and time lags between research studies and actual decisions can make it hard to identify use context in a review of the academic literature. More specifically there may be a number of reasons that valuation studies may fall short of policy-maker expectations:

- incompleteness of monetary relative to social values
- lacking relevance (in particular for distributional issues)
- inaccuracy (relative to expectations of the decision context)
- excessive costs of valuation studies
- lacking decision-maker training in economics
- regulatory framework not conducive to ecosystem service valuation
- excessive transparency relative to needed ambiguity in some political strategies

Laurans and Mermet (2014) point to a tension between desire of (most) economic valuation practitioners to provide objective information, and an equally strong dependence of valuation results on highly contingent decision-making contexts and processes. They argue for a much greater attention to the decision-making process to which ecosystem service valuation is intended to contribute. The potential 'gaps' listed above are useful to keep in mind when considering the move from commissioning valuation for informative - awareness-raising in the present study - to their use for decisive and technical purposes in a policy process.

3.2 Spatial ecosystem service accounting

Schröter et al. (2014a) argue that ecosystem accounting plays a much wider role than what is suggested by the policy-relevant valuation framework in ***Figure 2.1.*** They argue that ecosystem accounting can be used for simple awareness raising purposes, but also forms the information basis for much of assessments involving priority-setting and instrument design (***Figure 3.1***).

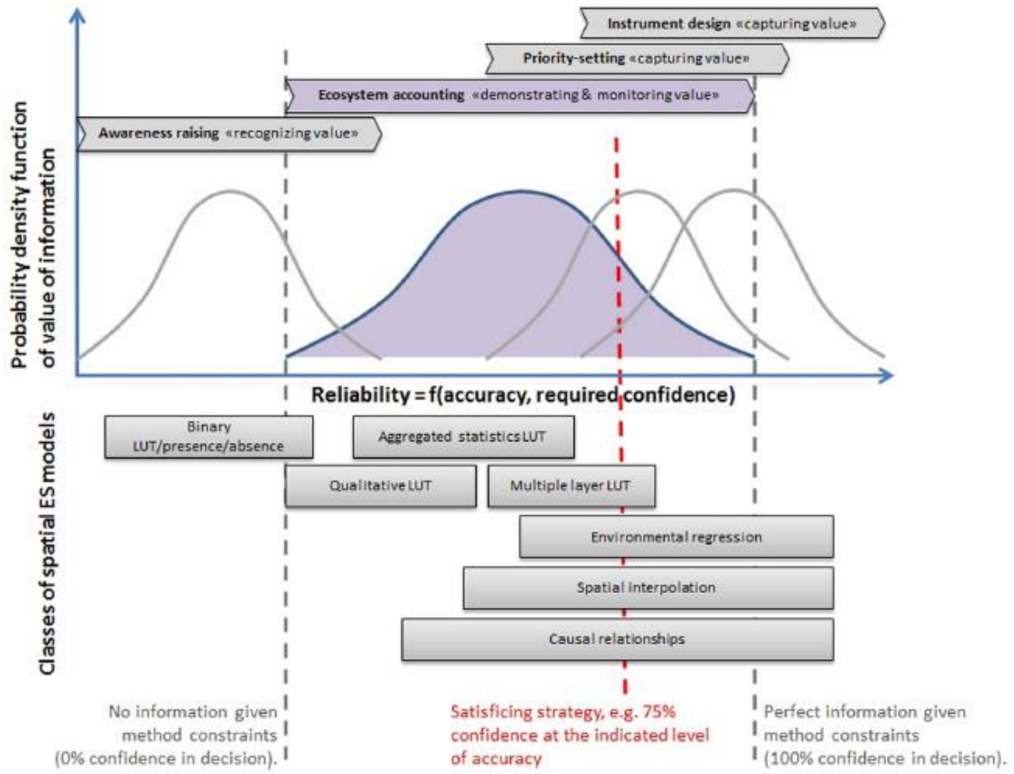


Fig. 3. Examples for niches of policy purposes. The purple bell indicates the ecosystem accounting niche. Types of spatial modelling methods are indicated at the bottom o the figure. Grey boxes show the spread of the model types in terms of accuracy and feasibility. The grey dashed line indicates the boundaries of the ecosystem accountin niche. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Figure 3.1. *The role of ecosystem accounting in policy and the reliability of spatial ecosystem service models. Source: Schröter et al. (2014a)*

They also clarify the concepts of reliability and accuracy discussed in ***Figure 2.1***. The accuracy of the ecosystem service accounting method and data defines the width of the probability distribution (variance of the value estimate). Reliability is then a function of the accuracy of the method and the confidence level required by the policy-maker for the policy context in questions.

Schröter et al. (2014a) evaluated a number of spatial ecosystem service accounting methods for their relative accuracy, but did not assess required confidence levels. Notably, required confidence cannot be determined before one knows the decision-context in which ecosystem accounting estimates will be used. Schröter et al. (2014b) discuss reliability requirements of ecosystem accounting for spatial priority-setting of forest conservation in Telemark, Norway.

Schröter et al. (2014a) review of spatial ecosystem service models refers to rural contexts only. For urban contexts spatial resolution of ecosystem services accounting needs to be higher because green infrastructure is more fragmented and small areas are more intensively used, with a higher 'density of preference' per surface area. Accuracy should be assessed both in terms of variance of estimate and whether the resolution of the model matches the smallest spatial extent of ecosystem service preferences for the urban project under evaluation.

3.3 Balance sheet approach of UK National Ecosystem Assessment Follow-up

The follow-up study to the UK National Ecosystem Assessment Follow-up assessment (UK NEAFO) developed a step-wise framework for representing data and evidence within increasing complex decision contexts in UK policy processes (Albon and Turner, 2014).

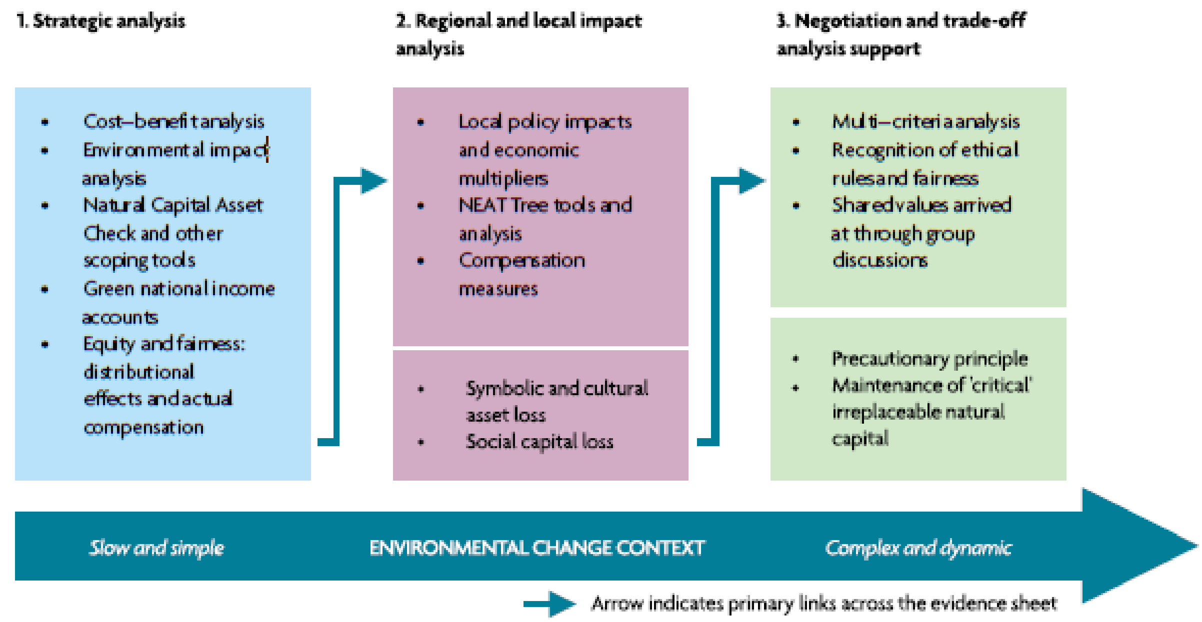


Figure 3.2 *The balance sheet approach showing the progression of information used as the environmental context becomes more complex and dynamic. Source: Albon and Turner (2014)*

The balance sheet approach (***Figure 3.2***) refers standard national and strategic policy appraisals as belonging to 'sheet 1', whereas more complex and dynamic contexts require more spatially explicit appraisals as represented by sheets 2 and 3. By comparison the policy context framework for valuation in ***Figure 2.1*** is more generic suggesting that decision-contexts apply over many scales and resolutions.

The 'balance sheet' approach emphasises that decision-support tools are specific to the complexity (scale, resolution) and dynamic nature of the policy issue. Economic valuation methods are mainly relevant for the 'sheet 1 – strategic analysis', whereas regional and local impact analysis (sheet 2) and negotiation and trade-off analysis support (sheet 3) rely on other methods. Scott (2014) argues that ecosystem services language of the NEA can be alienating to professionals working with the built environment. For the local level (sheet 2) the National Ecosystem Approach Toolkit (NEAT) emphasises using methods that speak to the project cycle of developers. They suggest finding 'built environment policy hooks', related to statutory plans, or planning application processes into which ecosystem thinking can be introduced.

4 Economic valuation methods for urban ecosystem services

4.1 Monetary valuation methods

This section contains a brief summary of *economic* valuation methods for ecosystem servicesto clarify the terminology for non-technical readers[1]. Economic valuation methods include those that are market-based /monetary or based on exchange value (***Figure 4.1***). The economic valuation methods are based on the evaluation of individual preferences for ecosystem services. The methods aim at quantifying direct use, indirect use, option values and non-use values of ecosystems. Different types of values can be addressed by different methods.

Direct use values refer to uses such as harvesting or recreation directly from in an ecosystem. Indirect use values refer to use of ecosystem's regulating services such as water purification which is 'indirectly' valuable for drinking water. Option value refers to the willingness to pay for keeping open the option to use an ecosystem in future (through e.g. conservation). Non-use values refer to willingness-to-pay to conserve ecosystems as a bequest/legacy for future generations or simply the value of knowing that species and ecosystem exist.

Figure 4.1 illustrates that there are other types of values associated with social values held by groups, expressed using non-monetary methods. There are also valuation methods based on biophysical approaches. The valuation examples in this report are all examples of monetary valuation and thus cover only a small part of the different ways values of ecosystem services can be expressed.

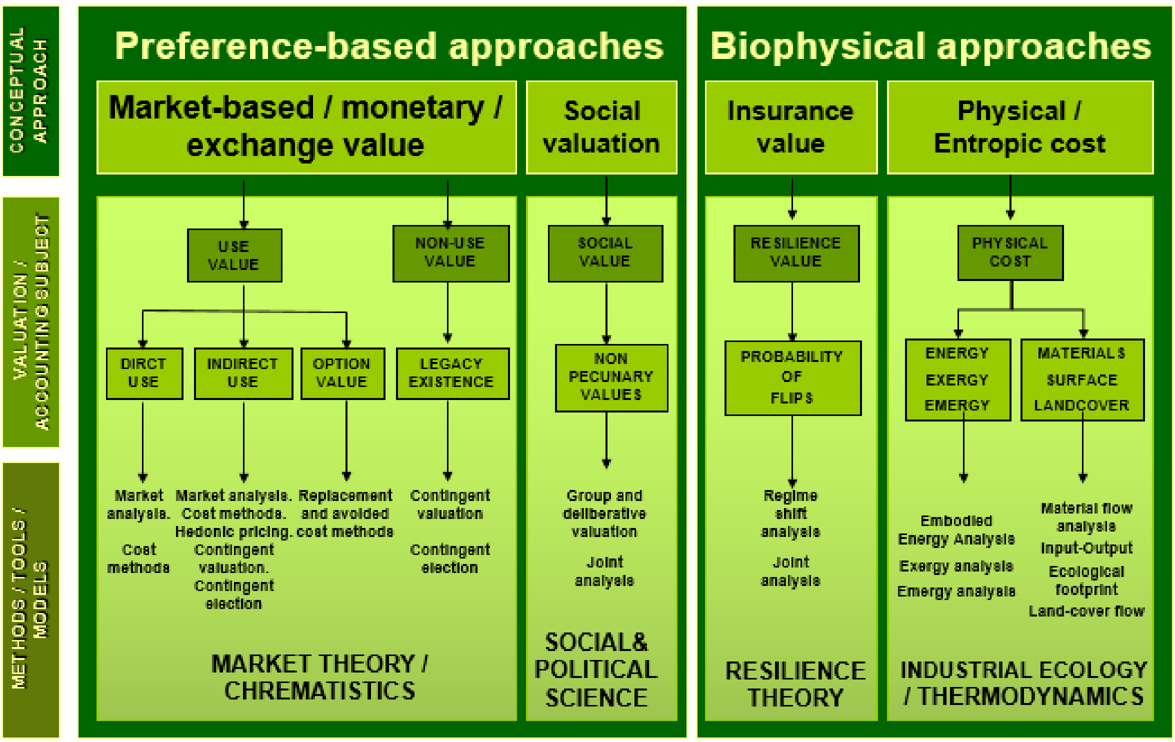


Figure 4.1 *Methods for the accounting and valuation of natural capital and ecosystem services. Source: Gómez-Baggethun and de Groot (2010)*

[1] based on an unpublished methodology brief developed for OpenNESS co-authored with Henrik Lindhjem, Berta Martín Lopez and Leon Braat

Below, we provide some brief summaries of monetary valuation methods for readers with non-economic backgrounds.

1. Direct valuation methods (marked price or cost based methods):[2]

Market price: These methods have in common that they use observed market prices to assign value to ecosystem services. These methods are closely related to the steps in the 'mitigation hierarchy' used in environmental impact assessment and planning, including 'avoid, minimize, mitigate and compensate'. They have in common that so far they use no information, or make very simple assumptions, about ecosystem function. In most cases this involves biomass products, water (processed via ecosystem work) or energy as in agriculture, forestry, fisheries, drinking water production. A market price method would also use information from the growing ecosystem service offsets markets (i.a. carbon, wetland restoration).

Avoided damage cost: Where an ecosystem service is the main cause of avoiding damage to property or economic production, the economic value at risk, valued at market prices, can be assigned directly as the value of the ecosystem service. If the avoided damage is co-produced with human management a production function approach is used where the contribution of the ecosystem service is estimated. Example: the removal of urban green space in urban micor-watersheds may lead to increased local flooding and property damage.

Prevention and mitigation cost: The costs of actions in preventing or mitigating damage that would be or is caused by the loss of ecosystem services are a conservative estimate of the value of the ecosystem service. Example: the costs of building extra sewage overflow capacity and clean-ups after eventual flooding that would not have been needed if the urban green space were still in place.

Replacement, restoration cost: Urban green space once removed may (in part) be replaced or restored with more or less artificial green surfaces on buildings. The costs associated with replacement or restoration are a conservative estimate of the value of the ecosystem services of the original wetland habitat.

Substitute cost: When an ecosystem service is lost it may be substituted by some other means of providing the service. While closely related to the idea of prevention and replacement cost, which happen on-site, substitution cost often refers to replacing the ecosystem service by importing it from *other locations*. This would be the case of pollinator-dependent apples grown in urban orchards,being replaced by apples imported from outside the city, thereby substituting for local pollinators.

The production function or productivity method[3]: is one of the key methods for valuing ecosystem services. In cases where ecosystem services are a combination of ecosystem function and human management, the approach estimates the marginal contribution of the ecosystem relative to human 'input' to the overall production of the service. The service is valued at market prices. But the main challenge is modeling ecosystem function and separating it from human management actions. Simple example: timber productivity in peri-urban forests depends on site specific natural factors (growth rates according to the site index, topography, climate etc.) and site specific human actions to optimize harvest(access, management and harvesting techniques). Estimating the net benefits from timber production requires econometric or simulated estimation of a production function assuming some optimization behavior on the part of the forester. Calibration of production functions is challenging due to natural variability in site quality and the assumptions required about human behavior.

[2] http://www.ecosystemvaluation.org/market_price.htm,
http://www.ecosystemvaluation.org/cost_avoided.htm

[3] Natural capitals project – INVEST http://www.naturalcapitalproject.org/InVEST.html
http://www.ecosystemvaluation.org/productivity.htm

Government spending: A special case of cost-based methods is public spending on damage avoidance, prevention, mitigation, restoration of ecosystems. Governments, in democratic political systems, are considered as representing the (majority of) the preferences of the people, and as such the decisions on how to spend tax money can be seen as an aggregate willingness to pay. So the analysis of budgets is step 1 (stated preference; intended spending) and actual spending is step 2 (revealed preference). It offers a vehicle to comparatively value ecosystems (natural capital) and services, at regional and national scale, by comparing the budgets for / spending flows to actual maintenance of natural capital and to co-producing the services.

2. Revealed preference methods[4]:

Revealed preferences estimate the value of a given ecosystem service without market price through the observation of substitute markets related to the service. The two main techniques are travel cost (TC) method and hedonic pricing (HP). Opportunity costs may be considered a lower bound estimate.

Travel cost: The TC is used to estimate monetary values of the contribution that ecosystems make to recreation experience by humans (which should be separated from the factor accessibility (roads, parking) and distance to the origin of the recreating people, thus estimate direct use values of nature tourism or recreational activities. The TC is based on the idea that the cost to arrive to the particular area should be at least equal to the utility obtained. As the travel cost can differ for different people, it is possible to construct a demand schedule on the basis of the number of visits and travel costs.

Hedonic pricing: The HP method can be used to estimate monetary values for ecosystem services that directly affect market prices of goods not necessarily produced by the ecosystem in question. In fact, it estimates the monetary value on the basis of changes in commodity prices (usually a property) according to changes on quality or quantity of specific attributes including an environmental one (e.g. an aesthetically pleasant landscape from the window).

Opportunity costs: Governments, businesses, land owners and agents in general may forego income streams from technologies or land uses when undertaking conservation actions. The foregone net income from alternative (less sustainable) opportunities is called 'opportunity cost' and can be understood as a lower estimate of the bundle of ecosystem services that are conserved by the conservation action.

3. Stated preference methods[5]:

Stated preference methods in environmental economics refers to a family of techniques which use individual respondents' statements about their preferences to estimate change in utility associated with a proposed increase in quality or quantity of an ecosystem service or bundle of services. Respondents are presented one or more hypothetical scenarios describing a project or policy that will lead to a specified environmental change compared to a baseline situation. The answers respondents give, in the form of monetary amounts, ratings, or other indications of preference, are scaled following an appropriate model of preference to yield a measure of value of the proposed ecosystem service change. This value is often monetary in the form of people's willingness to pay (WTP). WTP is the amount out for their households' income they are willing to forego to achieve the environmental gain (or to avoid a loss) and still be at the same utility

---

[4] Garrod, G., Willis, K.G., 1999. Economic Valuation of the Environment. Edward Elgar Publishing Ltd., Cheltenham, UK.

[5] Champ et al. (2003) A primer on non-market valuation methods. Kluwer. Particularly chapters 4-6.

Carson and Hanemann (2005) Contingent Valuation, In Handbook of Environmental Economics, Volume 2. Edited by K.-G. Mäler and J.R. Vincent, Elsevier, DOI: 10.1016/S1574-0099(05)02017-6, level before as after the change. The income they would give up represents the value of other goods and services that may otherwise give them utility, and therefore represents their stated trade-off between such goods and the environmental change.

Stated preferences are often elicited through surveys (typically web, phone, mail or in-person) that use questionnaires following strict guidelines. The surveys are administered to representative samples of the people affected by the environmental change and mean WTP per household or person then aggregated over the relevant population as a measure of welfare change.

The two most common forms of stated preference methods are **contingent valuation (CV)** and the more recent **choice experiments (CE)** (or choice modeling). CV elicits WTP by asking respondents directly their WTP for the change in the ecosystem service(s). CE breaks the description of the environmental good into physical attributes, where each attribute has different levels. The respondents then face a number of choice sets with different combinations of physical attribute levels combined with a cost attribute. This design yields indirectly the respondents' trade-offs between money and changes in individual attributes, and their WTP for a general environmental change described by combinations of the attributes.

The advantage of stated preference methods is that they can be used in any situation where there is no or limited data of people's actual behavior that can say something about their environmental preferences. In contrast with so-called revealed preference methods, stated preference methods are also able to estimate the utility loss or gain people may experience even if they do not directly utilize the ecosystem service ("non-use value"). The main disadvantage of stated preference methods is that the data collected are hypothetical in nature. A combination of stated and revealed (as validation) is much preferred.

4.2 Value transfer

Value transfer is used throughout the monetary valuation examples in this report. In this section we briefly discuss some of the terminology of using available valuation estimates in new policy contexts.

4.2.1 What is value transfer?

Older environmental economic literature referred to «benefits transfer» as the transfer of monetary estimates of preferences. More recently: «value transfer» refers to the transfer of quantitative estimates of ecosystem service preferences from existing studies to another context - from a 'study site' to a 'policy site'. Values may be monetary estimates of benefits, costs or also non-monetary estimates of benefit (following the logic of the ecosystem services cascade).

Much of the value transfer literature has focused on "single site" problems, for example for use in a benefit-cost analysis of local infrastructure. Because ecosystems function at a landscape level, value transfer of ecosystem services must consider spatially explicit transfers, both in terms of spatial variation in ecosystem capacity, but also in societal demand.

4.2.2 Value transfer for decision-support?

Following the logic of a policy cycle, ecosystem service valuation is not a "one-time" activity. As policy and information gathering proceed value estimates may be updated to improve their reliability and accuracy.

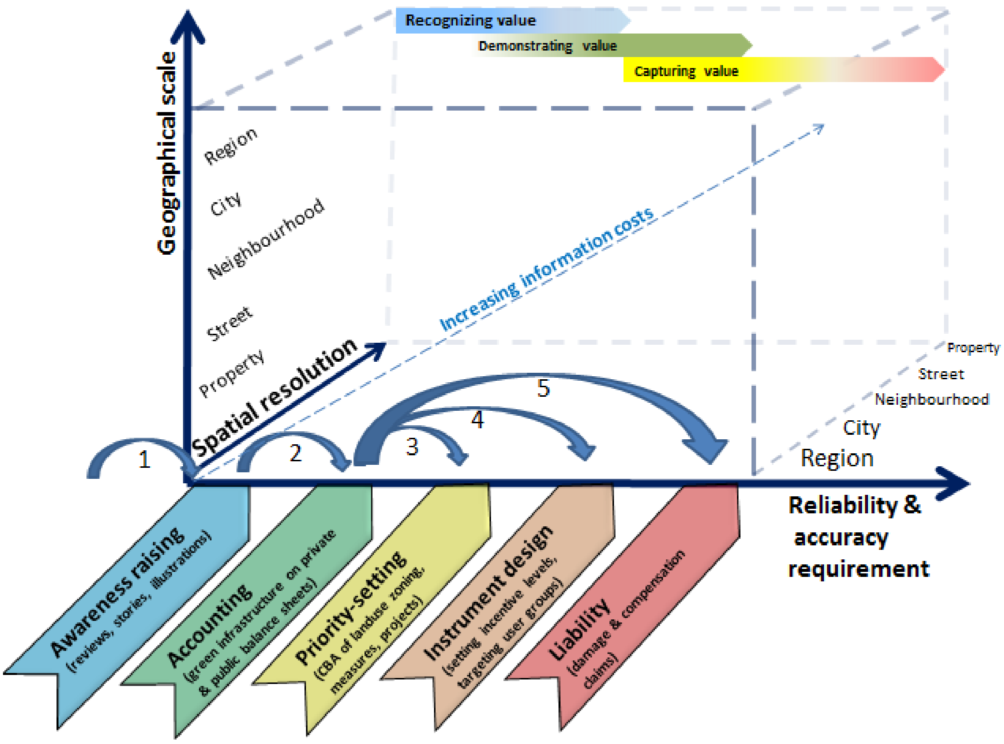
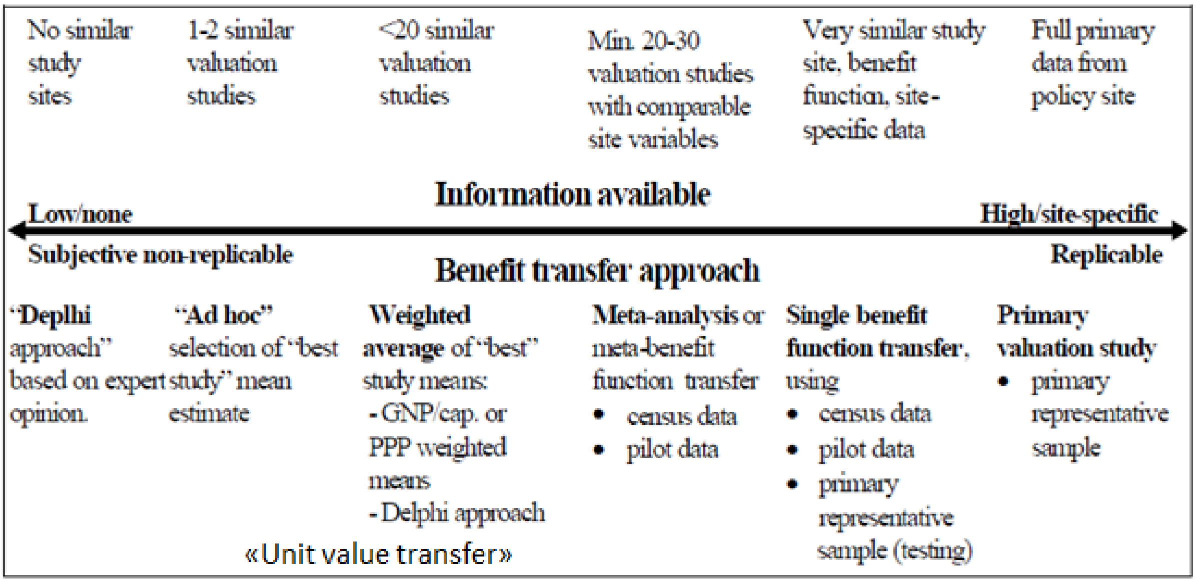


***Figure 4.2** Economic valuation and stepwise updating for different contexts.*
Starts with simple awareness-raising using value transfer (1) and then updated with new studies on-site information for more demanding contexts (2-5)
Source: adapted from Gómez-Baggethun and Barton (2013)

From initial “quick and dirty” value transfers for awareness raising (1), more geographically representative data can be gathered to carry out natural capital accounting(2). If spatial resolution of data is increased valuation can be made relevant for priority-setting(3), instrument design(4) and even environmental liability assessments (5) (***Figure 4.2***). While there may be a desire among decision-makers to “have the Rolls Royce” information as soon as possible, available time and research resources will always constrain the context legitimacy of valuation results. The framework is meant to encourage thinking among decision-makers about their minimum information requirements are to move ahead in the policy cycle.

Value transfer is not one specific method, but a continuum of approaches depending on the information available (***Figure 4.3***). All valuation of ecosystem services has at least an element of value transfer when estimates are applied to specific decision contexts (because each decision context is unique and therefore not identical to the decision context in which ES values were generated in the original study).

Figure 4.3 *Value (benefit) transfer methods depend on the information available*



Source: Barton (1999)

- Unit value transfer: Value estimates are assumed to be correct ‘on average’ and transferred without any form of adjustment.

- Adjusted unit value transfer: Value estimates are transferred with simple adjustments typically for study and policy site differences in income and purchasing power.

- Value function transfer: Signficant predictors at the study site of willingness-to-pay typically (from CV or CE studies), are identified at the policy site. The average value of predictors at the ‘policy site’ are then ‘plugged into’ the ‘study site’ value-function to derive an adjusted WTP figure for the policy site.

- Meta-analytic function transfer: Similar to value function transfer, but the value function is generated from a meta-analysis of many valuation study sites instead of a single study site. The method assumes that there is a meta-value function (i.e. similar preferences) that apply across all the study sites.

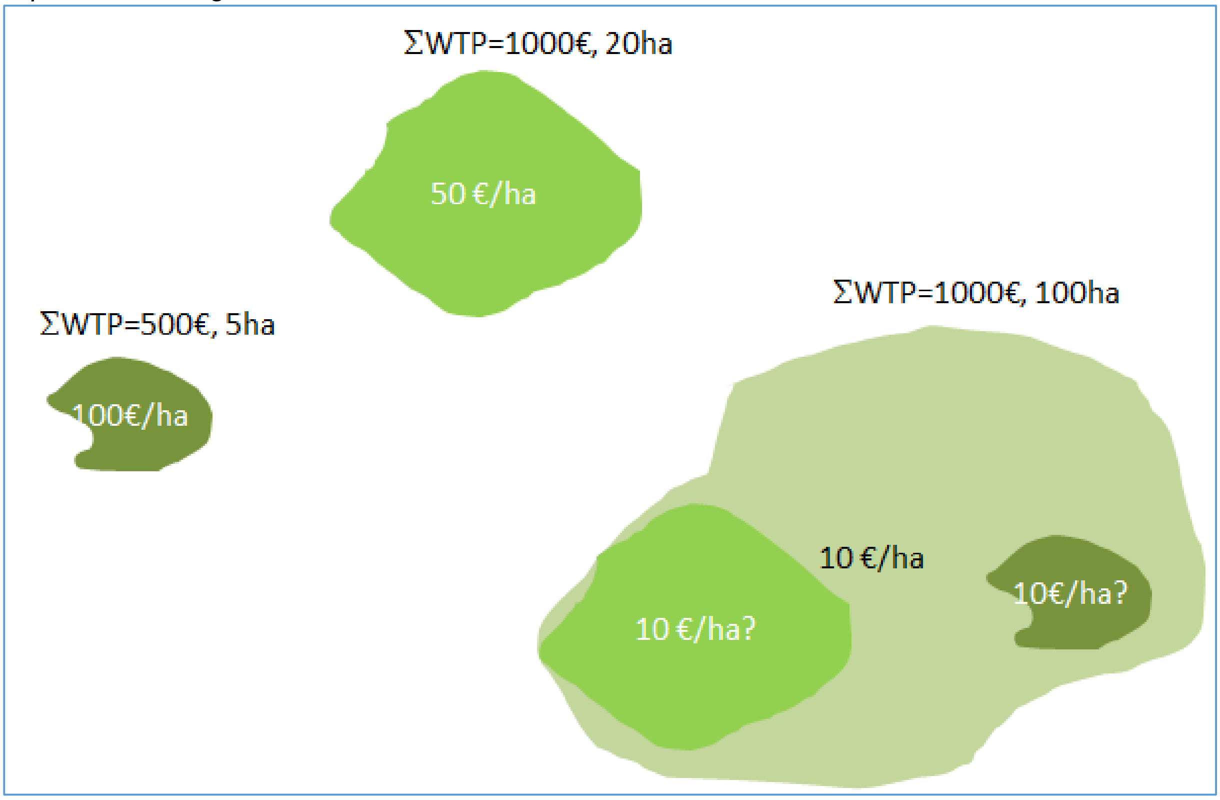
4.2.3 Key value transfer questions in valuation of urban ecosystem services

When "quick and dirty" valuation estimates are on the table, it is very tempting for stakeholders and researchers outside the team who produced the study to assign them more certainty than the original data can support. In this section we discuss what we think are three of the most problematic issues when moving from value transfer "for story-telling purposes" or awareness raising to decision-support.

1. **Marginal versus average area values**

A frequent issue in value transfer is that ecosystem services are specific to landscape context (because they are a function of landscape configuration). The loss of small green spaces has a particular marginal value. Does the loss of an equivalent area within large green spaces have the same marginal value?

Figure 4.4 *Are we using marginal values for decision support or average values for natural capital accounting?*

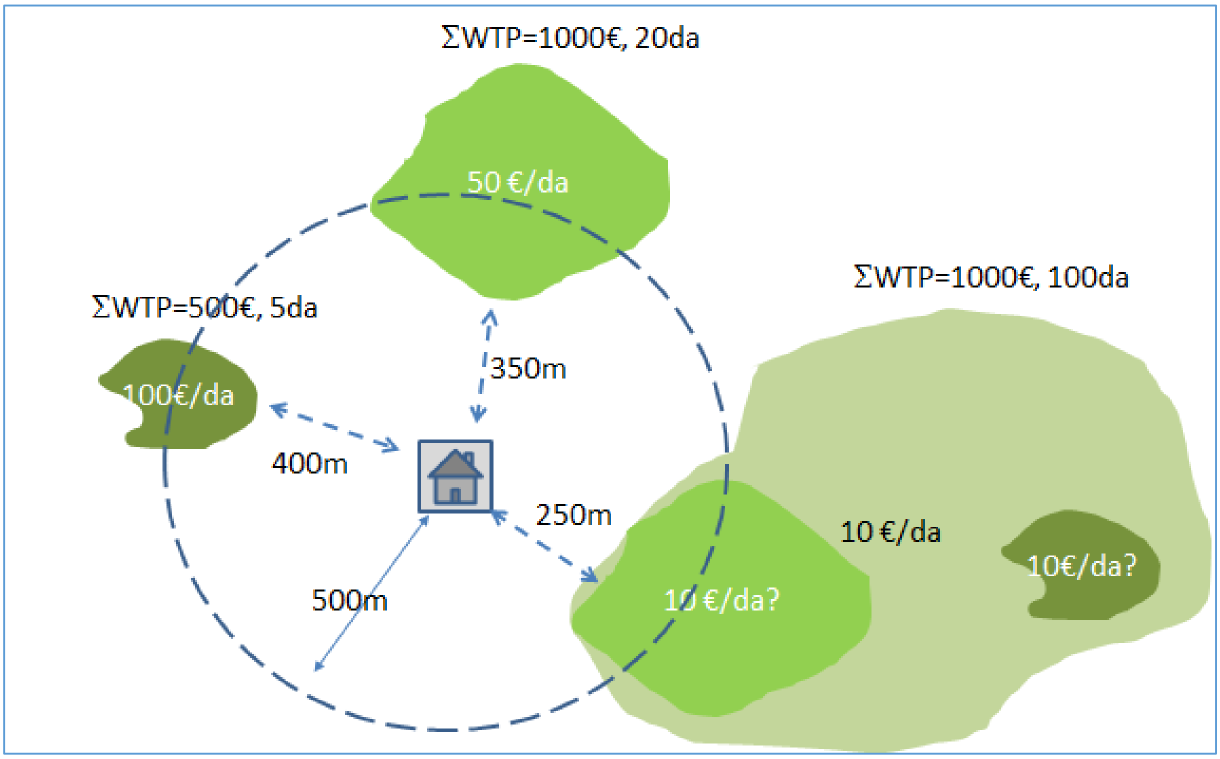


In ***Figure 4.4*** we can imagine a contingent valuation survey has revealed that the aggregate willingness-to-pay (ΣWTP) for the smallest area means that average value is 100 €/ha. In a separate study a somewhat larger area has a lower average value per hectare. In the largest green space there are plans afoot to develop property on two separate areas of equivalent size to those that were valued. What are the marginal values per hectare of these incremental changes in the largest area? We must be careful when transferring the average values from other green spaces. One reason we would expect marginal values to be lower is because there is more substitute green space in the vicinity.

2. Substitutes and complements

For a better understanding of whether different green spaces are substitutes e.g. in terms of their recreational ecosystem services we need to know not only the configuration of the landscape, but recreational users' / households' location and preferences (***Figure 4.5***).

***Figure 4.5**. Area of and distance to green infrastructure are often used as proxies for substitutes and complements of in urban areas*



At what distance is green area considered accessible for a particular type of recreation activity? In value transfer studies green space area and distance from the user population are easily measurable proxy indicators for whether sites are substitutes. So-called 'distance-decay' of willingness-to-pay for use of green space is amongst others a result of substitute sites becoming more numerous as we extend the radius of assumed accessibility to the site.

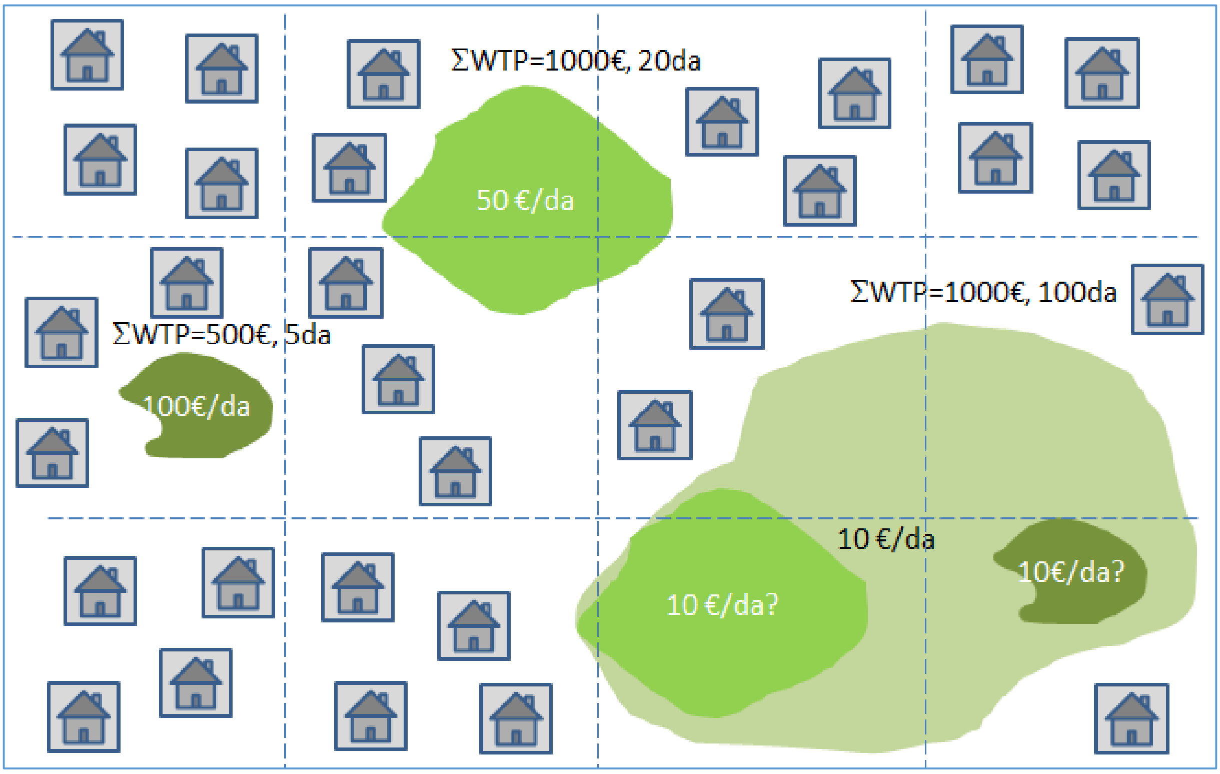
Sites of different size may be suitable for different recreational uses, and if accessible may also be complements. The use of proxy indicators necessary simplification and necessarily means inaccuracy in valuation estimates, relative to knowing in more detail what characteristics of the area besides size and distance make it suitable.

In urban context the areas that are considered valuable for different ecosystem services will vary with a number of different biotic, abiotic and built structural characteristics. A landscape approach is needed. Not only characteristics of the areas themselves, but their spatial configuration in relation to each other and in relation to the population determine ecosystem service value.

3. Size of the market (economic jurisdiction) and aggregation of values

Characteristics such as size and distance to green spaces are proxies for *potential* recreation value for individual or household access. In value transfer studies, we often don't know the actual use of the green spaces. Population density in the vicinity of green spaces is taken to be a proxy for the sum of values over the potential use population aggregate demand. Is population density a good proxy for individual demand or aggregate demand for urban green space? ***Figure 4.6*** illustrates that population density varies across a landscape.

Figure 4.6. *Population density as a proxy for demand for ecosystem services of green infrastructure*



Value transfer studies are often based on transferring average €/ha values adjusted for population density. A fixed distance for accessibility around a green infrastructure – also called 'economic jurisdiction – is assumed. Aggregate WTP is calculated by multiplying individual/household WTP across the population within this buffer area. Aggregate WTP is then divided by the area of the green space to obtain an average value/hectare. Population density is also calculated for the buffer area around the different study sites. A meta-analysis across many studies then regresses population density on average value/hectare.

Meta-analyses find that population density is often a significant predictor of per hectare value of green infrastructure. Population density is often correlated with accessibility of green space, scarcity and therefore with individual demand. However it should also be noted in this case that total population in the economic jurisdiction area – i.e. population density - was also used to calculate the dependent variable - average per hectare. In other words, the scarcity effect in the landscape may be exaggerated by the way the dependent and independent variables are specified.

A more robust approach uses a willingness-to-pay function with a distance decay variable and census data – if available. Actual population distribution is multiplied by site specific per household willingness-to-pay and then aggregated.

4.2.4 A simple value transfer check-list

Some basic knowledge of potential errors is useful when reviewing value transfer studies. Awareness of the reliability of value transfer will make it clearer whether values can be used for more demanding contexts such as priority setting. This section provides a check-list that decision-makers can consider when assessing valuation results they have commissioned. The first three questions on the list were discussed above, are related and perhaps the most important.

Table 4.1 *Value transfer checklist*

Issue	Explanation
1.Marginal vs. average values?	If the purpose of the valuation is to inform a policy decision affecting a particular area the study should be sensitive to changing marginal values across the landscape. For simple informative uses such as awareness raising or natural capital accounting average values may be adequate.
2.Substitutes or complements?	Has the study considered the landscape configuration of green infrastructure and whether particular sites are substitutes or complements for oneanother in terms of ecosystem services delivery?
3.Aggregation, distance decay?	Does the value transfer make any particular assumptions about accessibility and potential user populations which may change across sites?
4.Distributional impacts and selection bias?	Is it important how costs and benefits are distributed spatially, for example because there are different socio-economic constituencies in the study area? Spatially differentiated transfers are necessary. Check that population characteristics in the original study site cover the range of characteristics at the policy site.
5.Equivalence of positive and negative impacts?	Is the value estimate at the study site generated for the same kind of environmental change as at the policy site? Research has shown that willingness-to-pay for an improvement in ecosystem services, can differ from WTP to avoid a loss, which in turn can be different from willingness-to-accept (WTA) compensation for a loss, or WTA compensation for not obtaining an improvement.
6.Reference levels and perceived rights?	In addition to the +/- direction of the impact on ES, the perception of rights to a reference level of ES determine values. The difference in WTP and WTA is in part explained by differences in the perception of rights to a particular reference level of ecosystem services. If the perception of environmental rights varies between the study and policy site there is further bias.
7.Adaptive behaviour?	If populations at a study and policy site adapt differently to an impact on ecosystem services, valuation can be expected to differ as well. Adaptive behaviour may mitigate realised impact. This also produces a difference between ex ante valuation estimates and actual change in welfare which is a common challenge in all economic benefit-cost analysis.
8.Compatible end-points?	Is the economic valuation estimate expressed in similar units to biophysical models quantifying the 'end-point' impact. This concerns the extent to which models in the ecosystem service cascade or cause-effect chain are well integrated. Making model end-points compatible often involves expert judgement and introduces uncertainty in the integrated valuation estimate.
9.Ad hoc variables?	More generally are variables in a meta-analysis function or value function theoretical justified or do they appear ad hoc?
10.Documentation of uncertainty?	If the original valuation studies document statistical accuracy and model reliability using sensitivity analysis, more rational decision-making approaches can be taken as illustrated in Figure 13 above.

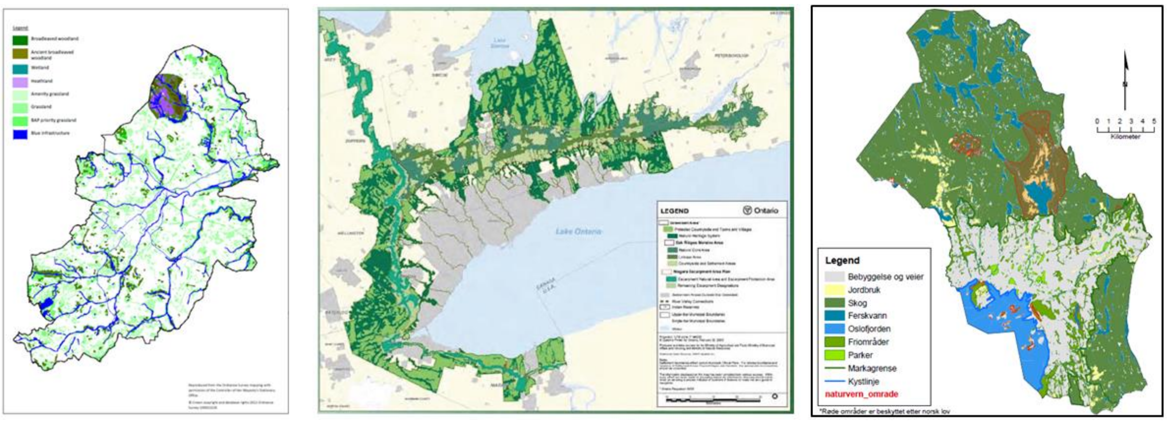
Source: based on Barton (1999)

5 Oslo pilot study area and other urban ES scoping studies

The number of valuation studies of urban ecosystem services is growing fast, but until recently no such study had been conducted in Norway (Lindhjem and Sørheim, 2012). Reinvang et al. (2014) recently conducted four local case studies demonstrating how economic valuation of ecosystem services could be applied at city district and project level.

In the present pilot study we take Oslo municipality as the study boundary. We look at examples of valuation of green infrastructure within the built area of the city and in the peri-urban forest. Four of the valuation examples within this study area have also been presented in a Norwegian language report to municipal authorities (Barton et al., 2015).

The pilot study boundaries were partly inspired by two earlier city-level valuation studies in the Toronto green belt (Wilson, 2008) and green infrastructure within Birmingham city (Holzinger et al., 2013). The Oslo pilot study area combines a focus on urban ecosystem services in the built area, but includes Oslo's green-belt with the municipal borders (***Figure 5.1***).



Birmingham, UK   Toronto Greenbelt, Ontario, Canada   Oslo Municipality

Figure 5.1 *A comparison of study boundaries between the Oslo pilot study and studies in Birmingham and Toronto*

Toronto and Birmingham have quite different landscape contexts from Oslo, but there are a few similarities in size and population which make a comparison of estimates of ecosystem service values between cities interesting. Oslo municipality has a total area of 454 km^2 of which 287 km^2 is peri-urban Marka forest. Parks and green spaces in Oslo cover 2837 hectares[6]. Oslo's population in 2013 was 635 000 persons. This meant a average population density of 4 458 persons/km^2 , or 6640 pers/km^2 in inner Oslo, and 2950 pers/km^2 in outer Oslo within the built area (excluding the Marka forest) (SSB, 2013).

Some characteristics of Oslo provide a unique context for urban ecosystem services. Oslo's population is predicted to grow to 830 000 people by 2030.. The projected population growth will require the construction of 100 000 new homes and 6-7 million m^2 of commercial area (OsloKommune, 2013a). The city's lateral growth is confined by the so-called 'Marka Law'[7] which restricts construction of homes and infrastructure into the peri-urban forest. The most recent municipal regulation plan has proposed reregulating some of the Marka-forest area along

[6] Estimates this study

[7] Lov om naturområder i Oslo og nærliggende kommuner (markaloven) https://lovdata.no/dokument/NL/lov/2009-06-05-35

the urban fringe to allow for recreational infrastructure (wider paths, sports facilities etc.) with the aim of providing a more varied recreational access near the city.

5.1.1 Toronto

Torontos city's total area is 630 km^2, with a population of 2,6 million (2011) and an average population density of 4150 persons/km^2. Wilson (2008) conducted value transfers for ecosystem services of 760 km^2 of "green belt" around the Toronto city. The study estimated the total value of ecosystem services from this area to be around $2,65 billion per year, or roughly 16,8 billion NOK/year. The total economic value refers to the alternative situation where the whole greenbelt is removed.

The largest ecosystem service values were estimated to be for habitat/refugia (21%), flood control from forests and wetlands, climate regulation, pollination, and waste treatment (***table 5.1***). Cultural ecosystem service values - recreation and aesthetics, cultural/spiritual value - was estimated to be only roughly 6% of total annual value.

Table 5.1 *Summary of ecosystem service valuation results from Toronto's greenbelt*

ECOSYSTEM SERVICE	TOTAL VALUE
Air quality	$68,868,821
Climate regulation (stored carbon)	$366,451,342
Climate regulation (annual carbon uptake)	$10,982,151
Flood control (wetlands)	$379,676,010
Water regulation (control of runoff – forests)	$278,103,520
Water filtration	$131,107,489
Erosion control and sediment retention	$532,417
Soil formation	$6,005,164
Nutrient cycling	$2,141,547
Waste treatment	$294,360,279
Pollination (agriculture)	$298,235,257
Natural regeneration	$98,001,705
Biological control	$8,175,746
Habitat/Refugia	$548,184,172
Genetic resources	n/a
Recreation and aesthetics	$95,207,535
Cultural/Spiritual (agriculture)	$65,674,796
Total value ($/year)	$2,651,707,951

Source: Wilson (2008)

In order calculate ES values for all major ecosystem Wilson (2008) applied the same average per hectare values for regulating services across some ecosystems. For example, values for flood control, water filtration, waste treatment, habitat/refugia and recreation & aesthetics were assumed to be the same across wetland types; water filtration and recreation & aesthetics values were assumed to be the same for forest and wetlands. This is a reflection of the challenges of spatially modelling regulating ecosystem services.

For the present study, a preliminary exercise lead us to abandon attempts to quantify regulating services such as flood control of urban green spaces – despite being identified as important by

Oslo Municipality - due to the heterogeneity in hydrological conditions of urban watersheds and the need for detailed site specific modelling.

5.1.2 Birmingham

Birmingham city's total area is 268 km^2 , of which green infrastructure within city limits comprises 2100 hectares. Population is approximately 1 million people with an average population density of 3,739 pers. per km^2. Holzinger et al. (2013) valued a range of ecosystem services from green infrastructure within the city (***Table 5.2***). The study finds a total annual value of £11.66 million, or about 134 million NOK per year. Of this total 86% is associated with cultural ecosystem services (recreation, aesthetics and sense of place) while regulating services - flood protection and water quality regulation - comprised about 9% of annual value.

Table 5.2 *Summary of ecosystem service valuation results from Birmingham*

Annual Values; 2011 Prices		Woodland	Heathland	Wetland	BAP Priority Grassland	Total
Provisioning Services	Water Supply			£0.001m		£0.001m
	Wild Species Diversity	£0.25m	£0.19m	£0.10m	£0.03m	£0.56m
Cultural Services	Recreation	£1.42m	£0.65m	£0.10m	£0.10m	£10.05m
	Aesthetic Values & Sense of Place	£7.78m				
	Cultural Heritage & Spiritual Values					
Regulating Services	Flood Regulation	£0.76m	£0.10m	£0.10m	£0.01m	£0.98m
	Storm Buffering					
	Water Quality Regulation			£0.08m		£0.08m
∑		£10.20m	£0.94m	£0.38m	£0.14m	£11.66m
Area of Habitat		1,528 ha	310 ha	199 ha	70 ha	2,107 ha
Average Value per Ha		£6,678	£3,034	£1,904	£2,005	£5,536
Notes: All values are 'best guess' estimates. Cells left blank can't be interpreted as 'no value', scientific evidence to date just doesn't allow to calculate a monetary value for these services. Not only because of that the real values may exceed the stated ones.						

Source: Holzinger et al. (2013)

The relative importance of specific ecosystem services as a percentage of total annual value depends on the scope of the study. Scoping and pilot studies such as this in Toronto and Birmingham will necessarily be opportunistic in the use of available data, determining which ecosystem services get addressed and how well.

Despite this caution we think that the two studies taken together suggest a research hypothesis: the relative value of regulating services can be expected to be greater than cultural services in peri-urban greenbelts, while cultural ecosystem services can be expected to be larger for green infrastructure within the built area.

6 Willingness to pay for recreation in urban parks

We base our calculations on a meta-analysis by Brander and Koetse (2011) of 20 different studies of willingness-to-pay for parks and green space, agricultural and undeveloped land and forests. Meta-analysis look across a number of study sites and as such can only adjust for ecosystem characteristics that can be classified at all sites. The description of ecosystem services in the meta-analysis is limited to broad categories of recreation, preservation, aesthetics and environmental/agricultural services. All supporting and regulating services are grouped as a single category. In this section we use the model to predict the willingness-to-pay for recreation in parks and green space as this represent perhaps the most well defined of the ecosystem services included in the original study.

6.1 Ecosystem demand assumptions

The meta-analysis estimated by Brander and Koetse (2011) was based on 20 contingent valuation studies of willingness –to-pay for urban open space and a total of 73 separate values (***Table 6.1***).

Table 6.1 *List of contingent valuation studies included in the meta-analysis*

L.M. Brander, M.J. Koetse / Journal of Environmental Management 92 (2011) 2763–2773 2765

Table 1
List of contingent valuation studies included in the meta-analysis.

Publication	Journal/Working paper	Study site	Type of area	Sample size	No. of obs.
Bergstrom et al. (1985)	*SJAE*	Greenville county, South Carolina, US	Agricultural land	250	4
Bishop (1992)	*JEPM*	Derwent and Watford, UK	Forest	100	2
Bowker and Diychuck (1994)	*ARER*	Moncton, New Brunswick, Canada	Agricultural land	92	4
Breffle et al. (1998)	*Urban Studies*	Boulder, Colorado, US	Undeveloped land	72	1
Chen (2005)	Working paper	Taiwan	Agricultural land	236	3
Fleischer and Tsur (2000)	Conf. Proceedings	Hula and Jezreel valleys, Israel	Agricultural land	161	2
Fleischer and Tsur (2004)	*ERAE*	Northern Israel	Agricultural land	350	1
Hanley and Wright (1992)	*JEPM*	Chester, UK	Agricultural land	119	1
Jim and Chen (2006)	*LUP*	Guangzhou, China	Urban green space	340	1
Krieger (1999)	Working paper	Chicago collar counties, US	Agricultural land	1681	3
Kwak et al. (2003)	*Urban Studies*	Seoul Metropolitan Area, South Korea	Forest	600	1
Lindsey and Knaap (1999)	*JPRA*	Marion County, Indiana, US	Urban green space	354	1
Lockwood and Tracy (1995)	*JLR*	Centennial Park, Sydney, Australia	Urban park	105	1
Maxwell (1994)	*JEM*	Marston Vale, Bedfordshire, UK	Forest	100	4
Rosenberger and Walsch (1997)	*JARE*	Routt County, Colorado, US	Agricultural land	171	4
Ready et al. (1997)	*Growth and Change*	Kentucky, US	Agricultural land	110	1
Scarpa et al. (2000)	*FPE*	24 forests in N. and Rep. Ireland	Forest	300	24
Tyrvainen and Vaananen (1998)	*LUP*	Joensuu, Finland	Forest	71–205	8
Tyrvainen (2001)	*JEM*	Salo, Finland	Forest	67–235	6
Willis and Whitby (1985)	*JRS*	Tyne county, UK	Agricultural land	103	1

Journal acronyms: *ARER*: Agricultural and Resource Economics Review, *JLR*: Journal of Leisure Research, *ERAE*: European Review of Agricultural Economics, *JPRA*: Journal of Park and Recreation Administration, *FPE*: Forest Policy and Economics, *JRS*: Journal of Rural Studies, *JARE*: Journal of Agricultural and Resource Economics, *LUP*: Landscape and Urban Planning, *JEM*: Journal of Environmental Management, *SJAE*: Southern Journal of Agricultural Economics, *JEPM*: Journal of Environmental Planning and Management.

Source: Brander and Koetse (2011)

Meta-analysis uses information from a number of different studies to estimate a value function across these sites. The assumption is that all populations at the different study sites demand similiar ecosystem services from urban open spaces, although how much can vary from site to site (in economic terms they share the same demand function).

The meta-analysis predicts willingness to pay (WTP) in US$/ha year as a function of site and study characteristics:

WTP= f(land use, services, area, payment vehicle, elicitation format, GDP/capita, Population density)

The variables in the meta-regression included:

- Land use (dummy variable)
    - **Parks and green space**
    - Agricultural and undeveloped land
    - (Forest as omitted category)

- Ecosystem Services (dummy variable)
    - **Recreation**
    - Preservation
    - Aesthtics
    - (Environmental/agricultural services as omitted category)
- *Area (ha)*
- Payment vehicle(dummy variable)
    - Entry charge
    - **Tax**
    - Donation
    - (other as omitted category)
- Elicitation format (dummy variable)
    - **Dichotomous choice** (yes/no)
    - Payment card
    - (open question as omitted category)
- Socio-economic
    - *GDP per capita ($/year)*
    - *Population density (persons/km2)*

We set the dummy variables for payment vehicle and elicitation format so that the model would produce conservative estimates. GDP/capita was set to the level for Norway.

When setting services dummy variable to “recreation=1” and Land use variable to “Parks and green space=1” the meta-regression gives extra weight to the park and green space recreation studies in the data set (from the US, Canada, Australia, Taiwan and China). Similarly for the other dummy variables. At the same time the regression ‘borrows explanatory power’ for the continuous variables from all the studies in the data set.

The meta-regression function parameters are shown in ***Table 6.2***. We used the variables outlined in red to estimate recreational values for Oslo’s parks and green spaces.

Table 6.2 *Meta-analysis regression function and variables adjusted to extrapolate willingness-to-pay estimates*

Table 2
CV meta-regression results.

Variable category	Variable	Coefficient	Standard error
	Constant	7.35***	1.13
Land use	Parks and green space	2.25**	0.85
	Agricultural and undeveloped land	1.75	1.07
Services	Recreation	1.44*	0.81
	Preservation	0.82	0.76
	Aesthetic	0.90	0.60
Area	Area (ln)	−0.80***	0.06
Payment vehicle	Entry charge	−0.76	0.81
	Tax	−1.52***	0.56
	Donation	−2.02*	0.83
Elicitation format	Dichotomous choice	−1.42**	0.56
	Payment card	−0.83**	0.44
Socio-economic	GDP per capita (ln)	0.30	0.60
	Population density (ln)	0.49***	0.11
Level 1 (estimate) variance		0.49***	0.10
Level 2 (regional) variance		1.53***	0.43
N		73	
−2 × loglikelihood		191.9	
Pseudo R^2		0.44	

Dependent variable: 2003 US$ per hectare per year (ln).
***, **, * = statistically significant at 1%, 5%, and 10%, respectively.

Source: adapted from Brander and Koetse (2011)

6.2 Mapping open space demand

In the meta-analysis all WTP per visit and WTP per household values from the original studies were aggregated based on information about the number of visits or households in the economic constituency in the original study. Brander and Koetse (2011) then divide aggregate value by the area of the study site to obtain values per hectare per year. We can then use the variables "area" and "population density" to estimate recreational WTP for specific parks and green spaces throughout Oslo based on a mapping of area and population density (***Figure 6.1***).

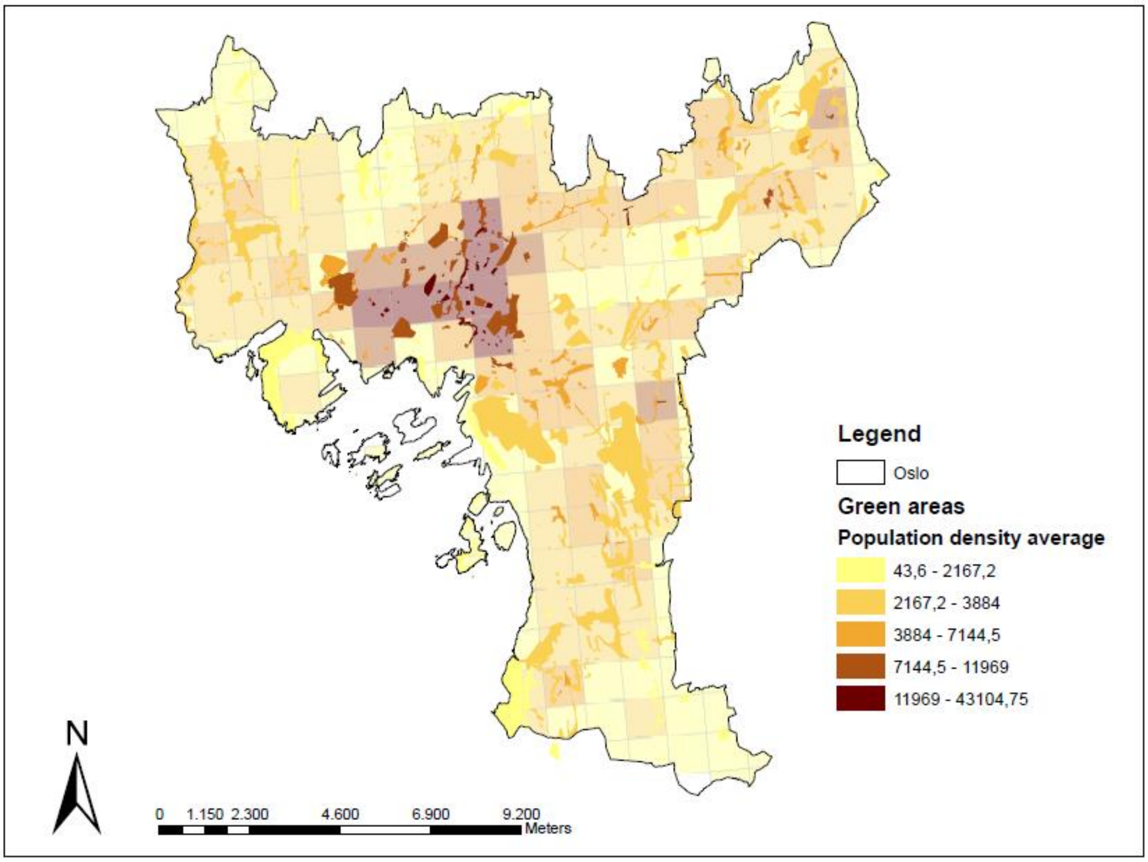


Figure 6.1 *Average population density within an assumed accessibility radius around each park. Population density was used as a proxy indicator for local demand for each open scape. Source: prepared by Emma Soy Massoni.*
GIS data: Bymiljøetaten, Plan- og Bygningsetaten, Oslo Kommune.

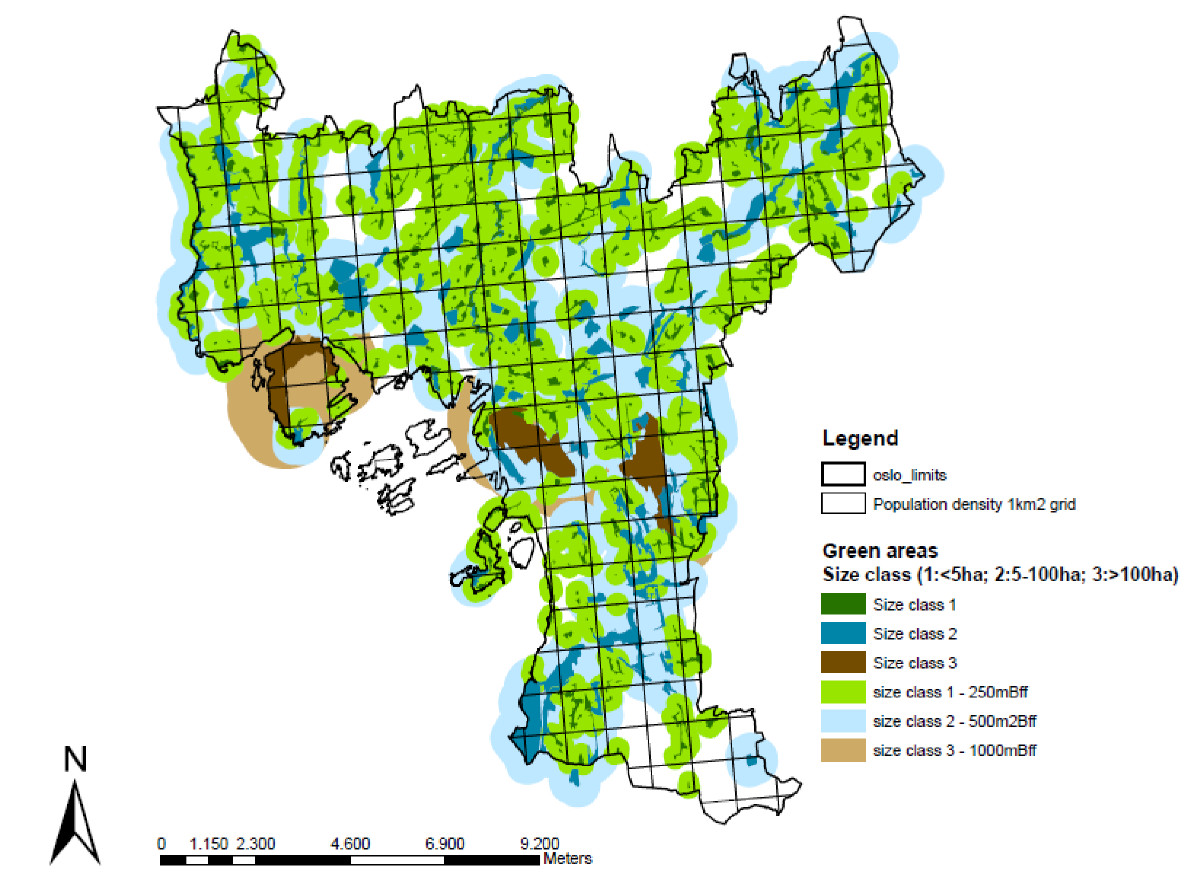


Figure 6.2 *Mapping of accessibility zones around open spaces in Oslo.*
Note: small parks <5ha are assumed to be accessed and have a local user population within 250m, medium parks 5-100ha within 500 meters and large parks >100ha within 1000m. Average population density was calculated within each buffer zone and used as a proxy for park demand in the meta-analysis function. Note that overlapping buffers around green spaces indicate that they are possible substitutes for recreation by our definition of accessibility.
Source: prepared by Emma Soy Massoni.
GIS data: Bymiljøetaten, Plan- og Bygningsetaten, Oslo Kommune

Population density is used as a proxy indicator for local demand for each park and open green space. Average population density within an assumed accessibility radius was calculated for 447 individual parks and green spaces throughout Oslo (***Figure 6.2***).

The standardization of value estimates in original studies in the meta-analysis from per visit and per household per year values to per hectare per year values has important implications. Brander and Koetse (2011) write “the difficult step of aggregating mean household or visitor values across the relevant economic constituency is not avoided, but conducted in the standardisation process using information on each study site from the primary valuation study”.

Crucially, this standardization assumes that the economic jurisdiction of each park and green space in Oslo (***Figure 6.2***) is the same as the (average) jurisdiction in the studies that went into the meta-analysis. ‘Economic jurisdiction’ is the term use to describe for what area around the ecosystem under study the population is expected to have a positive willingness-to-pay. For use values such as recreation it has been found that willingness-to-travel and to pay fall to zero at some distance from the site (known as ‘distance decay’ of WTP).

A challenge for our value transfer is that Brander and Koetse (2011) do not provide any information on the size of economic jurisdiction. In our study we have assumed that parks and green spaces are only locally important (out to 1000m for large parks), because of the large number of substitute green spaces in most of the city. If Brander and Koetse (2011) used studies with much larger jurisdictions and populations, their model will overestimate relative to what we expect for Oslo.

6.3 Value transfer

By plugging in specific area and population density figures for each park and green space in ***Figure 6.1*** we estimate willingness to pay per hectare per year for recreation. ***Table 6.3*** summarises how WTP varies across different spatial scales and population densities found in the meta-analysis and in Oslo.

Table 6.3 *Marginal willingness-to-pay (US$/ha yr) for "open space" for different open space areas conditional on population density*

	Area (hectare)							
Population density (per km)	0.2	2	10	100	1000	5000	10000	50000
20	54,782,249	8,682,401	2,395,873	379,720	60,182	16,607	9,538	2,632
200	169,293,334	26,831,185	7,403,956	1,173,448	185,979	51,320	29,476	8,134
500	265,234,773	42,036,879	11,599,906	1,838,461	291,376	80,404	46,180	12,743
1500	454,380,699	72,014,488	19,872,105	3,149,516	499,165	137,742	79,112	21,831
2500	583,614,083	92,496,599	25,524,060	4,045,291	641,135	176,919	101,613	28,040
6500	932,100,420	147,727,961	40,764,930	6,460,806	1,023,969	282,560	162,288	44,783
		Values in table: WTP (NOK/ha yr.)						

Source: own elaboration based on Brander and Koetse (2011)

Note: dotted black line in table represents the minimum area and maximum population density in the original meta-analysis data. The dotted rectangle represents the approximate mean predicted value for the meta-analysis data – the area of the model that is most reliable. Most of Oslo's parks and green spaces are smaller than this minimum and most population densities are greater

The meta-regression is more valid for larger parks and green space and lower population densities, we assess total WTP for all of Oslo's 2837 ha at a population density of 2600 persons/km2, equivalent to population density in outer Oslo. With these assumptions Oslo's total open green space would be worth approximately 1 billion NOK/year in terms of the populations willingness-to-pay to conserve them. This would be equivalent to an average 1985 NOK/year per inhabitant>15 years old. This is based on the assumption that Oslo's population would be willing-to-pay what other populations have said they would be willing to pay for open space in a number of different countries.

6.4 Challenges in downscaling value transfer models

The dotted line in ***table 6.3*** represents the minimum area and maximum population density in the original meta-analysis data. Most of Oslo's parks and green spaces are smaller than this minimum and most population densities are greater. The meta-regression therefore predicts what we think are excessively large recreational values for most of the green spaces in Oslo.

Examples of using the meta-analysis function at the edge of the data range it was based on can be seen by examining transferred values for individual parks. The meta-analysis is expected to be most reliable around the mean of the study variables which was about 10 000 ha of green space and 200 persons per km^2 population density. The further we get away from this context the less predictive power the meta-regression has.

For example the St. Hanshaugen city park is approximately 5.35 hectares in area, with an average population density in the vicinity of 11 359 persons. According to the meta-analysis function willingness-to-pay for conserving it as open space is approximately 88,3 million NOK/ha. The largest open space in Oslo Ekebergsletta has an area of 181 hectares, and a population density of about 2600 persons/km2 in the vicinity. The model predicts a willingness-to-pay of 2,6 million NOK/ha per year. Are these values credible? If one accepts willingness-to-pay in a survey as a valid measure of value of open space, there is still the problem of applying a model developed for individual open spaces, to an aggregate of all open spaces. Aggregating meta-analysis valuation across all 547 registered open spaces in Oslo produces an aggregate value of 122 billion NOK per year. This is equivalent to about 235 000 NOK/year for a population >15 years old of 520 000. Equivalent to a large share of average annual income per person this seems totally implausible.

How can such large values be generated? Because the model is logistic values rise non-linearly and more sharply outside the data range of the model. Most of Oslo's open spaces are too small, and in population densities that are too high to be predicted by the meta-analysis function.

The majority of Oslo's green open spaces are outside the data range of the meta analysis model developed by Brander and Koetse (2011). ***Figure 6.3*** below shows that 56,9% of open spaces in Oslo are <2 ha, which is the smallest open space used in the original meta-analysis 90.3% of open spaces are smaller than 10 hectares. The same problem with the relevance of the model applies to population density. 74% of the open spaces in Oslo have population densitities in the vicinity in excess of 2500 persons/km2, which represents the maximum observation in the original data set of the meta-analysis.

If we look at the largest open space in Oslo - Ekebergsletta - this is where we would expect the value transfer to perform the best. Ekebergsletta has an area of 181 hectares, and a population density of about 2600 persons/km^2 in the vicinity. The model predicts a willingness-to-pay of 2,6 million NOK/ha per year, or about NOK 467 million per year for the whole area. Assuming that visitors to the park do not travel more than about 1km the area of influence of Ekebergsletta is approximately 12km^2 around the park and the population in this area roughly 31 000 people. This in turn works out to an average WTP per local person for recreation at Ekeberg of about NOK 15 000/year. This in turn works out to about NOK 290 per weekend distributed across a whole year. When the aggregate values are distributed across the relevant population we get a further sense of the credibility of value transfer per household.

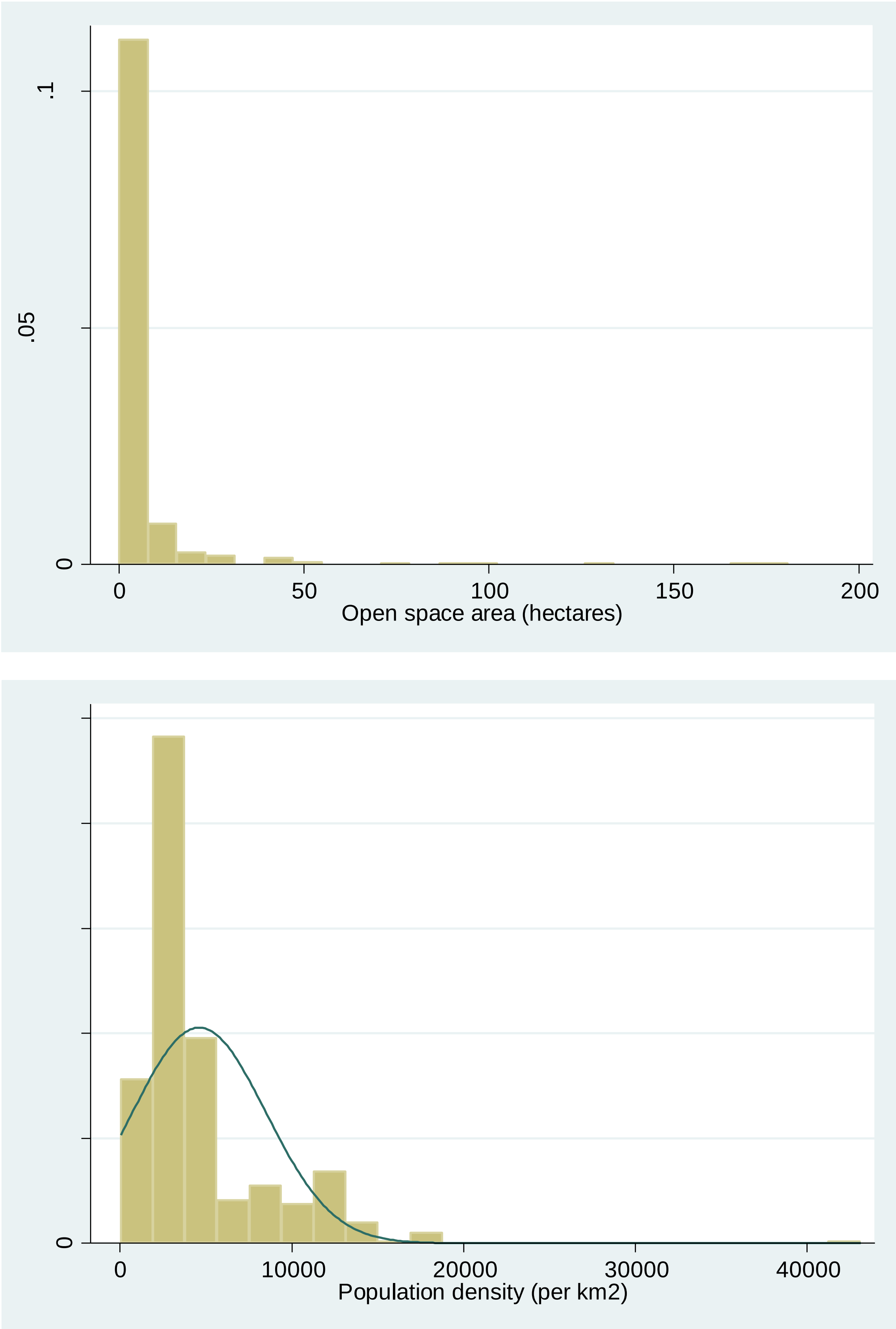


Figure 6.3. *Distribution of green space size and population density. The majority of Oslo's green open spaces are less than 2 hectares in size (upper panel), and population density greater than 2500 persons/km2 (lower panel). Most of Oslo's open spaces lie outside the data range of the meta analysis model.*

7 Capital value of blue-green areas in property prices

A hedonic pricing study evaluates the extent to which buyers and sellers include environmental characteristics of neighbourhoods in their negotiation of property price. Indirectly hedonic pricing studies reveal willingness-to-pay for environmental amenities that people in the market are aware of at the moment of sale/purchase. While properties may benefit from a number of ecosystem services, they will not be identified in a hedonic pricing study unless people are aware of them and act on this information when setting the price.

7.1 Ecosystem demand assumptions

Vågnes Traaholt (2014) examined the correlation between prices of 9441 apartments sold between 2004-2013 and proximity to different features of blue-green spaces in Oslo (***Figure 7.1***):

- Parks
- Parks with water features
- Cementaries
- Open space
- Fjord shoreline
- Open space along fjord shoreline (offering additional view)
- Marka forest border

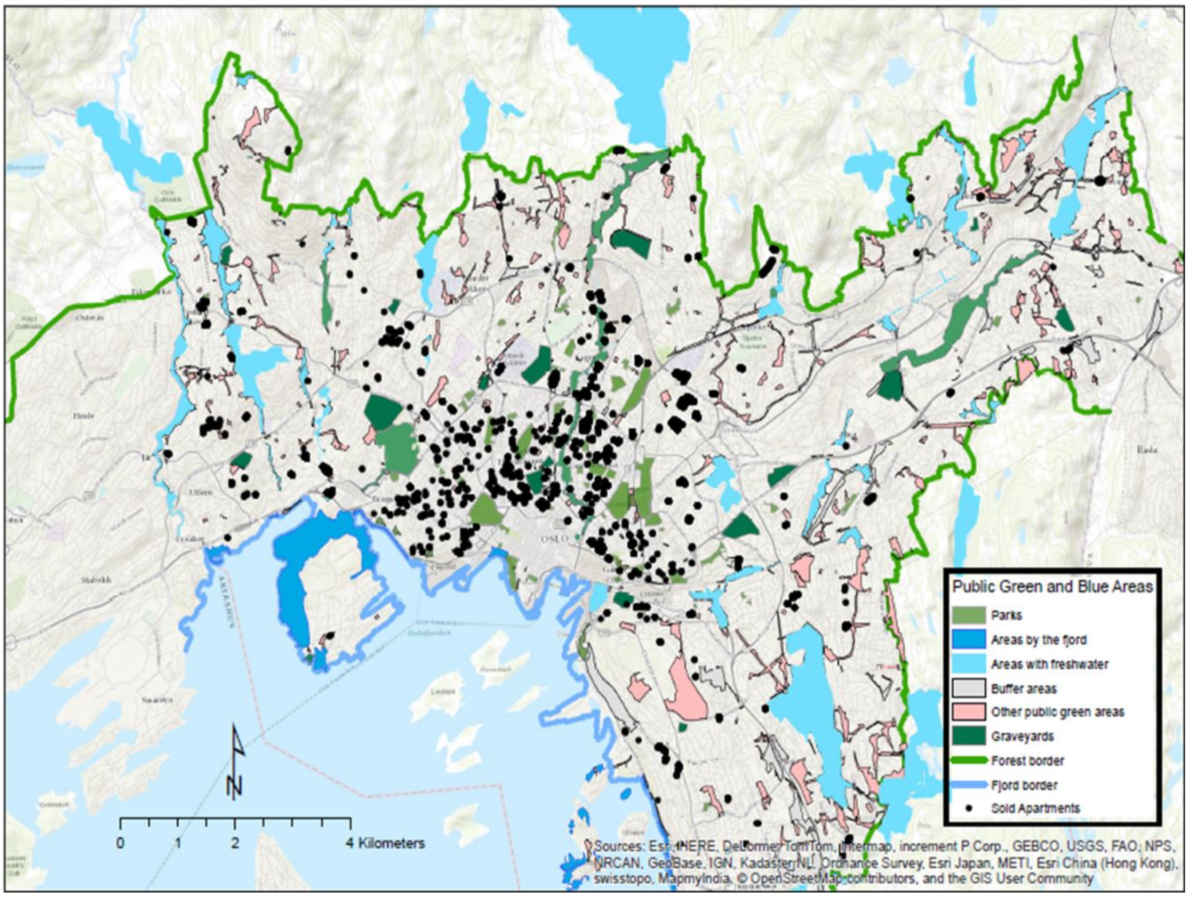
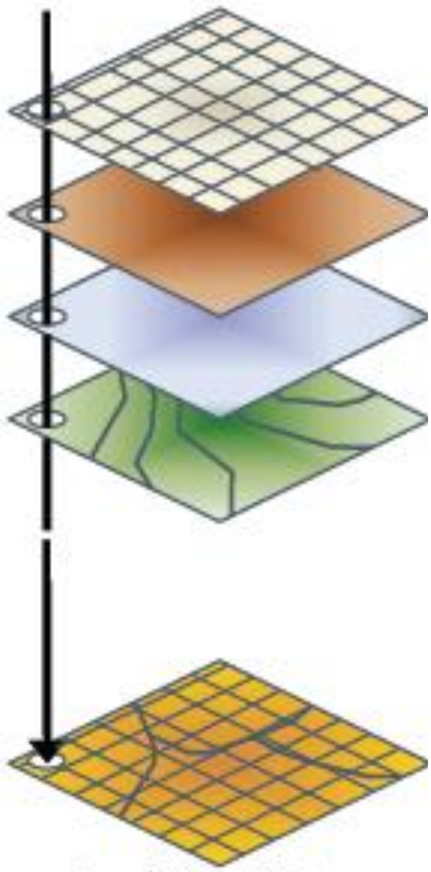


Figure 7.1 *Location of apartments sold 2004-2013 and blue-green infrastructure considered in the hedonic pricing study.*
Source: Vågnes Traaholt (2014). GIS data: BYM, Oslo Kommune.

Using statistical techniques the study controlled for the effect on apartment price of structural features of the apartments, neighbourhood characteristics such as access to public transport, roads, and proximity to city centre, and other environmental factors such as noise. By separately identifying these effects we can assess the marginal (per meter) effect of proximity to the different features of blue-green spaces in the city.

The hedonic pricing study assumes that all apartments sold in Oslo are bought and sold in a single market, in which buyers have information available on characteristics of apartments and their neighbourhoods for the whole city. On the one hand internet real estate search services make such information available for apartment structural characteristics, but only to a limited degree regarding neighbourhood characteristics.

7.2 Hedonic property pricing methodology



Source: Vågnes Traaholt (2014).

The following steps outlines the methodology used in Vågnes Traaholt (2014):

1. Prepare digital map data:

Structural characteristics (Si) and sales prices (Pi) for i=1..9441 apartments sold in Oslo between 2004-2013 were obtained Norges Eiendommer (Infoland). Sales prices were de-trended.Neighbourhood amenity variables such as proximity to roads and public transport (Ni) and environmental variables such as proximity to blue and green areas, and noise (Qi) were obtained from Oslo Municipality Environment Agency and Planning and Building Agency

2. **Model testing and estimation of the marginal effects of variables using hedonic pricing functions:**

A linear form of a hedonic property pricing function regresses property price (P) on the structural (S), neighbourhood amenity (N) and environmental characteristics:

$$\ln(\mathbf{P_i})=a+b\mathbf{S_i}+c\mathbf{N_i}+\mathbf{dQ_i}+e_i$$

A hedonic property pricing function was estimated using different econometric techniques, including Ordinary Least Squares (OLS), Fixed Effects(FE), Spatial Error Model(SEM) and Generalized Additive Model(GAM). A number of models were tested because the marginal value of environmental characteristics is very sensitive to how spatial auto-correlation between property characteristics is identified and dealt with in the estimation procedure.

3. Marginal value Vij(d) in NOK per meter proximity to blue and green space (j) was calculated

4. **Distance** (Di) to each blue green space were calculated individually for every apartment in Oslo.

5. **Marginal expected value for each apartment** with proximity to each blue green space was calculated for each apartment Vij (Ai)

6. **Marginal expected** value was summed over all apartments to obtain an aggregate value for each blue green space Σ Vij (Ai).

7.3 Testing and selecting a hedonic pricing function

Table 7.1 *Estimation of hedonic property pricing functions using Ordinary Least Squares (OLS), Fixed Effects(FE), Spatial Error Model(SEM) and Generalized Additive Model(GAM)*

Variables	OLS (H-robust errors)	FE (Clustered errors)	SEM (H-robust errors)	GAM k=80
(Intercept)	11.9627 *** (0.0383)	11.9910 *** (0.1962)	12.1540 *** (0.0475)	11.5231 *** (0.5225)
Structural variables				
Log (living_area)	0.6419 *** (0.0103)	0.60312 *** (0.0489)	0.6112 *** (0.0107)	0.5201 *** (0.0076)
Rooms	0.0114** (0.0041)	0.0356 ** (0.0118)	0.0395 *** (0.0040)	0.0170 *** (0.0028)
Toilets	0.1329 *** (0.0076)	0.1075 *** (0.0260)	0.0954 *** (0.0077)	0.0794*** (0.0048)
Bathrooms	0.0599 *** (0.0099)	0.03145 . (0.0164)	0.0266 ** (0.0097)	0.0189 ** (0.0058)
Floor_number	0.0361 *** (0.0011)	0.0336 *** (0.0028)	0.0333 *** (0.0010)	0.0296 *** (0.0008)
Basement	-0.0287 * (0.0128)	-0.0478 * (0.0222)	-0.0015 (0.0117)	-0.0254** (0.0083)
Five_pluss_storey	-0.0770*** (0.0057)	-0.0400 * (0.0191)	-0.0452 *** (0.0064)	-0.0188 *** (0.0047)
Age_30_15	-0.1172*** (0.0086)	-0.04701 (0.0321)	0.0073 (0.0101)	-0.0470 *** (0.0083)
Age_50_30	0.0476 *** (0.0113)	0.0582 (0.0657)	-0.0801*** (0.0189)	-0.1056*** (0.0127)
Age_75_50	0.0678 *** (0.0115)	0.0652 (0.0549)	-0.0617 *** (0.0151)	-0.0605 *** (0.0108)
Age_100_75	-0.0440 *** (0.0095)	-0.0914 ** (0.0281)	-0.0381 ** (0.0132)	-0.1082 *** (0.0099)
Age_120_100	-0.07203 *** (0.0091)	-0.0715*** (0.0171)	-0.0647 *** (0.0131)	-0.1001 *** (0.0080)
Age_155_120	-0.0830 *** (0.0091)	-0.0960 *** (0.0247)	-0.1158 *** (0.0118)	-0.1037 *** (0.0084)
Log(properties)	-0.0092 *** (0.0025)	-0.0012 (0.0082)	-0.0172 *** (0.0033)	-0.0131 *** (0.0021)
Neighbourhood and accessibility variables				
Prox_highway_1000	-0.0000 ** (0.0000)	-0.0000 (0.0000)	0.0000 (0.0000)	-0.0001 . (0.0000)
Large_road_200	-0.0124 * (0.0051)	-0.0225 (0.0139)	-0.0317 *** (0.0082)	-0.0246*** (0.0058)
Prox_med_road_500	-0.0001 *** (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
Prox_subway_500	0.0003 *** (0.0000)	0.0001 . (0.0001)	0.0001 (0.0000)	-0.0001 . (0.0000)
Prox_train_500	-0.0002 *** (0.0000)	-0.0001 * (0.0000)	-0.0002 *** (0.0000)	-0.0001 ** (0.0000)
Prox_tram_500	0.0002 *** (0.0000)	0.0001** (0.0000)	0.0002 *** (0.0000)	0.0001 . (0.0000)
Stations_300_buffer	-0.0043 *** (0.0007)	-0.0039 . (0.0022)	-0.0035 * (0.0015)	-0.0008 (0.0009)
Prox_cc_9000	0.0000 *** (0.0000)	0.0000 * (0.0000)	0.0000 *** (0.0000)	0.0002 * (0.0001)

Environmental variables				
Noise_65_80	-0.0312*** (0.0042)	-0.0143 * (0.0065)	-0.0111 ** (0.0043)	-0.0143 *** (0.0036)
Prox_forest_500	0.0001 ** (0.0000)	0.0000 (0.0001)	0.0001 (0.0000)	0.0000 (0.0000)
Prox_fjord_1000	0.0001 *** (0.0000)	0.0000 (0.0000)	0.0000 * (0.0000)	0.0000 (0.0000)
Area_fjord_100	0.1095 . (0.0659)	0.1032* (0.0484)	0.0206 (0.0703)	0.0408 (0.0259)
Prox_park_500	0.0001 *** (0.0000)	0.0001 * (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
Large_park	0.0116 * (0.0046)	-0.0144 . (0.0083)	-0.0028 (0.0050)	-0.0027 (0.0038)
Prox_graveyard_500	0.0001 *** (0.0000)	0.0000 (0.0001)	0.0000 (0.0000)	-0.0000 (0.0000)
Freshwater_200	0.0242 *** (0.0052)	0.0031 (0.0065)	0.0054 (0.0057)	0.0057 (0.0042)
Akerselva	-0.0430 *** (0.0090)	0.0390 (0.0261)	-0.0289 * (0.0114)	-0.0038 (0.0087)
Pc_green_500	-0.0001 *** (0.0000)	-0.0015 * (0.0007)	-0.0033 *** (0.0006)	-0.0009 . (0.0004)
Lambda (λ)			0.7583 *** (0.01072)	
Model summary				
Multiple R-squared:	0.76		0.805	
Adjusted R-squared:	0.76	0.824	0.804	0.821
F-statistic	933***	845***		
Wald statistic			5008***	
Degrees of freedom	9408	9394	9408	
F-value of s(x,y)				38.6***
Degrees of freedom of s(x,y)				76.411
N = 9441				
Significance levels:	'***' 0.001	'**' 0.01	'*' 0.05	'.' 0.1

Source: Vågnes Traaholt (2014)

Table 7.1 shows the estimation results for four different models that were tested. The Ordinary Least Squares model (OLS) showed most significant results for individual blue green structures. The Fixed Effects model controlled for spatial autocorrelation of apartment characteristics into city neighbourhoods ('bydeler'), assuming that each neighbourhood constitutes a different property market. The spatial error model (SEM) tries to control for spatial correlation of variables and error terms with a specific definition of what constitutes a neighbour for each variable.

Whereas FE and SEM use specific definitions of what constitutes a neighbour the Generalized Additive Model (GAM) assumes a probability of neighbour being correlated using a link function. The shape of the link function and hence the assumption about neighbours being correlated is adjusted by the researcher. Each approach aims to reduce bias and incorrect estimation of significance of the variables in the model.

In deciding which estimates to use we are faced with the dilemma that the model with the least amount of adjustment for spatial autocorrelation (OLS) is also the model that shows the most significant effects for proximity to blue green space. With the exception of noise none of the environmental variables are consistent across modelling approaches. The modeller makes assumptions about the property market and spatial auto-correlation in the FE, SEM and GAM which we test for, but cannot verify.

For this reason we would be sceptical to using the inconsistent OLS estimates for the marginal value of blue and green space as a basis for policy decisions. On the other hand we think that for a scoping study, and for the purpose of awareness-raising, the OLS results can be put forward as hypotheses regarding the potential importance of blue green spaces for private property value (awaiting further data and testing).

7.4 Marginal price effects

The hedonic pricing function estimates an expected marginal added-value of proximity to blue-green space for an average property. Each type of green space is evaluated to see at what distance it has a significant effect on property prices. This is called the 'effect area'. For example in the case of parks the effect area is 500m. If the marginal effect 264 kr/meter an apartment right next to a park is worth kr.132 000 more than an apartment 500 meters away). An apartment 50 meters from the park is worth NOK 118 800 more than an apartment 450 meters further away (***Figure 7.2***).

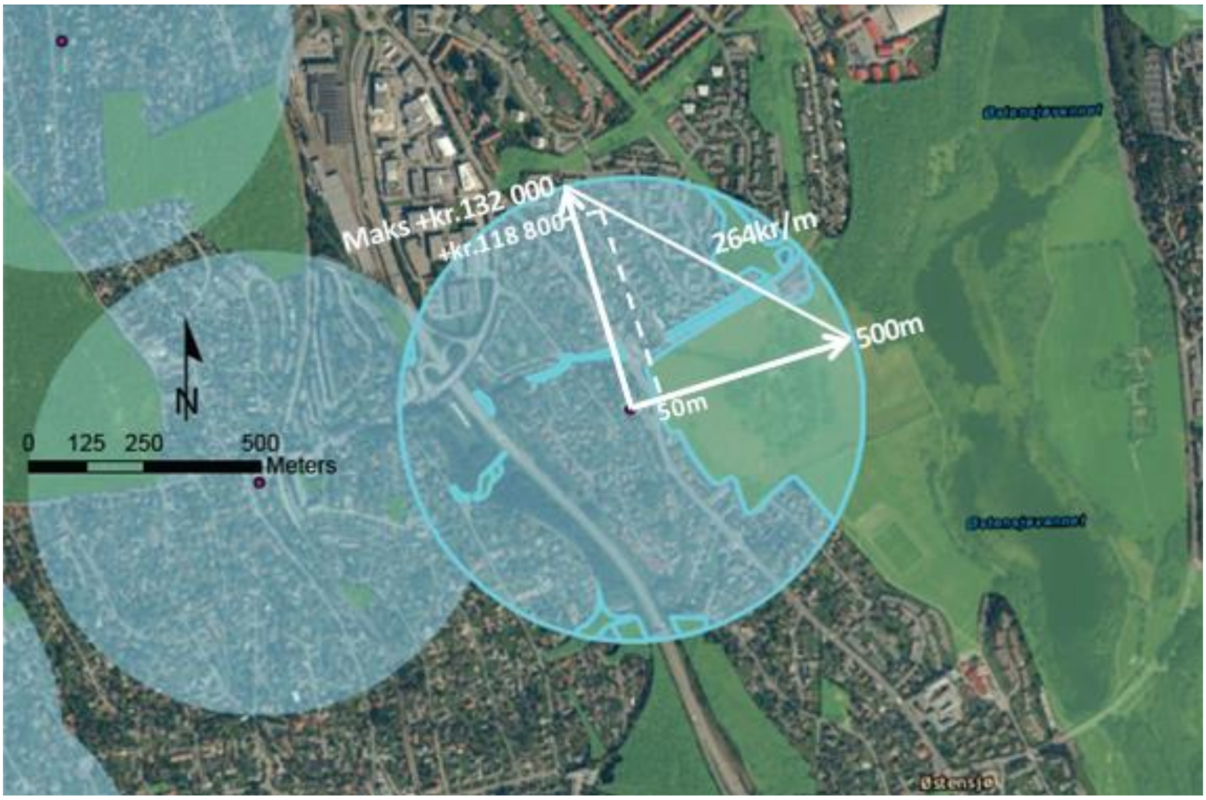


Figure 7.2 *Conceptual diagram of the expected marginal effect of proximity to a park for a single apartment. Source: adapted from Vågnes Traaholt (2014)*

Marginal values for each blue-green feature are listed in ***Table 7.2***. The table shows the 95% confidence interval of the expected effect. There is large uncertainty in the marginal effects because there is a lot of spatial variation that is not explained by the statistical techniques that were used.

Table 7.2 *Potential marginal value of proximity to different blue and green infrastructure*

Variable	Variable interpretation	Expected marginal effect (NOK)	Lower bound marginal effect (2,5%) (NOK)	Upper bound marginal effect (97,5%) (NOK)
Forest border	per meter closer to Marka forest, within 500m	291	100	484
Fjord shoreline	per meter closer to fjord, within 1000m	441	354	529
Fjord open space	if apartment within 100m of open space by fjord	410553	53347	808230
Park	per meter closer to a park, within 500m	264	162	368
Large park	if apartment' closest park > 100,000 m2	41502	9756	73967
Cementary	per meter closer to cementary, within 500m	356	209	504
Freshwater	if apartment within 200m of freshwater	86836	50328	124206
Green area	per % increase in green space within 500 m	-11931	-13868	-9965

We can note that all effects listed are positive except “Green area”, defined as % green space within 500m. This indicates that while proximity to the nearest park or cementary has valued-added in apartment prices, the more total green area there is within a 500 meter radius the less important this positive effect is. This is an example of a substitution effect - when there are more alternatives the marginal value of closest green space is lower.

7.5 Aggregation and valuation results

With this in mind we aggregate the marginal values across all apartments within the assumed 'effect area' around each blue and green space (***Figure 7.3***).

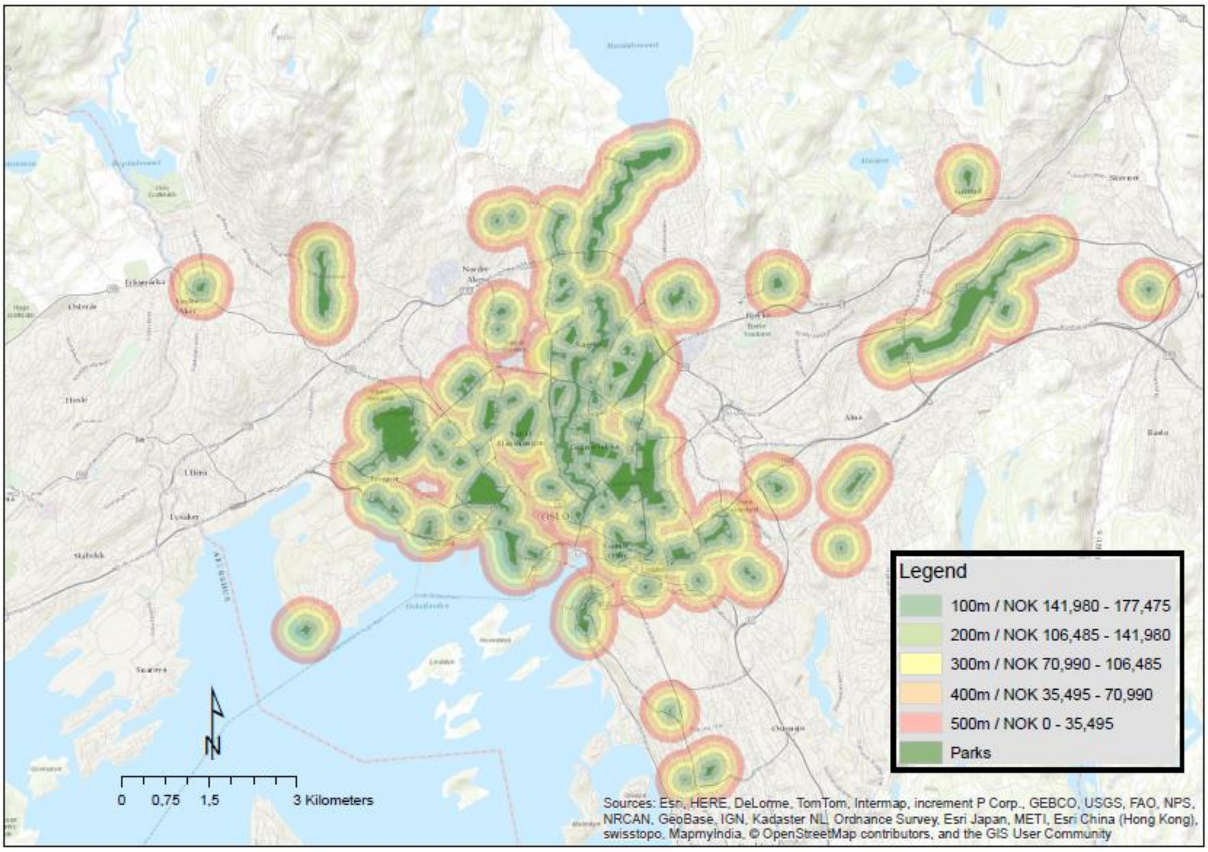


Figure 7.3 *Hedonic price effect areas for parks. Aggregation of marginal values for each type of blue green structure was carried out across all apartments within the assumed 'effect area' for each structure. Source: Vågnes Traaholt (2014)*

The results of these aggregations across all apartments in Oslo can be seen in ***Table 7.3***.

Table 7.3 *The aggregate marginal values of blue green infrastructures across all apartments in Oslo*

Variable	Effect area	Number of apartments in effect area	Sum over all apartments of.. ..expected marginal effects (MNOK)	..lower bound marginal effect (2,5%) (NOK)	..upper bound marginal effect (97,5%) (NOK)
Forest border	within 500m of Marka forest	36310	2467	845	4110
Fjord shoreline	within 1000m of fjord	34965	5875	4717	7048
Fjord open space	within 100m of open space by fjord	414	170	22	335
Park	within 500m of parks	160722	13595	8325	18935
Large park	when closest park > 100,000 m2	31147	1293	304	2304
Cementary	within 500m of cementary	45356	3535	2081	5010
Freshwater	within 200m of park with freshwater element	53089	4610	2672	6594
Green area	green area within 500m	224204	-317	-369	-265

The result is an aggregate estimate of the value-added for all apartments in Oslo of being close to a park. We repeat this procedure for other blue green features that are significant in the statistical modelling (parks with water features, cementaries, open space, fjord shoreline and view, Marka forest border). The results in ***Table 7.3*** are an example of value transfer in the sense that we extrapolate the marginal value from each apartment sold in our sample of about 9000 apartments, to all apartments in Oslo, provided they are in the effect areas of blue green infrastructures.

For every meter an apartment is closer to a city park its value is expected to increase by between NOK 162-368. There are 160 722 apartments within 500 meters of public parks in Oslo. The combined additional value of park proximity for these apartments is NOK 8.3 – 18.9 billion. If the park has a water feature it is even more valuable – the additional value across the 53 089 apartments within 500 meters of parks with water features in Oslo is estimated at NOK 2,8 - 6,6 billion.

The effects have been identified in a statistical model holding other factors constant, so in principle most of the effects can be added. For example, the effect of the closest park also being a "large park" is additional to effect of being close to any park.

This is also true for the substitution effect of "green area". Note that the sum effect of percentage "green area" for 224 204 apartments is negative, but considerably smaller than the positive effects of proximity to the closest park, park with water feature, large park and cementary. Regarding Oslo city as a whole, there is value-added in being close to managed parks, although this positive effect is somewhat lower if there is a lot of (other) green space around.

Note that the study only looked at apartments. The value-added of public blue-green space for houses in suburban areas was not evaluated by Vågnes Traaholt (2014). The hypothesis is that the marginal values will be lower than for apartments due to the availability of private gardens.

Table 7.4 below refers to "potential total value of proximity to different blue and green infrastructure across all apartments in Oslo". We use the word potential because these are marginal effects, in other words specific for a single factor without looking at how some characteristics combine across space.

Table 7.4 *Potential total value of proximity to different blue and green infrastructure across all apartments in Oslo*

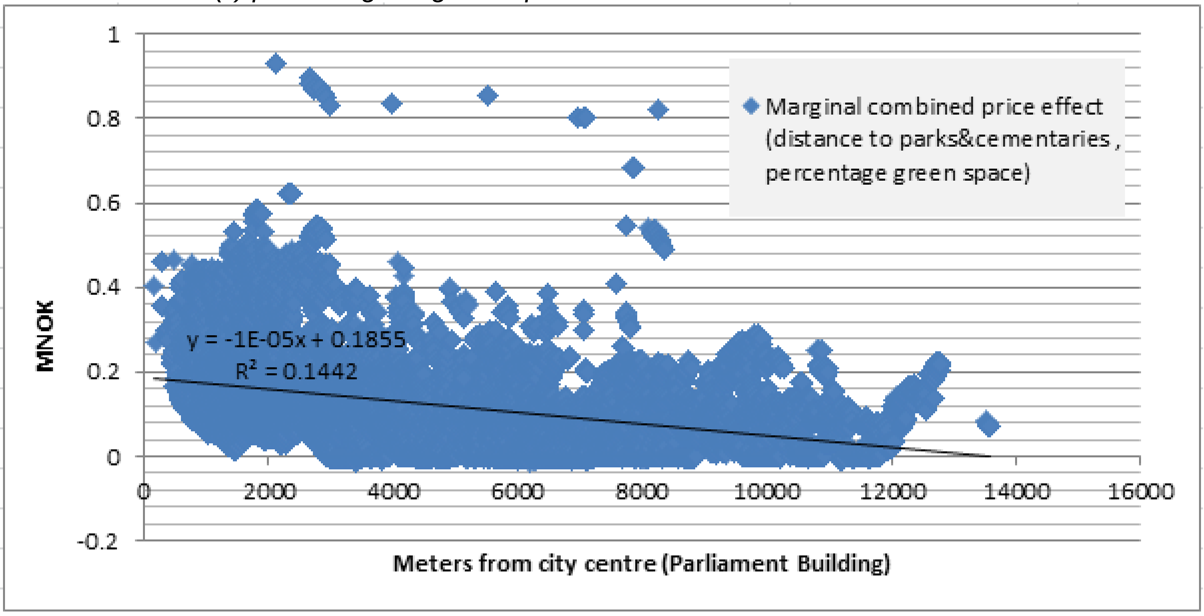
Variable	Effect area	Number of apartments in effect area	Sum over all apartments of.. ..expected marginal effects (MNOK)	..lower bound marginal effect (2,5%) (NOK)	..upper bound marginal effect (97,5%) (NOK)
Forest border	within 500m of Marka forest	36310	2467	845	4110
Fjord shoreline	within 1000m of fjord	34965	5875	4717	7048
Fjord open space	within 100m of open space by fjord	414	170	22	335
Park	within 500m of parks	160722	13595	8325	18935
Large park	when closest park > 100,000 m2	31147	1293	304	2304
Cementary	within 500m of cementary	45356	3535	2081	5010
Freshwater	within 200m of park with freshwater element	53089	4610	2672	6594
Green area	green area within 500m	224204	-317	-369	-265

The effects are uncertain as reflected by the confidence bounds in ***Table 7.4*** . Further methodological uncertainties are discussed below.

Substitution effects may be present - the positive effect on prices of the closest green space is not so large if there are a lot of accessible alternatives close by. It may increase the value of an apartment to be closer to parks and cementaries, but this is moderated by the total amount of green space that is available in the neighbourhood. Green space includes parks, cementeries, but also unmanaged green space (Norwegian 'friarealer').

Interaction effects deserve further research if the hedonic pricing function is to be used for policy assessment beyond awareness raising. An example of such an evaluation can be seen in ***Figure 7.4***.

Figure 7.4 *Combined effect on individual apartment prices of (i) distance to closest parks and cementeries and (ii) percentage of green space area within 500m*



Note: "green space area" includes parks, cementaries and umanaged green space. It does not include Marka forest.

It shows the combined effect of proximity to green space (direct effect) and percentage area green space (substitution effect) within 500m of an apartment. The combined effect of immediate proximity to and area of green structure is somewhat correlated with distance from the city centre. The distance from apartments to parks&cementaries decreases towards the city centre with a positive effect on prices. The negative substitution effect of having more available green space within a 500 m radius is not strong enough to completely cancel out the positive effect of immediate proximity. Notably, this is a marginal effect that has taken out/controlled for the proximity to city centre

Table 7.5 below shows some further confounding effects that should be taken into account when moving towards policy application of the hedonic pricing results.

Proximity to city centre. We removed/controlled for the proximity to the city centre in the model results – the closer the apartment is to the centre the higher its value (independent of other property characteristics). Other confounding effects include a negative effect of proximity to the Akerselva River in the Grünerløkka city district. A hypothesis is that the green space has a disservice in terms of safety concerns due to drug dealing in the area. Notably the drug dealing is not an "ecosystem disservice" in the sense that it is not an inherent quality of the green structure (can be improved with policing).

Another noteworthy and consistent effect is the negative influence of noise on price of apartments. This is consistent across different hedonic pricing models. Surprisingly there is low correlation between noise maps and presence of green space (Vågnes Traaholt 2014). This merits further research as the noise mapping models use of simple buffer assumptions may not be accounting for the influence of green space on noise dissipation.

Table 7.5 *Potential marginal value of confounding variables for the value of blue and green infrastructure*

Variable	Variable interpretation	Expected marginal effect (NOK)	Lower bound marginal effect (2,5%) (NOK)	Upper bound marginal effect (97,5%) (NOK)
Proximity city centre	per meter closer to city center, within 9 km	103	91	116
Green area	per % increase in green space within 500 m	-11931	-13868	-9965
Akers elva	if apartment within 200m of Akerselva in Grünerløkka district	-149437	-209511	-87378
Noise	if apartment exposed to > 65 dB	-109116	-136597	-81007

8 Recreational value of peri-urban forest

8.1 Ecosystem function assumptions

An estimated 86% of Oslo's population aged 15 or older uses the 'Marka' peri-urban forest for recreation in the course of a year (Synnovate, 2011). A large majority use it for multiple purposes including trekking, physical recreation, skiing and experiencing nature.

It is interesting to note that "Recreation, physical and mental health" is defined as part of "experiential and knowledge services"[8] by Oslo Municipality (Reinvang et al. 2014). The very high use of Marka among the population suggest that the peri-urban forest is providing a more fundamental 'supporting service' as temporary habitat for a large part of Oslo's population. The importance of Marka for mental and physical health is fundamental and as such invaluable (Hågvar, 2014).

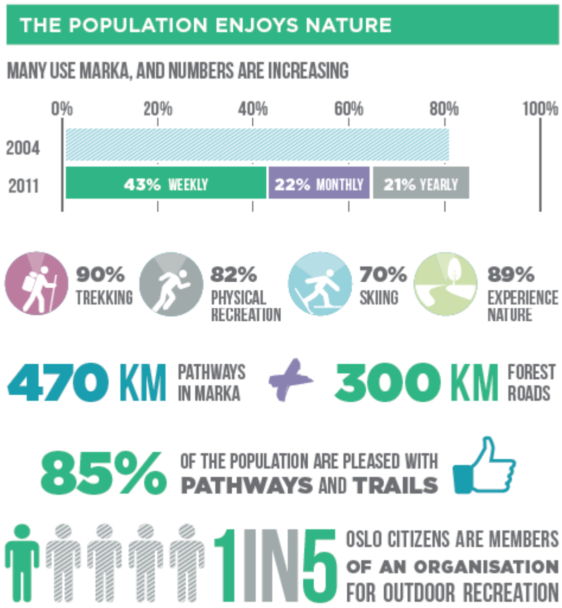


Figure 8.1 *Characteristics of recreational use of Oslo's Marka forest. Source: OsloKommune (2013b)*

The Marka forest ecological function as attractive 'recreational habitat' by urban residents depends on the accessibility and qualities of the forest. Recreational qualities of Marka and related conflicts with forestry in the area has been widely studied by researchers (Gundersen et al., 2005; Gundersen et al., 2011a; Gundersen et al., 2011b) and are a continuing source of contention between environmental movement and private forest owners. Management of conflicting interests is regulated by the Marka Act[9]. The Marka Act provides amongst others the legal basis for forest protection based on 'experiential values'. Forest in Oslo protected under the law is popularly know as 'Fairytale forests' (ref. Eventyrskoger). The Marka Act effectively provides a definition for classifying forest according to subjective experience i.e. forest cultural ecosystem service values. The Marka Act also regulates the use of the forest for sports and location of sports facilities. As such the Marka Act regulates what characteristics of the forest should be conserved for it to continue to provide cultural ecosystem services.

In the following valuation example we estimate the total recreational visits per year to Marka. We do not address how recreational use varies across different parts of the Marka forest according to its qualities. This is obviously correlated with accessibility combined with forest qualities for example represented by the trail network and protected areas.

Based on estimates of the share of the adult population (>15 years of age) that visits Marka and their daily, weekly, and monthly distribution per season we estimate the total number of visits per year (***Table 8.1***). Based on an average of 3 hours per visit (Gundersen et al., submitted) we estimate the total visitation per year by Oslo residents to Marka use to be about 70 million hours. This estimate does not include the time spent by children, nor by tourists.

[8] Norwegian: "opplevelses- og kunnskapstjenester"
[9] *Lov om naturområder i Oslo og nærliggende kommuner*, Stortinget 2. april 2009

Table 8.1 *Time spent in Marka forest by season and per year*

	Estimated total number of visitation hours					
	Daily	Weekly	Monthly	More seldom	Never	Total per season (hours)
Spring	7,449,681	7,429,271	2,694,131	204,101	-	**17,777,184**
Summer	4,966,454	5,306,622	1,632,807	176,887	-	**12,082,770**
Autumn	7,449,681	7,252,383	2,939,052	190,494	-	**17,831,611**
Winter	9,932,908	9,905,695	3,374,467	204,101	-	**23,417,171**
Total per year	**29,798,724**	**29,893,971**	**10,640,458**	**775,583**	-	**71,108,736**

Source: own calculations
Comment: Average hours per visit 3.04   Source: (Gundersen et al., submitted)

Section 8.4 provides further documentation of the calculations of total number of visits per year.

8.2 Value transfer assumptions

Given our estimate of the total number of recreational visits and total time spent we explored a number of ways of assigning value per trip to or per recreation hour in Marka forest.

Value of recreation time – recreation time can be valued according to its opportunity cost, measured as the disposable income foregone from not spending the same time in paid work. Literature on time value argues that monetary opportunity cost of time is a fraction of income/hour, although what fraction to use is unclear. We therefore try both 33% and 100% of average wage after tax. We also estimate recreational value based on the price per hour of training in a health studio in Oslo as an alternative to training in the Marka forest.

Willingness to pay - we based our estimates on a choice experiment valuation study by Sælen and Ericson (2013) conducted on visitors in Marka (***Table 8.2)***

Consumer surplus – we based our estimates on Sælen and Ericson (2013) estimates of willingness-to-pay for trips to Marka, and their data on travel time costs and expenses. We calculated expected consumer surplus by subtracting total travel costs from willingness-to-pay. We conservatively assume that 50% of all trips are by car and 50% by public transport, thereby discounting trips on foot which have no travel expenditures.

Table 8.2 *Example of estimated consumer surplus - visitation by car*

	Snow	Bare ground	Slush
Willingness-to-pay (Kr.)	209	125	47
Expected travel cost (kr)	34	34	34
Expected consumer surplus (kr.)	175	91	13

Source: calculated based on Sælen and Ericson (2013)

Finally, we compared these estimates to mean consumer surplus estimated from a travel cost meta-analysis (Zandersen and Tol, 2009).

Why do we call this value transfer if visitation estimates are for Oslo, and most of the willingness-to-pay and travel cost information is also obtained from Marka visitors? It is value transfer in the sense that findings from the relatively small sample collected by Sælen and Ericson (2013) have been extrapolated to the whole of Oslo's adult population. We know that there are transfer errors such as not estimating the value of recreation time for children.

Section 8.5 provides further documentation of the value transfer assumptions.

8.3 Valuation transfer results for awareness raising

Given the assumptions above we find that the opportunity cost of time spent on recreation in Marka forest could be between 2,7-13,3 billion NOK/year (***Table 8.3***). We find that total willingness-to-pay for recreation could be about 3,6 billion NOK/year based on results from a choice experiment conducted on local visitors. If we subtract travel costs consumer surplus based on this study is about 2,3 billion NOK/year. Finally, we compare these estimates to a value transfer based on the mean consumer surplus from a meta-analysis of a number of travel cost studies for forest recreation from around the world, finding an estimate of 3,4 billion NOK/year.

Table 8.3 *Total value of visits to Marka forest by Oslo's adult population*

Valuation methods	Per month	Per hour	Per trip	Totalvalue of visits to Marka (NOK/år)	Assumptions and sources
Value of recreation time					
Opportunity cost of time; wage after tax (100%)		187		13,297,333,559	based on interviews in Svartdalen Park (August 2014)
Opportunity cost of time; wage after tax (33%)		62.271		4,428,012,075	assumptions in Sælen and Ericson(2013) & Svartdalen sample
Cost of training studio	453	37.75		2,684,354,769	Din Side (assume 12 hours/week)
Willingness to pay (WTP)					
Choice experiment (spring-summer-autumn)			124.8	1,957,550,484	based on Sælen and Erikcson (2013)
Choice experiment (winter)			209.3	1,612,318,420	based on Sælen and Erikcson (2013)
Choice experiment (whole year)				3,569,868,904	based on Sælen and Erikcson (2013)
Consumer surplus (=WTP - travel cost)					
Choice experiment (spring-summer-autumn)			71.09	1,115,313,264	Sælen and Erikcson (2013) ; 50% car, 50% public transport
Choice experiment (winter)			155.64	1,198,923,192	Sælen og Erikcson (2013) ; 50% bil, 50% offentlig transport
Choice experiment (whole year)				2,314,236,456	Sælen og Erikcson (2013) ; 50% bil, 50% offentlig transport
Travel cost method (meta-analysis)			143.6	3,358,718,206	Zandersen and Tol(2009)

Source: own calculations

8.4 Ecosystem service demand quantification

In this section we provide the details of the quantification of number of visits and time spent in the Marka forest.

Table 8.4 shows the estimate of the total share of the population believed to use Marka based on results from the survey by Synnovate (2011).

Table 8.4 *Estimated user population of Marka peri-urban forest*

Estimated population (>15 years) using Marka forest	Estimate	Confidence 2.50%	Confidence 97.50%
Total population of Oslo (per 1.1.2014)	634,463		
Total population (age >15years per 1.1.2014)	520,453		
Estimated share >15 year using Marka forest	86%	83.7%	88.3%
Estimated population >15 year using Marka forest	447,590	435,619	459,560

Source: Oslostatistikken, Utviklings- og Kompentanse-etaten, Oslo Kommune
Confidence bounds: estimated based on Synnovate 2011

The survey asked people whether they visited daily, weekly, monthly or more seldom for different seasons (***Table 8.5***).

Table 8.5 *Observed distribution of visits in a sample of Oslo inhabitants*

	Visitation distribution per season				
	Daily	Weekly	Monthly	More seldom	Never
Spring	6%	42%	33%	15%	3%
Summer	6%	45%	30%	13%	6%
Autumn	6%	41%	36%	14%	3%
Winter	6%	42%	31%	15%	6%

Source:Synnovate(2011)

Combining tables 3.4 – 3.5 we generate the estimated number of visitors per season from the user population (**Table 8.6**).

Table 8.6 *Estimated number of visitors per season and year to Marka peri-urban forest*

	Number of visitors per season				
	Daily	Weekly	Monthly	More seldom	Never
Spring	26855	187988	147705	67138	13428
Summer	26855	201415	134277	58187	26855
Autumn	26855	183512	161132	62663	13428
Winter	26855	187988	138753	67138	26855

Source: own calculations

To estimate visitation frequency per season per person we make a conservative assumption for the weekly(=1) and monthly(=1) visitation rates and the length of the seasons (***Table 8.7***)

Table 8.7 *Assumptions about visitation frequency per season*

	Visitation frequency definitions per season				
	Daily	Weekly	Monthly	More seldom	Never
Spring(3 months)	91	13	6	1	0
Summer(2 months)	61	9	4	1	0
Autumn(3 months)	91	13	6	1	0
Winter(4 months)	122	17	8	1	0

Source: own calculations (weekly=once/week; monthly=once/month)

Combining ***Tables 8.6 and 8.7*** we estimate the total number of visits per season across the population (***Table 8.8***)

Table 8.8 *Estimated total number of visits to Marka peri-urban forest*

	Estimated total number of visitation days					
	Daily	Weekly	Monthly	More seldom	Never	Total per season (visits)
Spring	2,450,553	2,443,839	886,227	67,138	-	5,847,758
Summer	1,633,702	1,745,599	537,107	58,187	-	3,974,595
Autumn	2,450,553	2,385,652	966,793	62,663	-	5,865,661
Winter	3,267,404	3,258,452	1,110,022	67,138	-	7,703,017
Total per year	**9,802,212**	**9,833,543**	**3,500,151**	**255,126**	-	**23,391,031**

Source: own calculations

Based on survey data on time use per visit (Gundersen et al., submitted) and the total number of visits (***Table 8.8***) we estimate the expected total number of hours spent by visitors in Marka in a year (***Table 8.9***)

Table 8.9 *Estimated total number of hours spent by visitors in Marka peri-urban forest*

	Estimated total number of visitation hours					
	Daily	Weekly	Monthly	More seldom	Never	Total per season (hours)
Spring	7,449,681	7,429,271	2,694,131	204,101	-	17,777,184
Summer	4,966,454	5,306,622	1,632,807	176,887	-	12,082,770
Autumn	7,449,681	7,252,383	2,939,052	190,494	-	17,831,611
Winter	9,932,908	9,905,695	3,374,467	204,101	-	23,417,171
Total per year	29,798,724	29,893,971	10,640,458	775,583	-	71,108,736

Source: own calculations
Comment: Average hours per visit 3.04 . Source: Synnovate (2011) and (Gundersen et al., submitted)

8.5 Value transfer approaches

In this section we provide some further background to the different valuation methods used to generate the different estimates in ***Table 8.3*** above.

8.5.1 Opportunity cost of time

We based our evaluation of the opportunity cost of recreation time on average wages after tax og kr. 187/hour, based on 40 interview conducted in Svartdalen park August 2014 backed up by similar estimated in Sælen and Ericson (2013)

8.5.2 Alternative cost of physical training

We based the alternative cost of physical training on the monthly subscription paid for a health studio in Oslo, assuming 12 training sessions per month of one hour each.

8.5.3 Travel cost

Travel times to Marka have been calculated by Veisten (1994) (***Table 8.10***). They are similar to Sælen and Ericson (2013). We based our calculations on the more detailed data of the latter study (***Table 8.11***), which also contained information on travel expenses (***Table 8.12***).

Table 8.10 *Average travel time to Marka*

	Car	Public	Bicycle	On foot
Average travel time Oslomarka(min.)	30	66	35	36

Source: Veisten (1994)

Table 3.11 *Travel time (minutes)*

Distance(km)	Car	Public	Bicycle	On foot
5	7	20	0	0
20	20	30	0	
40	40	75		
70	70	150		
mean/km	1.01	2.04		

Source: adapted from Sælen and Ericson (2013)

8.5.4 Willingness-to-pay (WTP) and willingness-to-travel (WTT)

We based our estimates of willingness-to-pay on the choice experiment survey (***Figure 8.2***) conducted by Sælen and Ericson (2013) at different entry points to Marka (***Figure 8.3***). The choice experiment asked Marka visitors their preferences for recreational sites in the forest given ground conditions, temperature and travel distance from home. Based on the choice experiment Willingness-to-pay (WTP)and willingness-to-travel (WTT) could be estimated for different weather conditions (***Table 8.13***). We applied their "snow " estimates to value winter visits and their "bare ground" estimates to value visits the rest of the year.

Winter scenario 8		
	A	**B**
Conditions	Bare ground	Snow/skiing conditions
Temperature	+5°C	-5°C
Distance from your home	5 km	20 km
Illustration		

Figure 8.2 *Example choice set in choice experiment by Sælen and Ericson (2013)*

Table 8.13 *Willingness-to-pay (WTP)and willingness-to-travel (WTT) by weather condition*

	Snow	Bare ground	Slush
WTP(Kr.)	209.31	124.76	47.47
$WTP_{5\%}$	194.21	115.05	33.35
$WTP_{95\%}$	224.73	134.81	59.65
WTT(km)	45.18	23.21	1.52
$WTT_{5\%}$	41.49	20.83	-2.23
$WTT_{95\%}$	48.96	25.77	5.39

Source: Sælen and Ericson (2013)
WTT - maximum willingness to travel each way(km)
WTP - maximum willingness to pay(Kr.)

8.5.5 Consumer surplus

We also estimated consumer surplus based on Sælen and Ericson (2013) results by subtracting expected travel costs from WTP for forest visits for different modes of transport (***Tables 8.14-8.15***).

Table 8.14 *Consumer surplus - visitation by car*

	Snow	Bare ground	Slush
Willingness-to-pay (Kr.)	209	125	47
Expected travel cost (kr)	34	34	34
Expected consumer surplus (kr.)	175	91	13

Source: calculated based on Sælen and Ericson (2013)

Table 8.15 *Consumer surplus - visitation by public transport*

Source: calculated based on Sælen and Ericson (2013)

	Snow	Bare ground	Slush
Willingness-to-pay (Kr.)	209	125	47
Expected travel cost (kr)	73	73	73
Expected consumer surplus (kr.)	136	51	-26

For the value transfer we assumed that 50% of the population travel by car and 50% travel by public transport. This estimate could be further refined by using Sælen and Ericson's (2013) original data on choice of travel mode. Estimates could be further refined by evaluating the actual number of "snow" versus "slush" and bare ground days in the winter season.

Finally, in a meta-analysis of travel cost studies Zandersen and Tol (2009) found a sample mean of €17.3 (2013 prices). We used this mean consumer surplus estimate as an example of what we could expect if we had conducted a "quicker and dirtier" value transfer, i.e. without access to the local study by Sælen and Ericson (2013).

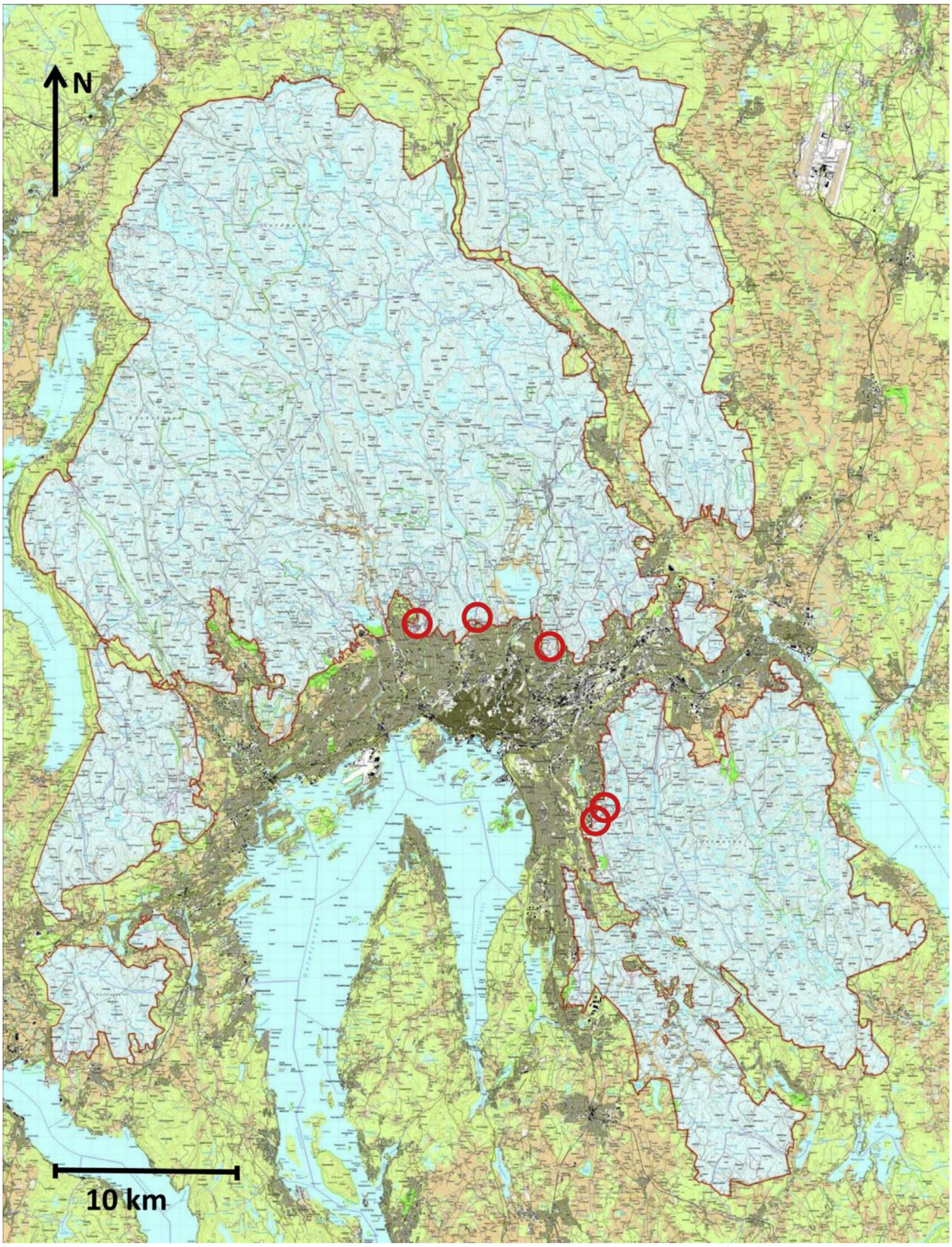


Figure 8.3 *Interview locations for Sælen and Ericson (2013) study used to estimate willingness to pay for Marka recreation, travel costs and consumer surplus of visits.*

9 Ecosystem service liability value of city trees

9.1 Ecosystem function assumptions

Because ecosystem services integrate over space and time it is challenging to identify and quantity the marginal effect of individual trees to individual ecosystem services.

With the current state of knowledge in Oslo and in a rapid assessment the assignment of the relative importance of trees for individual ecosystem services has to be based on expert judgement.

We based our modelling of the relative importance of individual city trees on the so-called "VAT03" developed by Randrup et al. (2003). VAT03 was developed in Denmark as a 'model for plant appraisal'. It is used to calculate of the liability value of city trees. Liability value is assessed by municipalities in cases of the damaged or killing of city trees, for example during construction works. Oslo Municipality's Environmental Agency has adopted the approach and used it in a number of cases of tree damage to assess the fine to be paid by responsible parties (both other public agencies and private actors) (COWI, 2014; VaktmesterKompaniet, 2014).

An overview of the model shows the types of information required to calculated liability value (***Figure 9.2***).

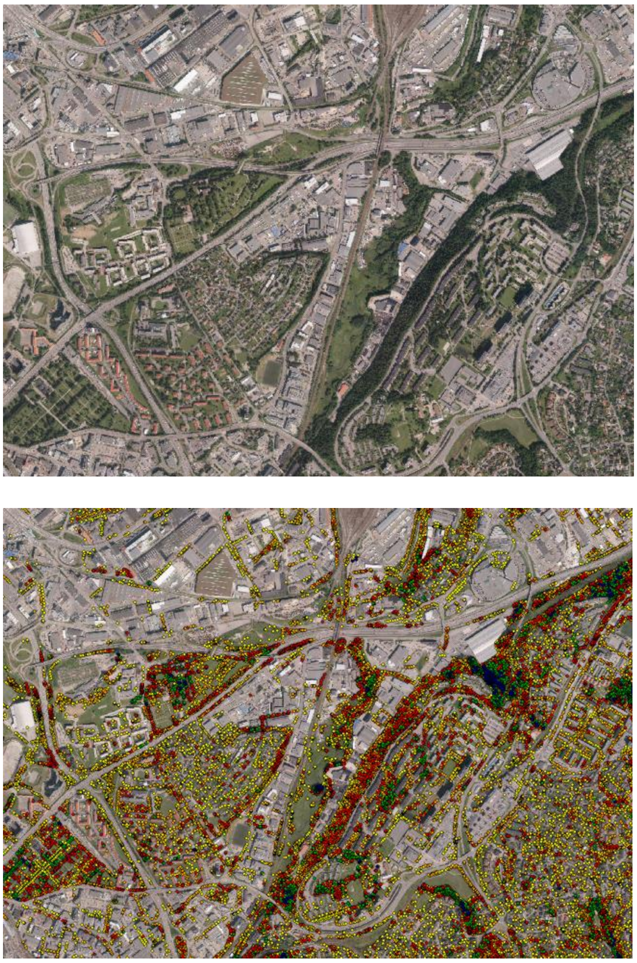


Figure 9.1 *An example of laser registration (lower panel) of trees(upper panel) in Oslo. Tree height is indicated by the colour of each point (lower panel) with blue representing highest tree crowns.*
GIS data: Bymiljøetaten, Oslo Kommune

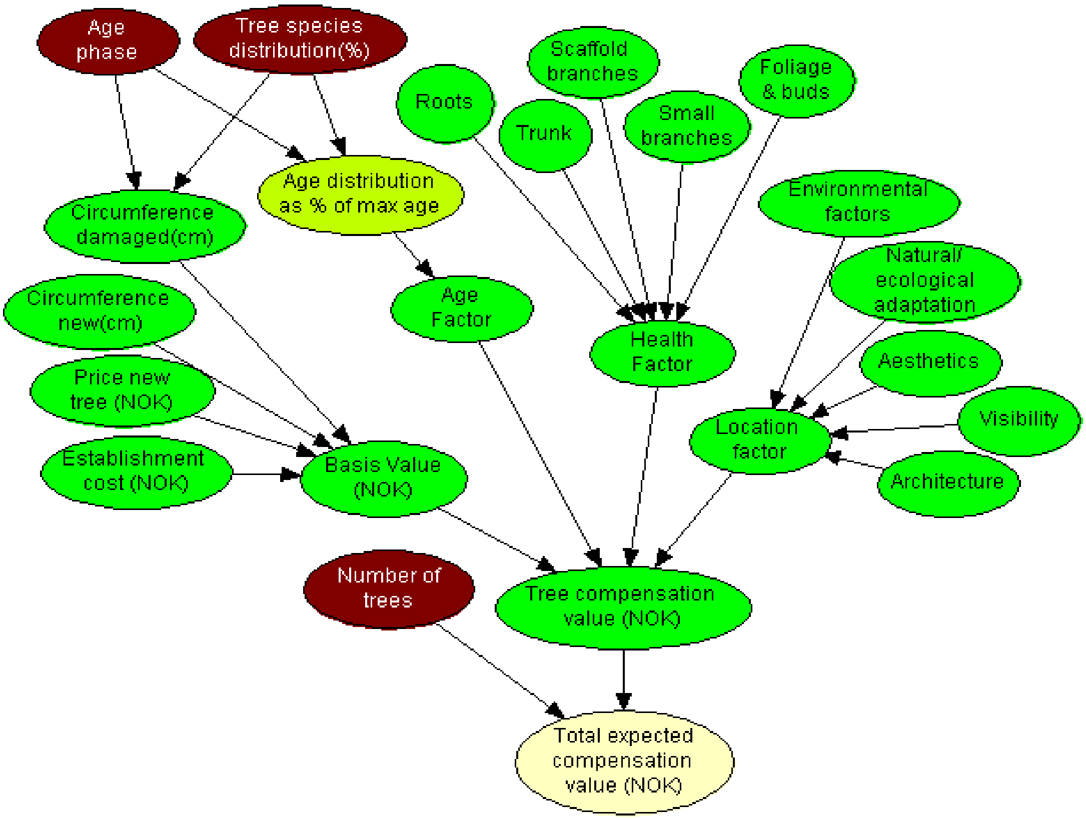


Figure 9.2 *Overview of the VAT03 model for assessing city trees liability value. Variables in green are required input in VAT03 in order to calculate tree liability value. We used the model to assess total liability value summed over all registered individual city trees in Oslo. Data on tree species distribution, age and numbers are shown in brown and were obtained from Bymiljøetaten (2015).*

The following factors are scored on a qualitative scale in the on-site assessment of by arborists. The following discussion is based on Randrup (2005), with the addition of an ecosystem services interpretation of the model variables.

Location factor

While the methodology was developed before the concept of ecosystem services became popularised, the location factor summarises information most closely aligned with of ecosystem services and disservices. Each factor is rated 0-5 where 2.5 is a neutral score (Randrup 2005). Based on this logic one can the interpret a score of >2.5 indicates a positive contribution of the factor – an ecosystem service – while a score <2.5 indicates an ecosystem disservice. The first three criteria relate to 'experiential/cultural ecosystem services' , while the last two relate to regulating ecosystem services.

- Architecture Whether the tree contributes positively or negatively to surrounding architecture

- Visibility. Based on the relative number of people who can see tree. Presumably the visibility of the tree may also have a negative influence if blocking visibility(score<2.5).

- Aesthetics. Flowers, bark, fruits, foliage, and other features, in relation to the specific location of the tree. Presumably aesthetics may also be considered to be negative (score<2.5).

- Natural/ecological adaptation. An assessment of the tree's vulnerability to de-icing salts, air pollution, or other unavoidable abiotic stress factors. Presumably score<2.5 indicates vulnerability, while score>2.5 indicates resilience in face of stressors. This factor is presumably conditional on tree health and presumably conditions the extent to which trees can provide regulating ecosystem services described by the environment factor (below).

- Environmental factor. Related to the climatic and environmental consequences that the damaged tree has on its specific location, such as shade or light, protection against wind, dust, and contribution to other factors such as allergies. This factor summarises a number of regulating and supporting ecosystem services into a single factor.

In our initial run of the model we assumed an expected neutral score of 2.5 for each of the locations factors (with a uniform distribution bounded 0-5). I.e. our assumption is that the contribution to ecosystem services/disservices of city trees is on average neutral.

Health factor.
This summarises the rating of tree health where 5 represents no health problems and 0 indicates that the tree is dead or dying. Tree structures are rated individually because damage can also be localised on particular parts of the tree (roots, trunk, scaffold branches, small branches and twigs, and foliage/buds).

In our initial run of the model we assume that the average city tree in Oslo has an expected neutral score of 2.5 for each of the health factors (with a uniform distribution bounded 0-5).

Age factor
In the VAT03 a high age of the tree will influence the overall liability value of the tree negatively, as illustrated in Figure 9.3. As the tree reaches its expected lifetime the age factor reduces the value of the tree substantially. A trees life expectancy is based on biological growth potential, but also conditional on safety considerations.

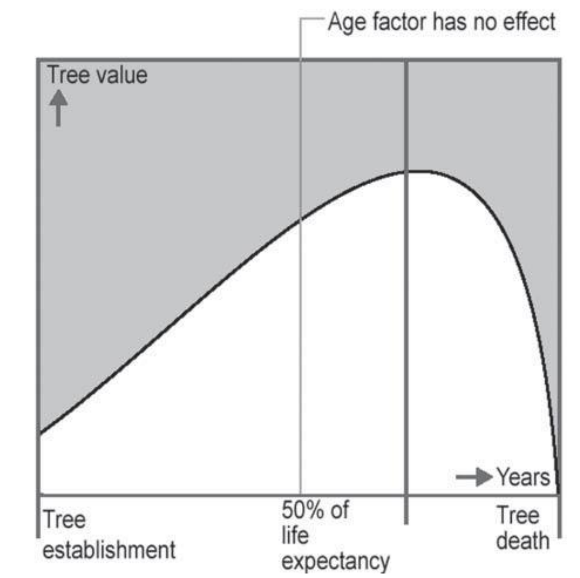


Figure 9.3. *Age factor influence on tree liability value. Source: Randrup (2005)*

For our modelling we obtained the age class and species distribution for approximately 13 500 city trees in the Environment Agency tree database (Bymiljøetaten, 2015). We based life expectancy by species on expert judgement[10] concerning life expectancy in a non-stressed environment (not city streets). We assumed that all identified trees had the same characteristics as the trees registered in the Environment Agency tree database.

Laser registration data from the flyovers have been used to estimate that there are between 700 000 – 1,2 million individual city trees in Oslo (Bymiljøetaten, 2015), not counting forest patches within the city.

[10] Personal communication Erik Sofjeld, Environment Agency

9.2 Value transfer assumptions

Values in the VAT03 model are of two basic kinds. Expert judgement regarding the relative importance of tree location, health and age discussed above is used to scale a monetary 'basis value'. Our estimates involve 'value transfer' in the sense that we assume that all city trees in Oslo have average location and health characteristics. Further, we assume that all city trees have the same characteristics of age and species as the roughly 1-2 % of trees that are managed by the Environment Agency.

Basis value

The 'basis value' constitutes the second type of value transfer. Basis value is calculated as the price of a new tree, including establishment costs, adjusted for the difference in size when the tree is damaged and at planting. In our application of the VAT03 model we assume that tree circumference for all trees in Oslo is distributed in the same way as for trees in the Environment Agency tree register. Total monetary value is very sensitive to replacement and establishment cost. We assume these costs would be the same for all trees in Oslo as for two cases where we have actual cost data[11] (COWI, 2014; VaktmesterKompaniet, 2014)

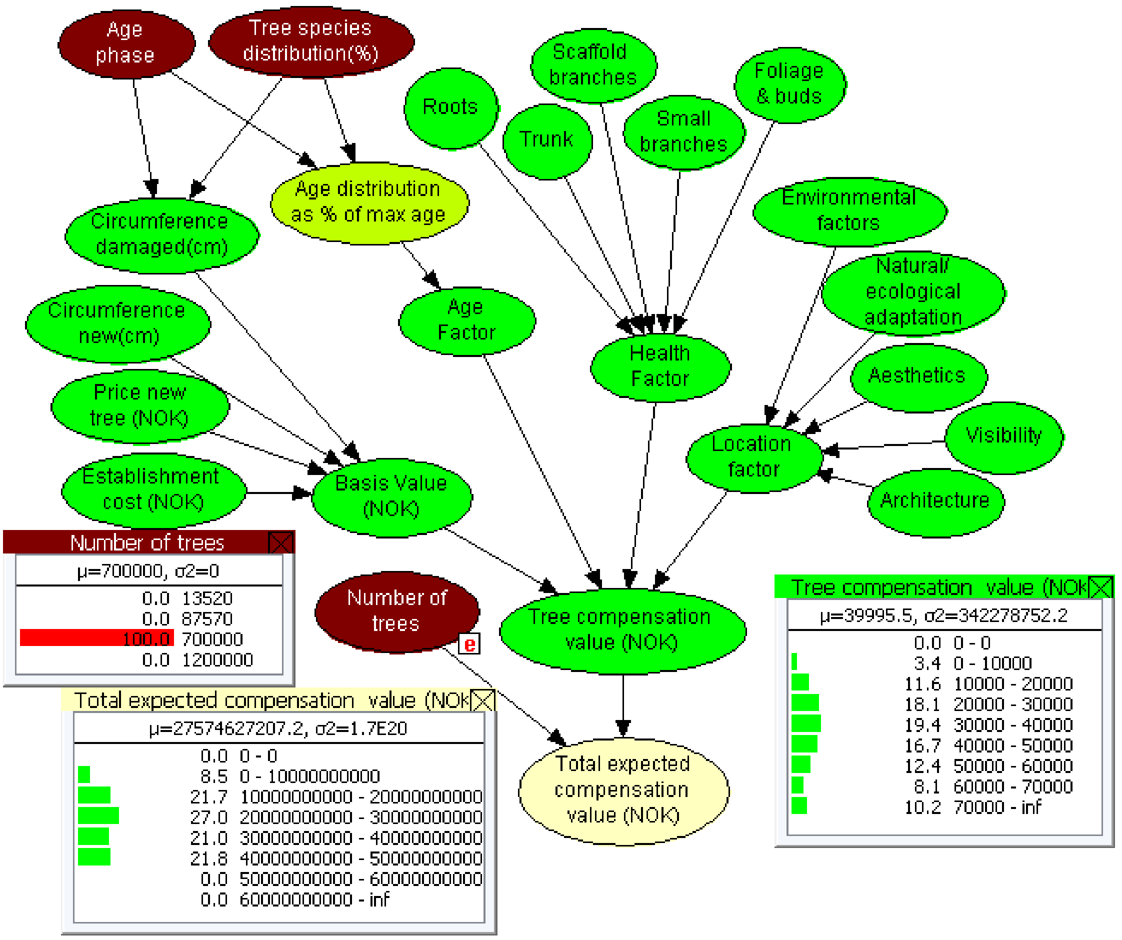


Figure 9.4 *Liability value distribution using the VAT03 model per tree and total assuming a conservative estimate of 700 000 city trees.*

[11] Akerselva, Trondheimsveien and Kåres vei. Average replacement cost was kr. 60 000 in these cases - average price of a new tree was kr.5000 and average establishment cost of kr. 55 000.

9.3 Valuation transfer results for awareness raising

Given our assumptions the expected liability value for a randomly chosen city tree in Oslo is roughly kr. 40000. This is kr. 20 000 less than the (unscaled) replacement cost per tree in the cases we know from Akerselva and Kåresvei in 2014. The average tree in Oslo is inferior to the trees that were damaged in these concrete cases.

It is a fact that Oslo Municipality imposes a fine on entrepreneurs or property owners equivalent to the VAT03 liability value. This is the per tree environmental liability of city trees proscribed by a public body, and as such an expression of social value. We saw from the model structure that this is also a surrogate value for a number of ecosystem services associated with trees.

Based on this assumption of the individual social environmental liability value of trees what would be the total expected social value of trees in Oslo?

The expectation is 27.6 billion NOK if we conservatively assume 700 000 trees or 43.3 billion NOK if we assume the upper range of 1 200 000 trees. Given the uncertainty about the location, health and age characteristics of the population[12] of trees the uncertainty around this estimate is very large (see the distribution in ***Figure 9.4***).

We are using the best available data of trees on site and a valuation model that has been adopted by the city authorities. Why is this a case of value transfer for ecosystem service? (1) It is value transfer in the sense that we are extrapolating tree values and characteristics from a (very) small sample to the total population, even though this is within the same study site. (2) we are assuming that the marginal environmental liability value also scales spatially to all city trees.

Can we confidently assume that the marginal environmental liability value can be interpreted as an average value across the whole population of trees? Two reasons why this may not be so come to mind. (1) the marginal social value of trees should be increasing with increasing scarcity, which would indicate that current marginal liability value is lower than average value; (2) from a economic welfare theory point of view there could be reason to question whether value's can be aggregated across green structures or whether we first need to determine individual WTP per tree and then aggregate across

[12] We use the population concept because these are individual city trees, versus a forest stand.

9.4 Data on city trees

The study of liability value of city trees used available data in the Municipal "Strategy for City Trees in Oslo" (OsloKommune, 2015). This section describes the data available in the municipal tree register and is based on translated excerpt from the Strategy.

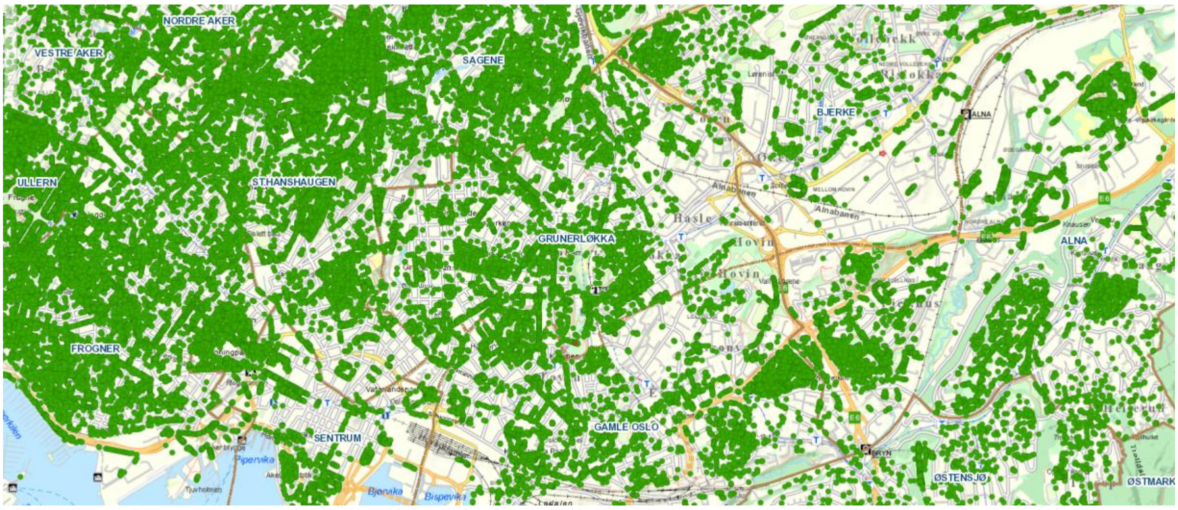


Figure 9.5 *Individual city trees higher than 5 meter identified by Oslo Municipality's Planning and Building Agency. Based on LiDAR registration there are between 0,7-1,2 million trees within Oslo's built zone. Source: Bymiljøetaten, Oslo Kommune*

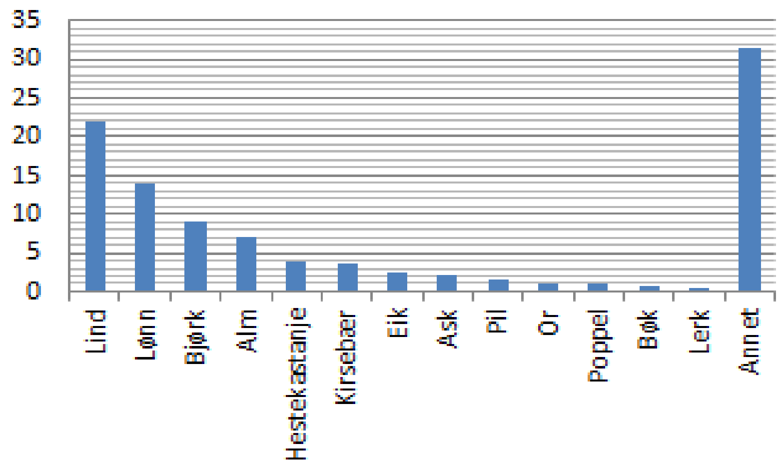
How many city trees are there in Oslo? The Planning and Building Agency (PBE) has conducted a laser (LiDar) registration of city trees within the built zone and estimated between 700 000 and 1 200 000 individual trees taller than 5 meters. An exerpt of the mapping of city trees is shown in ***Figure 9.5*** for the city centre. PBE has furthermore digitised 87 570 particularly large trees in the built area. These trees were identified for their large size and distinction in the landscape. This registration includes municipal, state and private trees. At present there is no information regarding which of these 'noteworthy' trees are the responsibility of the Municipal Environment Agency

Municipal Environment Agency data on city trees. 13 520 city trees have been registered in a 'Tree Register' for inner city districts under the responsibility of the Environment Agency (BYM). The inner city is defined as districts Sentrum, Gamle Oslo, Grünerløkka, Sagene, St. Hanshaugen og Frogner. The distribution of Tree Register are located on city streets (27%), city district installations (42%), parks (22%) and unidentified landuse (9%). These figures do not include the outer city districts relatively few trees have been noted in the Tree Register.

What are the characteristics of the tree species in the Register?

Information on tree species, age, and type can be found in the Tree Register*(**figures 9.6- 9.7***).

Figure 9.6: *Percentage distribution of tree species in the Tree Register (inner city).*



Note: Lind= Lime ; Lønn= Maple ; Bjørk= Birch ; Alm= Elm ; Hestekastanje= Horse-chstnut ; Eik= Oak ; Ask= Ash ; Pil= Willow ; Or= Alder ; Poppel= Poplar ; Bøk= Beech ; Lerk= Larch ; Annet= Other (unregistered species or species <0.5%). Source: OsloKommune (2015)

Figure 9.7 shows the age phase distribution of inner city trees in Tree Register***.***

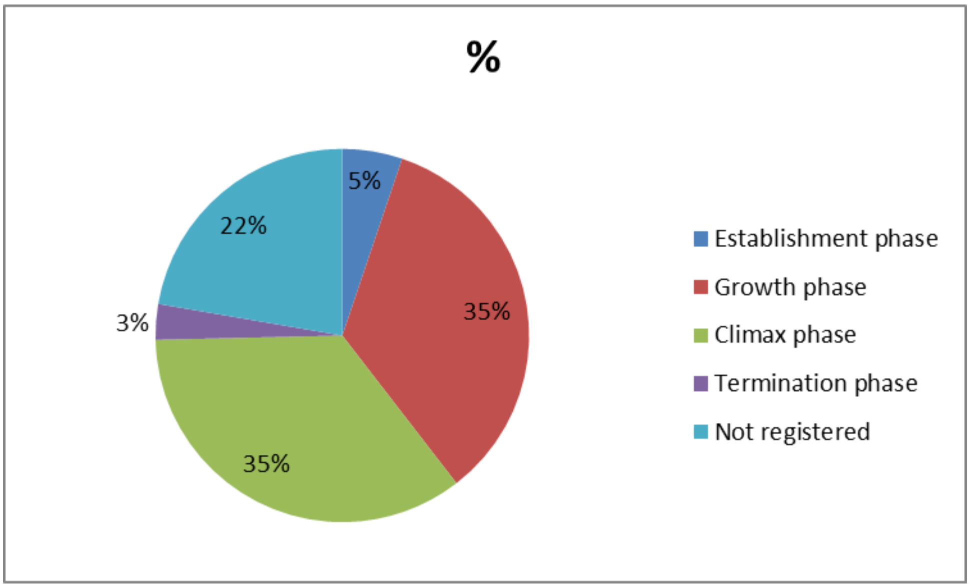


Figure 9.7 *Age phase distribution of inner city trees in Tree Register.*
Source: adapted from OsloKommune (2015)

In determining the "age" variable for the VAT03 liability value model we assumed that the age distribution of all city trees was the same as for inner city trees. Likewise we assumed that the species distribution was the same as what is registered in the inner city sample. The inner city sample constitutes as little as 1,1% of the total number city trees. Further fine tuning of the model would require further registration work for outer city trees, or possibly extrapolation using a spatial predictive model.

In order to determine age in years and expected circumferences in different phases based on the registered information on age phase we consulted an arborist working with BYM to produce ***Table 9.1***

Table 9.1 *Expected life expectance for city trees in urban environment*

Species	Life expectancy in urban setting	Expected circumference Establishment phase	Expected circumference Growth phase	Expected circumference Climax phase	Expected circumference Termination phase
Lime	300	27	After 50 years 125 cm	250 cm	376 cm
Maple	200	27	after 40 years 100cm	200 cm	251 cm
Birch	120	27	after 30 years 94 cm	188 cm	226 cm
Elm	200	27	after 40 years 126cm	252 cm	314 cm
Horse-chestnut	150	27	after 30 years 94 cm	188 cm	235 cm
Cherry	100	27	after 25 years 62 cm	124 cm	125 cm
Oak	500	27	after 70 years 176 cm	352 cm	628 cm
Ash	300	27	after 50 years 125 cm	250 cm	376 cm
Willow	100	27	after 30 years 113 cm	226 cm	251 cm
Alder (black)	100	27	after 30 years 94 cm	188 cm	188 cm
Poplar	100	27	after 30 years 94 cm	188 cm	251 cm
Beech	200	27	after 40 years 126cm	252 cm	376 cm
Larch	250	27	after 40 years 100cm	200 cm	314 cm

Source: Personal communication Erik Solfjeld, BYM.

10 References

Albon, S., Turner, K., 2014. Evolving a conceptual framework to explore the links between human wellbeing and the environment. environmental SCIENTIST. Journal of the Institution of Environmental Sciences December 2014, 9-14.

Barton, D.N., 1999. The Quick, the Cheap, and the Dirty. Benefit transfer approaches to the non-market valuation of coastal water quality in Costa Rica", Ph.D. thesis. No. 1999-34, Agricultural University of Norway. http://www.nlh.no/IOS/publikasjoner/avhandling/a1999-3.html.

Barton, D.N., Vågnes Traaholt, N., Blumentrath, S., 2015. Naturen i Oslo verdt milliarder. Økonomisk verdsetting av urbane økosystemtjenester fra grønn infrastruktur. NINA Rapport 1113.

Brander, L.M., Koetse, M.J., 2011. The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. Journal of Environmental Management 92, 2763-2773.

Bymiljøetaten, 2015. Strategi for bytrær i Oslo.

COWI, 2014. Verdivurdering av trær langs Akerselva. Mai 2014 for Bymiljøetaten VAT03.

Dronnningalandskap, COWI, Møller, C.F., 2014. Blågrønn Faktor. Eksempelsamling 29.05.2013 Plan- og bygningsetaten, Oslo Kommune, Bærum Kommune, Dronnningalandskap, COWI, C.F. Møller.

Gómez-Baggethun, E., Barton, D.N., 2013. Classifying and valuing ecosystem services for urban planning. Ecological Economics 86, 235 – 245.

Gómez-Baggethun, E., de Groot, R., 2010. Natural capital and ecosystem services: The ecological foundation of human society. In:, in: Hester, R.E., Harrison, R.M. (Eds.), Ecosystem services. Cambridge: Royal Society of Chemistry, Issues in Environmental Science and Technology 30, 118–145.

Grêt-Regamey, A., Weibel, B., Bagstad, K., Ferrari, M., Geneletti, D., 2014. On the Effects of Scale for Ecosystem Services Mapping PLoS ONE 9, e112601.

Gundersen, V., Löfström, I., Jørgensen, B.B., Falcke, J., Øyen, B.H., 2005. Urban woodland management – The case of 13 major Nordic cities. Urban for Urban Gree, 189–202.

Gundersen, V., Skår, M., Tangeland, T., Vistad, O.I., 2011a. Særskilt vern av friluftsområder i Oslomarka etter markalovens § 11:
Kunnskapsgrunnlag, kriterier og registreringsmetode. – NINA Rapport
664. 78 s.

Gundersen, V., Stange, E., Björck, M., Elsrud, O.E., Frivold, L.H., 2011b. Opplevelsesverdier i skog – effekter av økologisk og økonomisk informasjon - NINA Rapport 739. 52 s.

Gundersen, V., Tangeland, T., P.B., K., submitted. Development of a four-part planning concept for the urban forests of Oslo: A review of management, research and theory. Urban Forestry and Urban Greening.

Holzinger, O., Coles, R., Christie, M., Grayson, N., 2013. Ecosystem Services Evaluation for Birmingham's Green Infrastructure. Green Living Spaces Plan Appendix 1. September 2013. https://www.birmingham.gov.uk.

Hågvar, S., 2014. Naturopplevelsens kvaliteter. Grevlingen Spesialutgave 5-2014, 6-11.

Laurans, Y., Mermet, L., 2014. Ecosystemserviceseconomicvaluation, decision-supportsystem or advocacy? Ecosystem Services, 98–105.

Laurans, Y., Rankovic, A., Billé, R., Pirard, R., Mermet, L., 2013. Use of ecosystem services economic valuation for decision making: Questioning a literature blindspot. Journal of Environmental Management 119, 208-219.

Lindhjem, H., Sørheim, M.D., 2012. Urbane økosystemtjenester i Norge: Status, utvikling, verdi og kunnskapshull. Rapportnummer 2012/37 Vista Analyse AS.

OsloKommune, 2013a. Kommuneplan for Oslo. Oslo mot 2013. Høringsutkast Del 1.

OsloKommune, 2013b. OSLO! GoGreen. Application European Green Capital 2016. Submitted 31.10.2013.

OsloKommune, 2015. Strategi for bytrær i Oslo, Bymiljøetaten.

Randrup, T.B., 2005. Development of a Danish model for plant appraisal. Journal of Arboriculture 31(3): May 2005 31, 114-123.

Randrup, T.B., Poulsen, L., Holgersen, S., 2003. VAT 03— Værdisætning af Træer [Valuation of Trees in Danish]. Forlaget Grønt Miljø, Copenhagen.

Reinvang, R., Barton, D.N., Often, A., 2014. Verdi av urbane økosystemtjenester: Fire eksempler fra Oslo. Rapport nummer 2014/46. Vista Analyse A/S, NINA.

Schröter, M., Remme, R.P., Sumarga, E., Barton, D.N., Hein, L., 2014a. Lessons learned for spatial modelling of ecosystem services in support of
ecosystem accounting EcosystemServices.
Schröter, M., Rusch, G.M., Barton, D.N., Blumentrath, S., Nordén, B., 2014b. Ecosystem services and opportunity cost levels shift spatial priorities for forest biodiversity conservation. PLoS ONE 9, e112557.
Scott, A., 2014. Mainstreaming ecosystem science into policy and decision-making. environmental SCIENTIST December 2014, 56-61.
SSB, 2013. Statistisk Årbok for Oslo 2013. Statistisk Sentralbyrå.
Synnovate, 2011. Kommentarrapport. Undersøkelse om bruk av Oslomarka 10.-17. september 2011. Utarbeidet for Oslo Kommune, Bymiljøetaten av Erik Dalen, Synnovate 6. oktober 2011.
Sælen, H., Ericson, T., 2013. The recreational value of different winter conditions in Oslo forests: A choice experiment. Journal of Environmental Management 131, 426-434.
VaktmesterKompaniet, 2014. Verdisetting av 24 trær på eiendommen Kåres vei 3. Oslo 3.6.2014.
Veisten, K., 1994. En undersøkelse blant brukere av Oslomarka: synspunkter på skogtilstanden og skogbehandling. Rapport 6/94 fra forskningsprogrammet "Skogøkologi og flersidig skogbruk". Skogforsk.
Vågnes Traaholt, N., 2014. Valuing Urban Recreational Ecosystem Services in Oslo -A hedonic pricing study. Master Thesis, Department of Food and Resource Economics, Faculty of Science. University of Copenhagen.
Wilson, S.J., 2008. Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Services. David Suzuki Foundation
http://www.davidsuzuki.org/publications/downloads/2008/DSF-Greenbelt-web.pdf.
Zandersen, M., Tol, R.S.J., 2009. A meta-analysis of forest recreation values in Europe. Journal of Forest Economics 15, 109–130.

www.nina.no

1115

NINA Report

The Norwegian Institute for Nature Research (NINA) is Norway's leading institution for applied ecological research.

NINA is responsible for long-term strategic research and commissioned applied research to facilitate the implementation of international conventions, decision-support systems and management tools, as well as to enhance public awareness and promote conflict resolution.

ISSN: 1504-3312
ISBN: 978-82-426-2737-7

Norwegian Institute for Nature Research
NINA head office
Postal address: P.O. Box 5685 Sluppen, NO-7485 Trondheim, NORWAY
Visiting address: Høgskoleringen 9, 7034 Trondheim
Phone: +47 73 80 14 00
E-mail: firmapost@nina.no
Organization Number: 9500 37 687
http://www.nina.no

Cooperation and expertise for a sustainable future