Landscape Ecol (2014) 29:1361–1375
DOI 10.1007/s10980-014-0014-2

RESEARCH ARTICLE

Using expert knowledge in combining green infrastructure and ecosystem services in land use planning: an insight into a new place-based methodology

Leena Kopperoinen · Pekka Itkonen · Jari Niemelä

Received: 21 June 2013 / Accepted: 28 February 2014 / Published online: 13 March 2014

Abstract Green infrastructure (GI) is a strategic planning instrument to achieve sustainable development. The main functions of GI are to protect biodiversity and safeguard and enhance the provision of ecosystem services (ES). In this paper we present the development of a semi-quantitative place-based method, aiming at assessing GI based on the provision potential of all main ES. Our method combines a wide spectrum of GIS data with expert assessments. Here we focus especially on how interaction with experts and local and regional actors impacted the method development. Our results showed that involving experts in dataset selection is very useful in compiling the most relevant data for the assessment of ES. Expert knowledge is also valuable in evaluating the actual coverage and quality of datasets. By involving both experts and local and regional actors in assessing ES provision potential we can add local knowledge to the general scientific understanding. Qualitative assessments can be complemented with quantitative data in our method. The resulting maps support land use planning, as they assist in identifying the multifunctional key areas of GI and in examining the provision potential of various ES. The group discussions involved in our method provided an additional benefit, as the experts and local and regional actors felt that this discussion platform enhanced their understanding of both GI and ES.

L. Kopperoinen (✉) · P. Itkonen
Environmental Policy Centre, Finnish Environment Institute SYKE, P.O. Box 140, 00251 Helsinki, Finland
e-mail: leena.kopperoinen@ymparisto.fi

J. Niemelä
Department of Environmental Sciences, University of Helsinki, P.O. Box 65, 00014 Helsinki, Finland

Keywords GIS · Mapping · Method development · Expert knowledge · Expert assessment · Participatory assessment

Introduction

Green infrastructure (GI) and ecosystem services (ES) are concepts currently proposed for land use planning aiming at sustainable development and the green economy (Pauleit and Breuste 2011; LaFortezza et al. 2012). Land use planners are gradually getting acquainted with these concepts but need more knowledge about the tools to operationalise them in planning. In many cases, land use planners acknowledge the great potential brought about by the concept of ES both in promoting discussion of the relevance of green areas with decision-makers and in classifying green areas according to what different beneficial functions and services they produce (Ahern et al. 2014).

A customary way to assess GI has been to carry out various types of core area, network, connectivity, and fragmentation analyses based on structural and functional features of habitats (e.g. Calabrese and Fagan

2004; Girvetz et al. 2008; Jaeger et al. 2008; Minor and Urban 2008; Vogt et al. 2009; Kuttner et al. 2012). However, analyses of GI using the whole spectrum of ES provision as a premise have not existed so far. ES provision of a landscape or limited areas have been mapped in several studies (e.g. Burkhard et al. 2012; Egoh et al. 2012; Frank et al. 2012; Maes et al. 2012; Söderman et al. 2012; Larondelle and Haase 2013), but they have dealt with a single or a small group of ES. Such mappings have usually been based on land use and land cover data (e.g. CORINE in Europe), some other type of spatial classification of the physical environment (e.g. biotope data, Vihervaara et al. 2012), combination of landscape metrics coupled with participatory assessments (Frank et al. 2013) or locations of ES individually identified by the general public (e.g. Raymond et al. 2009; Brown et al. 2011). The focus has not been on identifying the GI from a holistic ES point of view, although the potential of areas to provide several different forms of ES has been recognised. The capability of areas to provide a wide variety of ES cannot be deduced based on the provision of one or a couple of ES: a site providing a certain ES might not be suitable for providing some other ES. Assessing the importance of sites in providing bundles of ES can be difficult (Egoh et al. 2008). In addition, it could be tempting to use rich biodiversity as a proxy of ES provision but only a weak correlation between species richness and ES provision has been found (Naidoo et al. 2008). This is especially true in urban areas where the significance of green areas is based mostly on attributes other than biodiversity.

In this paper we will present a new methodology which seeks to address the challenge of assessing GI in a holistic way using the ES approach. Our aim was to develop an innovative, place-based method which (a) helps to identify and spatially locate different elements of GI (including blue infrastructure, i.e. water areas) based on the provision potential of ES at the landscape scale, (b) will illustrate the provision potential of all ES according to selected classification, (c) rests on a wide variety of best available GIS datasets giving more detail and internal variance to land use and land cover classes, (d) combines spatial data with the knowledge of both experts and regional and local actors, and (e) is relatively easy to carry out for the needs of a rapidly developing land use planning process.

We define the key concepts used in our approach as follows:

- Of the many definitions used for *GI* the one articulated by Naumann et al. (2011, p 14) reflects our conception:

> GI is the network of natural and semi-natural areas, features and green spaces in rural and urban, terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ES.

It is important to note that according to this definition GI is needed for the provision of ES.

- *Provision potential of ES* is understood as the perceived potential of an area to produce ES which differs from (a) the quantified actual used set of ES or (b) the hypothetical maximum yield of selected ES used by Burkhard et al. (2012) to define the (a) supply and (b) potential supply of ES. Areas with high provision potential have qualities that are seen as good prerequisites for producing specified ES. Although we exclude the demand side from our concept of provision potential, we see it as an important measure in identifying elements of GI and in making future plans about land use based on that. However, we acknowledge the term *supply* and define it as *actual provision* which means that part of ES provision potential which is or can be made use of.
- *ES section* is the main division level of ES. According to CICES classification v.4 used in our study there are three sections of ES: (1) provisioning services, (2) regulation and maintenance services and (3) cultural ES.
- *ES groups* in our study are modified from the CICES classification v.4 by integrating group and class levels.
- *GIS dataset* is an acronym of Geographic Information System dataset. It refers to a set of spatially referenced data either in vector or raster form representing a specified geographic feature or phenomenon.
- *Theme* is a combination of several GIS datasets representing related geographic features or phenomena.
- *Experts* are either researchers or other specialists of various fields and themes (see above).

- *Local and regional actors* are local and regional level stakeholders coming from various authorities, natural resource managers, non-governmental organisations, or any other group having knowledge of local and regional conditions.

With this background, our aims for this paper are to

(1) present development of a new methodology on assessing GI based on the ES provision potential, and
(2) examine how interaction with experts and local and regional actors impacted method development.

Methods

Study area

The method development was carried out using a single case study area in southern Finland (61°29′N, 24°55′E; Fig. 1). It consists of three watersheds covering 9,900 km^2. There are two major cities within the study area: the city of Tampere has a population of 219,624 inhabitants which makes it Finland's third biggest city, while the city of Hämeenlinna is much smaller with a population of 67,636 inhabitants (both figures from August 2013). Both cities are surrounded by scattered small towns, villages and countryside, i.e. the area forms an urban–rural continuum. The natural environment is a mosaic of land and water. Large lakes and boreal forests make up a significant attraction but water bodies also constitute natural barriers to movement. Agriculture is important especially in the southern parts, while the northern parts are relatively remote from major urban centres and can be seen as almost forest-dominated wilderness.

The case study area was selected due to its representativeness in terms of the Finnish regional administrative level, which is responsible of strategic land use planning in Finland. At this stage of the

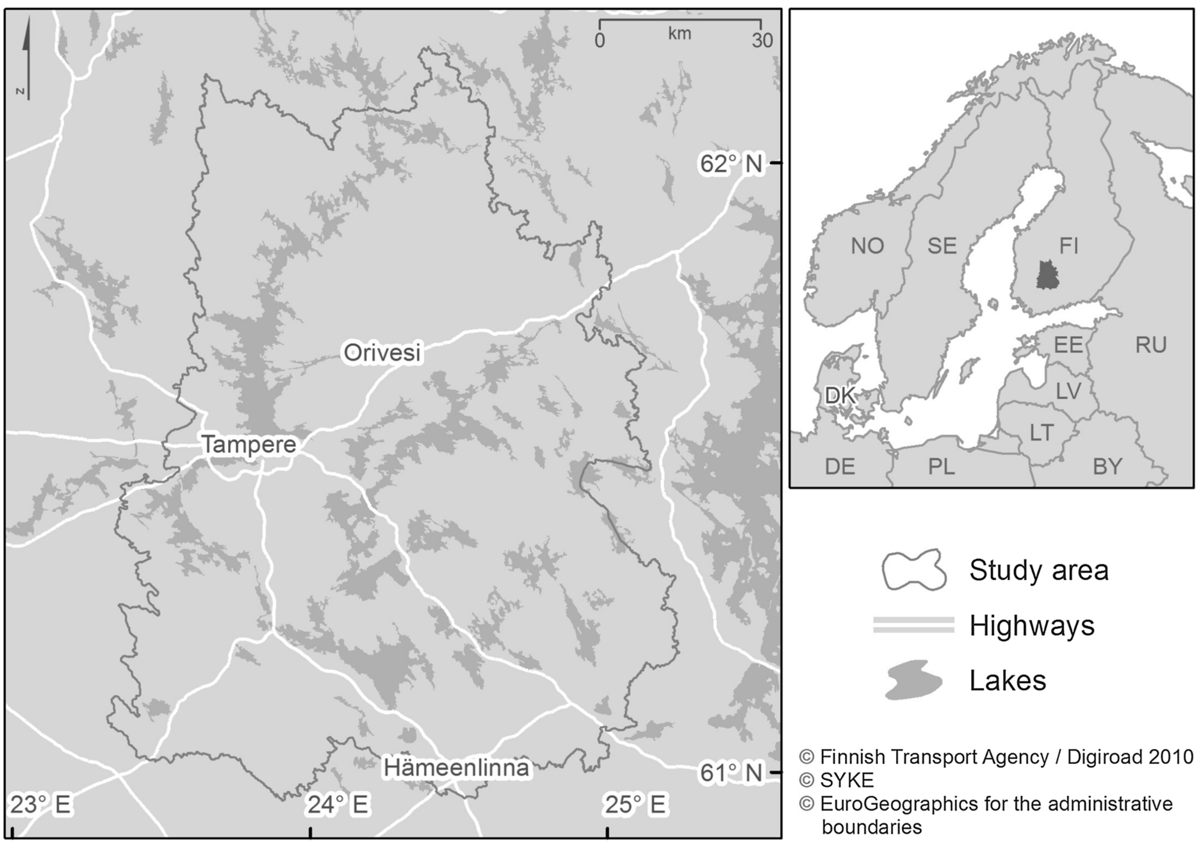


Fig. 1 Location of case study area

Table 1 ES classification used in the research based on the Common International Classification of Ecosystem Services (CICES) version 4, modified by Kopperoinen and Itkonen

ES section	ES group code	ES group
P: provisioning	P1	Produced terrestrial plants and animals for food
	P2	Wild terrestrial plants and animals for food
	P3	Wild edible fish
	P4	Aquaculture products
	P5	Water for human consumption and agricultural use
	P6	Water for industrial and energy uses
	P7	Biotic materials
	P8	Biomass based energy
RM: regulation and maintenance	RM1	Air flow regulation
	RM2	Water flow regulation
	RM3	Mass flow regulation
	RM4	Carbon sequestration
	RM5	Local and regional climate regulation
	RM6	Water quality regulation
	RM7	Pedogenesis and soil quality regulation
	RM8	Pollination
	RM9	Habitat and gene pool protection
C: cultural	C1	Aesthetics and heritage
	C2	Prey for hunting, fishing or collecting (enabling recreation)
	C3	Landscape character for recreational opportunities
	C4	Scientific and educational information and knowledge

method development we were targeting the regional level, representing European NUTS 3. Our case study area did not, however, coincide with exact regional administrative borders because we also wanted to work on a watershed basis, which allows better consideration of the impacts caused by environmental circumstances both in upper and lower reaches of water systems. The method is transferable as it is not dependent on specific regional characteristics. Thus, it could be applied in any other region in Europe, provided that enough suitable spatial datasets and experts are available.

ES classification system

The ES classification system used in our research was the newly developed Common International Classification of ES (CICES) version 4 (Haines-Young and Potschin 2013). We slightly modified the classification to meet our needs and the circumstances of the case study area: we did not consider the provision of sea weed, which is not relevant in our inland study area, for example. The original CICES classification has four levels: three sections, ten divisions, twenty-two groups and fifty classes. Because it would be too complicated to apply our methodological approach of scoring datasets according to the provision potential of each ES using fifty classes, we modified the classification. We used the group level as a starting point but when necessary, we merged some groups and broke some others into class levels to make the classification apprehensible and workable for scoring. The final ES classification used in our research is presented in Table 1.

Selection and compilation of GIS datasets

GI has two main functions: (1) it should protect valuable nature areas and therewith biodiversity, and (2) it should safeguard and enhance ES provision for the benefit of people. Therefore, our method is based on using areas of high nature value (HNV) as core areas around which other relevant parts of GI from ES's point of view are founded on. Land cover and land use types support the provision of ES differently (see e.g. Burkhard et al. 2009) but in order to get a deeper insight into the ES provision potential of areas knowledge about the general land cover and land use is not sufficient. For instance, the class of "water bodies" provides several ES but in reality various qualities of water bodies determine the real ES provision potential. To achieve our objective, we combined GIS datasets on recognised valuable nature areas with other spatially explicit data on environmental features or phenomena which presumably affect the capacity of land and water areas to produce ES. A flowchart describing the phases in the application of our method in detail is presented in Fig. 2.

To ensure smooth application of the method and the consistency of the analysis results, we decided on the following criteria for the GIS datasets: (1) data covers the whole study area (preferably nationwide coverage to allow for the comparison of different areas at a later stage), (2) data is available for research purposes either for free or at a reasonable cost, and (3) data is up to date (i.e. it represents the current situation). The Finnish Environment Institute's database includes an extensive supply of data on the environment and nature, which we searched systematically. We compiled a preliminary list of GIS datasets which we identified as relating to the provision potential of ES and meeting the above-mentioned criteria. The list was completed with the help of an invited focus group consisting of researchers and experts working on ES-related issues (Focus group 1 in Fig. 2). Of the thirteen experts invited, six participated in the Focus group 1. They represented following fields of expertise: water quality issues, water infiltration and storm water retention, agriculture and biodiversity, habitats, pollination, and nutrient retention.

At the beginning of the Focus group 1 we presented our methodological approach on assessing GI on the basis of ES provision potential, clarified the concept of ES and the ES classification used, as well as the criteria for selecting GIS datasets. The focus group discussed the required datasets freely for half an hour after which they were asked to agree on the most important missing datasets. The resulting complemented list consisted of 40 GIS datasets. After we had made a final check of the list according to our criteria, we selected 30 datasets which we considered to be representative in describing different aspects of ES provision potential. To avoid double-counting some of the distinct but similar types of datasets were combined under a common theme, e.g. the theme "conservation areas" consists of multiple datasets, such as Natura 2000 sites and nature reserves. As a result, we ended up with 23 themes. The themes and selected datasets are presented in Table 2.

We also consulted the experts on the appropriate pre-processing and data reclassification methods, because some data needed to undergo reclassification in order to be applicable to our approach. For example, the data on the surface water formations of the Water Framework Directive was divided into two themes based on the ecological status (high or good ecological status/moderately poor or bad ecological status).

Some of the datasets had to be generalised due to confidentiality or in order to give the data a spatial extent in case of point and polyline data. In case of confidential data, simply applying a distance buffer is not a sufficient way of generalisation because the centre of the resulting feature can be easily detected in the resulting maps. Therefore, the data on observed sites of endangered species and important forest habitats on private land were generalised to polygons varying in shape, derived from the Finnish national CORINE Land Cover raster. In addition, the features of individual datasets become obscured in our analysis, which involves overlaying several datasets. Point or polyline-shaped data had to be processed to polygons by applying suitable buffers or aggregating the observations into appropriate spatial units. Point data on fish passages was aggregated into the upper reaches of the water system, data on algae blooms into lakes and data on HNV farmlands into field plots they fall within. A 15 m buffer zone was applied to the streams, since they were digitised as polylines in the surface waters data. One dataset left out from the analysis due to difficulties in assessing the areal extent was the point data on mineral extraction sites.

Scoring of themes by experts and regional and local actors

Experts and regional and local actors scored the selected themes according to how favourable or harmful the areas represented by them are in potentially providing each ES (see below for the used scores). Experts also scored the land cover classes (Finnish national CORINE Land Cover raster 2006) based on their capacity to provide the three ES sections: provisioning, regulation and maintenance, and cultural ES.

Two focus groups for scoring were arranged: the first one (Focus group 2 in Fig. 2) for experts in Helsinki in October 2012 and the second (Focus group 3 in Fig. 2) for local and regional actors of the case study area in Tampere in November 2012. The Focus group 2 was the same that was used in forming the list of the most important GIS datasets (see above). From the local and regional level we wanted to target major actors involved in natural resource and environmental management, land use planning, and non-governmental nature conservation organisations. The major organisations carrying out these tasks comprise regional councils, municipalities, regional Centres for Economic Development, Transport and the Environment, the Forest Service, and nature conservation and environmental associations. Altogether, twenty-four local and regional individuals were invited to the Focus

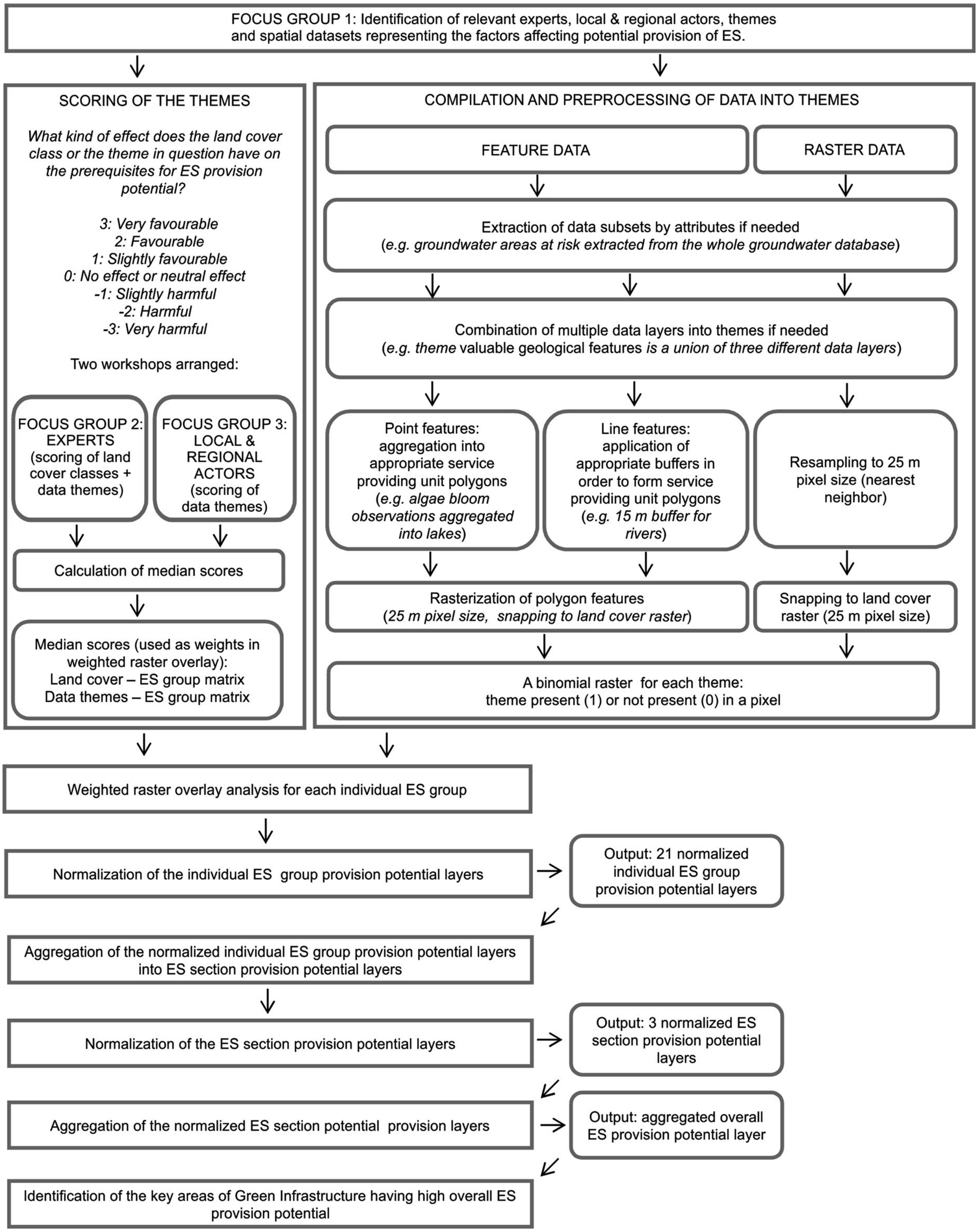


Fig. 2 A flowchart presenting the phases of method application

Table 2 List of GIS datasets grouped into themes

	Theme	Dataset	Type	Year
1.	Conservation areas	1.1 Natura 2000 areas	Polygon vector	2012[a]
		1.2 Nature reserves on public and private land, founded based on Nature Conservation Act	Polygon vector	2012[a]
		1.3 Nature conservation program areas	Polygon vector	2010
		1.4 Forest Service's property reserved for conservation purposes	Polygon vector	2012[a]
		1.5 Conservation areas of regional plans	Polygon vector	2012[a]
2.	Observed sites of endangered species	2. TAXON database on endangered species	Point vector	2012[a]
3.	Important bird areas (IBA)	3. Important bird areas (IBA)	Polygon vector	2010
4.	Valuable landscapes	4.1 Nationally significant landscapes	Polygon vector	2010
		4.2 Regionally significant landscapes: National database on regional plans	Polygon vector	2012[a]
5.	Valuable geological features	5.1 Nationally significant bedrock outcrops	Polygon vector	2012
		5.2 Nationally significant moraine landforms	Polygon vector	2008
		5.3 Nationally significant windblown and shore deposits	Polygon vector	2012
6.	Old forests (age ≥120 years)	6. Multi-source National Forest Inventory	Raster	2012
7.	Important forest habitats	7. Habitats of special importance according to Forest Act	Polygon vector	2012[a]
8.	Undrained peatlands	8. Draining status of peatlands	Raster	2011
9.	National hiking areas	9. VIRGIS database on outdoor recreation opportunities	Polygon vector	2009
10.	Regional recreation areas	10. National database on regional plans	Polygon vector	2012[a]
11.	National urban parks	11. National urban parks	Polygon vector	2012[a]
12.	Urban green areas	12. Corine Land Cover 2006 (Finnish National Raster)	Raster	2008
13.	Discontinuous urban fabric	13. Corine Land Cover 2006 (Finnish National Raster)	Raster	2008
14.	HNV farmlands	14. HNV farmlands	Point vector	2008
15.	Traditional agricultural biotopes	15. Traditional agricultural biotopes	Polygon vector	2005–2012
16.	Surface waters of high or good ecological status	16. Surface water formations of the Water Framework Directive, first planning term (2010–2015)	Polygon vector	2010
17.	Groundwater areas	17. Groundwater areas	Polygon vector	2012[a]
18.	Fish passages	18. Database on hydraulic engineering	Point vector	2012[a]
19.	Peat extraction sites	19. Draining status of peatlands	Raster	2011
20.	Sealed surfaces	20. Urban Layer	Raster	2007
21.	Surface waters of moderate, poor or bad ecological status	21. Surface water formations of the Water Framework Directive, first planning term (2010–2015)	Polygon vector	2010
22.	Sites of frequent algae bloom observations	22. National algal bloom monitoring database	Table	2012[a]
23.	Groundwater areas at risk	23. Groundwater areas	Polygon vector	2012[a]

[a] Data is updated regularly

group 3, seven of which participated in it. Each invited organisational level, although not every organisation, was represented in the workshop. Municipalities were represented by the cities of Tampere (Sustainable Community Unit and City Planning Services) and Valkeakoski (Green Areas Division of Public Space Construction and Maintenance). Not all the invited individuals were able to attend due to other commitments.

The Focus groups 2 and 3 started their work with a presentation in which the concepts of GI and ES were explained. In the case of ES, the combination of presenting ES cascade (a model presenting the relationship between biodiversity, ecosystem function and human wellbeing; Haines-Young 2011) together with our modified CICES classification with concrete examples was appropriate because it clarified the connection between ecosystem structures and processes with the actual service. This is important when assessing the spatial units providing various ES. After presenting the task, the respondents performed the scoring individually without discussing with each other.

> The available scores for assessing the effect of each theme on the prerequisites for the provision potential of each ES group were:
> 3 = Very favourable
> 2 = Favourable
> 1 = Slightly favourable
> 0 = No effect or neutral effect
> −1 = Slightly harmful
> −2 = Harmful
> −3 = Very harmful

Respondents were advised to give a score of 0 if they saw no connection between the theme and the provision potential of the ES group in question, and to draw a line if they could not conclude the relationship between the two.

Processing and analysis of GIS datasets and given scores

The given scores were compiled into a matrix of themes and ES groups. If a respondent differed in his or her scoring considerably from the others, he or she was contacted afterwards and we checked if the task was understood correctly; if it was not, the respondent had an opportunity to do the scoring anew. One local stakeholder took the opportunity to rescore. The median number of given scores was used as a measure of relevance for the ES provision potential. The resulting medians were applied as coefficients in weighted raster overlay analysis carried out in ESRI® ArcGIS 9.3.1 software using the *Raster calculator* tool. Thus, if a given theme was deemed having a neutral effect or no effect at all on the provision potential of a given ES group (i.e. it obtained zero as its median value), it was not included in the analysis. First each individual ES group was analysed, resulting in 21 output raster surfaces depicting their provision potential. The cell values of the raster surfaces were normalised between 0 and 1 and aggregated into three ES section raster layers. The normalisation was carried out in order to treat each ES group as equally important when aggregating them into ES section provision potential raster layers. Without the normalisation, some ES groups would be weighted more than others due to the greater number of themes deemed favourable for their provision potential. Before aggregating the three ES section raster layers into the total ES provision potential raster layers, they were also normalised in order to give them equal importance.

Assessment of the contribution of experts and regional and local actors

The three focus groups were arranged to get input to dataset selection and to make use of both expert and local actor knowledge related to ES provision potential of different areas. The discussions in focus groups were systematically recorded and subsequently transcribed. The transcripts were qualitatively analysed to find out how interaction with experts and local and regional actors impacted method development. The following aspects were analysed:

- Was integration of expert knowledge into the selection of datasets beneficial?
- What did we learn from involving experts and local and regional actors in the scoring exercise?

Results

Integration of expert knowledge into dataset selection

Involving experts in the data selection phase supported the identification of the most appropriate data for our purpose. To begin with, there are many datasets which are not yet available in any public database, but which can be obtained from their authors. Such data is usually produced in specific research projects, often in cooperation with other organisations and is updated more or less regularly. Among these were the data on HNV farmlands and the data on the traditional agricultural biotopes, which complements the HNV data.

Experts also pointed out publicly available complementary datasets important for assessing ES provision potential, such as the hydraulic engineering database which includes data on both harmful and beneficial structures to fish movement and on the restoration of waterways, thus improving their condition. The experts also gave valuable advice and information on who to contact and where to acquire the data they recognised as relevant but which is not freely available. An example of such datasets was habitats of special importance, as set out in the Forest Act, located in privately-owned forests.

Experts' views were especially valuable in assessing the credibility and quality of available datasets. This is indispensable "silent" information, which is not necessarily included in the metadata of the datasets. Experts know how the datasets are updated, what is their real coverage, what problems and deficiencies there are in the data, which datasets are overlapping and which one of the overlapping datasets is the best for each purpose (e.g. IBA areas versus national protection areas of birds), what issues have to be taken into account when using the datasets (e.g. the implementation level of conservation areas), and what is the proper interpretation of specific terminology in the datasets.

When identifying the best areas for provisioning ES purely from the production point of view, quantitative data on the actual or potential production is useful. From the sustainable ES provision potential point of view, quantitative data should be complemented by datasets that represent better management practices of economically used land, for example on farming practices that enhance safeguarding farmland-related biodiversity. Expert knowledge helped us to sort out the best datasets for that purpose, as not all information on the management practices is equally useful. For example, the data on the certification status of commercial forests was excluded from the analysis, as nearly all commercial forests in Finland have been certified. Therefore, using the data would not have provided any added value in our analysis.

Participatory assessment of ES provision potential

Participants of Focus groups 2 and 3 saw the task of scoring themes based on provision potential of the whole spectrum of ES groups very interesting, but at the same time rather demanding because no one is an expert in everything. They took the task seriously and our challenge was to guide them to avoid thinking about overly complicated interrelationships and far-reaching indirect consequences. In cases of concurrent good potential for e.g. provisioning services and sensitive natural values represented by specific themes, our methodological approach visualises overlapping contradictory high potentials, which makes a basis for discussion in a real-world planning situation.

After the Focus group 1, we dropped three ES groups due to difficulties in defining which areas can act as service providing units for them. These groups were (1) bioremediation, (2) biogeochemical processes, filtration, sequestration, and (3) biological regulation. Filtration was seen as a notable ES, and therefore the difficulty in assessing the potential capacity of different areas to provide for filtration was a surprise even to the experts. Including these ES groups in our methodological approach needs further study.

We learned from the focus groups that although most of the themes were familiar and understandable, some themes had to be explained even more clearly. Such themes were groundwater areas at risk and sealed surfaces. For example, sealed surfaces are areas where water cannot penetrate into the soil but some participants thought they were areas where no vegetation can grow. Sometimes customary management practices make it difficult to interpret which are natural and which are cultivated products. For example, when assessing the provision potential of aquaculture products, some participants contemplated whether stocked fish should be regarded as produced or wild. Here we made a distinction between freely moving fish and those growing up in fish hatchery. Fish are often stocked to compensate for lost opportunities of spawning. Only one theme, the water construction sites, had to be removed because of substantial inconsistencies in scores given to it.

ES provision potential according to scored themes

Median scores were used in order to obtain a plausible measure of central tendency as the scores were given on a relative scale, the sample was relatively limited ($n = 14$) and the distributions of the scores were occasionally skewed.

Based on the median scores given by the respondents, the used themes were considered to have most relevance in assessing the provision potential of cultural ES (Table 3). In 8.7 % of the matrix cells dealing with cultural ES the median score was zero. The themes were least relevant in assessing provisioning services (64.1 % of the cells obtained zero as the median value). For regulation and maintenance services, the median was zero in 23.7 % of the cells.

Habitat and gene pool protection was the only ES group to obtain a non-zero score for all 23 themes, i.e. all themes were perceived to have an impact on the provision potential of the ES group in question. The 23 selected themes proved to be most insufficient in assessing the provision potential of the provisioning service groups of aquaculture products and biomass based energy, as only 17.4 % of the cells considering them obtained a score other than zero.

Some themes were found to be more suitable in assessing the ES provision potential than others. Peat extraction sites were perceived to have an impact on the provision potential of almost all ES groups (95.2 %). On the other hand, ground water areas at risk were deemed to have an impact on only 23.8 % of the ES groups.

ES provision potential maps were produced based on the matrix. Synthesis maps of provisioning, regulation and maintenance, and cultural ES, as well as all ES sections together are presented in Fig. 3.

Discussion

The results of this study indicated that our approach can provide a useful tool for assessing ES provision potential over a landscape. By involving expert knowledge, the assessment has a robust foundation. It yields a holistic view on all ES groups taking into account the local and regional actors' perspectives. Because it is a transparent method in a way that all score matrices and map layers based on them can be examined both together and separately, the assessments behind the results can always be tracked back.

One of the major benefits of our approach comes as a by-product of applying focus groups: they offer a platform for discussion and a sharing of understanding of GI and ES. Both experts and local and regional actors regarded the exercise as very fruitful and widening their conceptions of the functions and services provided by GI. Land use planning in practice is about resolving conflicting targets and our method provides one solution to help that process.

However, the results also highlighted issues that have to be taken into account in further applications and development of our method. These will be discussed next.

The first challenge relates to ES. The variety of ES is so wide that no one can be an expert in all of them. Therefore, the applied classification of ES has to be explained thoroughly to the focus groups to avoid differing interpretations. We got valuable information from our focus group participants for further refinement of the classification.

Secondly, the use of a wide range of datasets needs attention. The expert focus group should represent diverse knowledge on all ES sections, including also "non-ecological" experts familiar with other prerequisites than purely ecological conditions for ES provision potential. This helps in identifying all relevant datasets. Dataset selection is also reliant on scale. National datasets are an important starting point but when applying the methodology at a finer scale, the applied datasets also need to be more detailed. In a real-world planning situation, local and regional authorities, such as regional councils, municipal planners and environmental experts, have a crucial role in the data selection phase, owing to their wide knowledge on the availability and quality of local and regional data.

We wanted to cover both land and water areas in our approach. The results showed that there are fewer themes and datasets covering aquatic habitats than terrestrial ones. This data therefore tends to be overemphasised in our analysis, as in the case of the ecological status of the surface waters and observations of algae blooms. Analysing terrestrial and aquatic areas separately could yield more reliable results.

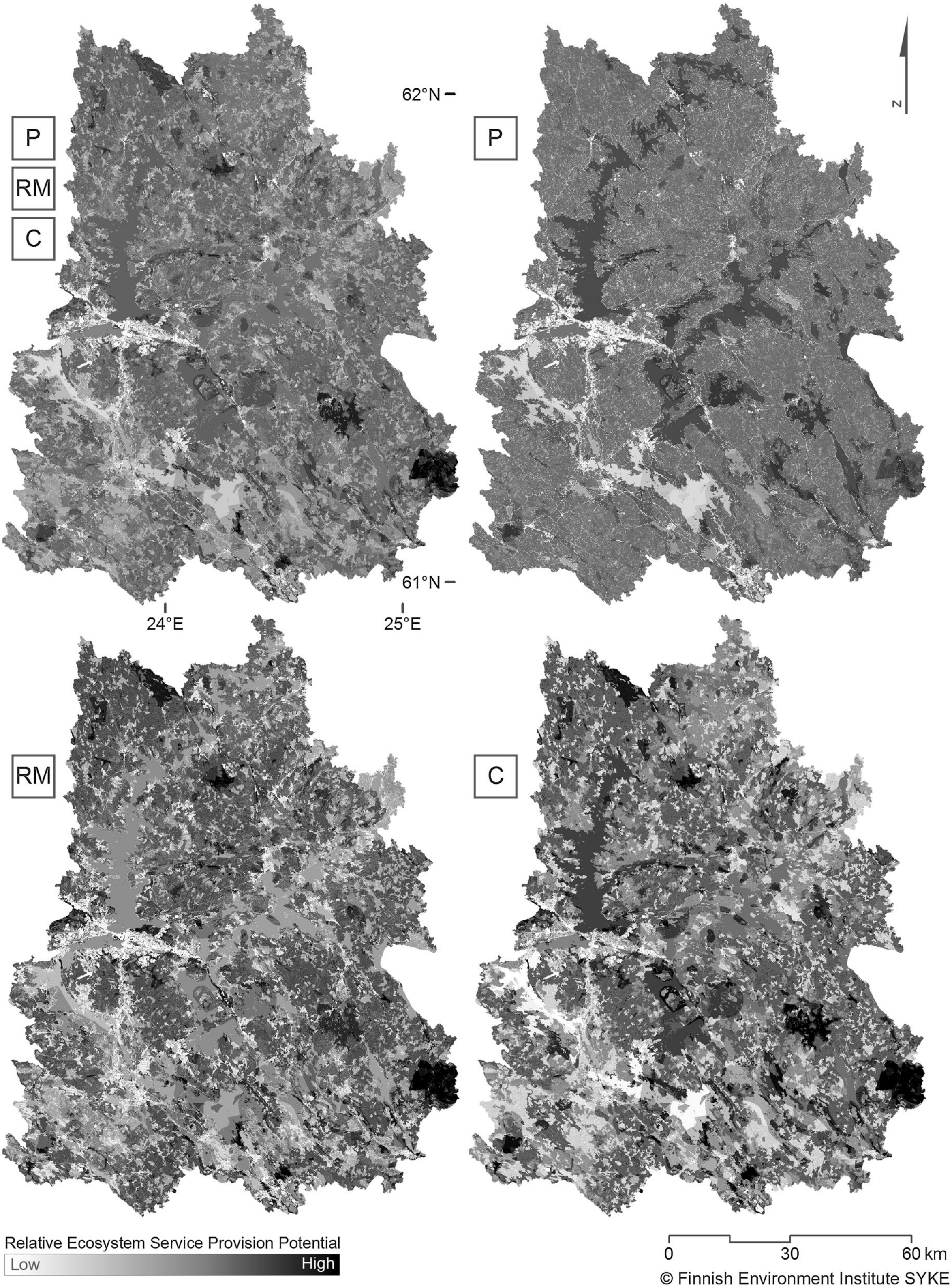
Another issue that requires attention when using a large number of datasets is the possibly long period needed to gather them. Retrieving confidential data might require formal procedures and signed contracts,

Table 3 Median scores matrix representing the relevance of the themes to the provision potential of ES groups. See Table 1 for the ES group codes. The scores presented here were used as coefficients in weighted raster overlay analysis (map algebra) in order to produce provision potential rasters for each ES group

	ES GROUP CODE																				
THEME	P1	P2	P3	P4	P5	P6	P7	P8	RM1	RM2	RM3	RM4	RM5	RM6	RM7	RM8	RM9	C1	C2	C3	C4
1. CONSERVATION AREAS	0	1	1	0	1	0	0	0	1	1	1	3	2	1	1	2	3	3	2	3	3
2. OBSERVED SITES OF ENDANGERED SPECIES	0	0	0	0	0	0	0	0	0	0	0	1	0	0.5	0.5	1	3	1	1	2	3
3. IMPORTANT BIRD AREAS (IBA)	0	1	1	0	0	0	0	0	0	1	0.5	1	1	2	1	1	3	2	2	2	3
4. VALUABLE LANDSCAPES	2	1	0	0	0	0	0	1	0.5	1	1	1	0.5	1	1	2	2	3	1	2	2
5. VALUABLE GEOLOGICAL FEATURES	0	1	0	0	2	0	0	0	1	1	1	0.5	0.5	1	1	0	3	3	2	3	3
6. OLD FORESTS (AGE ≥ 120 YEARS)	0	2	0	0	0	0	0	0	2	1	1	3	2	1	2.5	1	3	3	3	3	3
7. IMPORTANT FOREST HABITATS	0	2	0	0	0	0	0.5	0	1.5	2	1	2	2	1.5	1	2	3	2	2.5	2	2.5
8. UNDRAINED PEATLANDS	0	2.5	0	0	0	0	0.5	0	0	3	0	3	2	3	2.5	2	3	3	3	3	3
9. NATIONAL HIKING AREAS	0	3	2	0	0	0	1	0	1	1	1	2	1	1	1	1	1.5	2	3	3	2
10. RECREATION AREAS OF REGIONAL PLANS	0	1	1	0	0	0	0	0	1	1	1	2	1	1	1	1	1	2	2	3	1
11. NATIONAL URBAN PARKS	0	1	1	0	0	0	0	0	1	1	1	2	2	1	1	2	1.5	3	1	2	2
12. URBAN GREEN AREAS	0	1	0	0	0	0	0	0	1.5	1	1	2	2	1	1	1	1	2	1	2	1
13. DISCONTINUOUS URBAN FABRIC	1	0	0	0	0	0	0	0	1.5	1	1	1	1	1	0.5	2	1	1	0	0.5	0
14. HIGH NATURE VALUE FARMLANDS	3	1	0	0	0	0	1	1	1	0	1	1	1	1	2	3	3	3	1	1.5	2
15. TRADITIONAL AGRICULTURAL BIOTOPES	2	1	0	0	0	0	1	0	1	0	1	1	1	0.5	2	3	3	3	1	2	3
16. SURFACE WATERS OF HIGH OR GOOD ECOLOGICAL STATUS	0	0	3	2	3	2	0	0	0	0	0	0	0	0	0	0	2	2	3	2	2
17. GROUNDWATER AREAS	0	0	0	0	3	3	0	0	0	2	0.5	0.5	0	1	1.5	0	1	0	0	1	2
18. FISH PASSAGES	0	0	3	1	0	0.5	0	0	0	2	0.5	0	0	1	0	0	2	2	3	3	2
19. PEAT EXTRACTION SITES	-1	-3	-2.5	0	-1.5	-1	-2	-2	-1	-3	-1	-3	-2	-3	-3	-1.5	-3	-3	-3	-3	-2
20. SEALED SURFACES	-2	-3	0	0	-1	-1	-2	-2	-2	-2	-1	-2	-2	-2	-2.5	-2	-3	-2	-2	-3	0
21. SURFACE WATERS OF MODERATE, POOR OR BAD ECOLOGICAL STATUS	-1	-1.5	-3	-3	-3	-2	0	0	0	0	0	0	0	-2	0	0	-2	-1	-2.5	-3	-1
22. SITES OF FREQUENT ALGAE BLOOM OBSERVATIONS	0	0	-3	-2	-3	-2	0	0	0	0	0	0	0	0	0	0	-2	-3	-3	-3	-1
23. GROUNDWATER AREAS AT RISK	0	-1	0	0	-3	-2	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0

and it can sometimes last long before the data actually is in use. We retrieved one of the datasets in our case study only after several months of negotiations.

The third challenge is how to deal with a large variation in given scores. We inferred from the results that in cases of great variation there is usually a lack of



P
RM
C
62°N
61°N
24°E
25°E
P
N
RM
C
Relative Ecosystem Service Provision Potential
Low
High
0
30
60 km
© Finnish Environment Institute SYKE

◀ **Fig. 3** Aggregated ES provision potential maps of the study area depicting the spatial variation in the provision potential, based on expert scores and GIS data. *Top left* an aggregate of three normalised ES section layers (*P* provisioning services, *RM* regulation and maintenance services, *C* cultural services). *Top right* an aggregate of eight normalised provisioning service layers. *Bottom left* an aggregate of nine normalised regulation and maintenance service layers. *Bottom right* an aggregate of four normalised cultural service layers

knowledge in the background, as well as differences in viewpoint and appreciation. The most striking difference in given scores was between experts working with built environment issues, e.g. having a background in landscape architecture, and those working to safeguard biodiversity, having a background in natural sciences. While it is important to acknowledge the different viewpoints it is also a problem for researchers applying the method to deduce whose scores to rely on when great variation occurs. On the basis of our experience, there seems to be a need for specialised expertise especially in the case of understanding ES in urban settings.

Fourthly, when applying focus groups it is often difficult to get all the invited people to participate. In our case study, the biggest problem was the current hectic pace of work which inhibited about half of the invited people from participating, regardless of several reminders. The composition of the actual focus group has to be kept in mind when analysing the results.

The fifth observation is about the relationship between the ES group and the themes. In some cases it is very difficult to perceive the actual spatial extent of the impact of the theme on specific ES provision potential. For example, assessing the extent of the area which is affected by structures both prohibiting movement of fish (e.g. dams) and easing the movement (e.g. fish ladders) was problematic. How far upstream or downstream does the area of influence stretch? Another example was peat extraction, which may have adverse effects on the quality of surface waters downstream, thus reducing their capacity to provide many ES.

As the sixth discussion point, we bring out the normalisation of ES groups inside the ES sections as well as ES sections themselves. In our case study it was the appropriate way to process the scores because we wanted to give equal importance to all ES. However, depending on the premises of the analysis there are also other solutions, if more weight is given to some ES groups due to place-specific planning targets, for example. This needs further study.

Conclusion

The method applied here allows for the relatively rapid acquisition of an overall picture of the multifunctional key areas of GI having the highest provision potential of multiple ES within a study area. The analysed ES groups can be examined either individually or in desired combinations in order to support decision-making and land use planning. Like Burkhard et al. (2012), we acknowledge that results based on expert evaluations can be complemented with quantitative assessments of ES, if available. Complementary quantitative analyses on provisioning services would undoubtedly benefit the result. Although there is spatial data on various provisioning services, such as the estimated timber volume, the data on many provisioning services is scarce or its spatial resolution is too coarse for regional assessments. When it comes to assessing intangible regulation and maintenance, and cultural services, suitable quantitative data is even more difficult to find. Carrying out detailed quantitative assessments of all the individual ES is a time-consuming and expensive task and therefore usually unfeasible in a tightly scheduled land use planning process. Thus, in our opinion, more easily adoptable semi-quantitative expert evaluation-based methods can bring added value to decision-making and land use planning.

This paper only covers the very first steps in developing an easily accessible tool utilising expert scores and a host of GIS data in assessing GI based on ES provision potential. We acknowledge that there is plenty of room for improvements and further refinements in the proposed methodology. In the current stage, our method helps in framing areas based on ES provision potential, hence the name GreenFrame. Other necessary aspects to be examined, and also to be included in our GreenFrame method in the future, entail firstly the actual ES provision, i.e. the portion of ES provision potential actually consumed or possible to consume, taking into account the flow of ES between areas (c.f. fruition used in relation to recreational ES in Maes et al. 2012). Secondly, both the potential and the actual demand for ES require attention. The potential demand for ES can be defined by the number and location of potential users or beneficiaries of ES in the research area. This relates to potential pressure of use as well. Actual demand for ES can be assessed only through user surveys (use of such data see e.g. Lankia et al. 2012), interviews, or by using participatory data collection methods (Raymond et al. 2009; Brown et al. 2011; Kyttä and Kahila 2011; Kyttä et al. 2013). The integration of all of these aspects into GI-focused land use planning is a vast challenge. In order to tackle the challenge, more close cooperation is required – not only with the land use planners and other practitioners, but also with researchers from various disciplines.

Acknowledgments We would like to acknowledge the Ministry of Environment in Finland for funding our research, and all the experts and local and regional actors that have given their valuable time for the benefit of the GreenFrame method development. We also want to thank the anonymous reviewers for their very constructive comments on the manuscript.

References

Ahern J, Cilliers S, Niemelä J (2014) The concept of ecosystem services in adaptive urban planning and design: encouraging transdisciplinarity. Landscape and Urban Planning. http://dx.doi.org/10.1016/j.landurbplan.2013.07.014

Brown G, Montag JM, Lyon K (2011) Public participation GIS: a method for identifying ecosystem services. Soc Nat Resour 0:1–19

Burkhard B, Kroll F, Müller F, Windhorst W (2009) Landscapes capacities to provide ecosystem services: a concept for land-cover based assessments. Landsc Online 15:1–22

Burkhard B, Kroll F, Nedkov S, Müller F (2012) Mapping ecosystem service supply, demand and budgets. Ecol Ind 21:17–29

Calabrese JM, Fagan WF (2004) A comparison-shopper's guide to connectivity metrics. Front Ecol Environ 2(10):529–536

Egoh B, Reyers B, Rouget M, Richardson DM, Le Maitre DC, van Jaarsveld AS (2008) Mapping ecosystem services for planning and management. Agric Ecosyst Environ 127: 135–140

Egoh B, Drakou EG, Dunbar MB, Maes J, Willemen L (2012) Indicators for mapping ecosystem services: a review. JRC Scientific and Policy Reports. Publications Office of the European Union, Luxembourg

Frank S, Fürst C, Koschke L, Makeschin F (2012) A contribution towards a transfer of the ecosystem service concept to landscape planning using landscape metrics. Ecol Ind 21:30–38

Frank S, Fürst C, Koschke L, Witt A, Makeschin F (2013) Assessment of landscape aesthetics: validation of a landscape metrics-based assessment by visual estimation of the scenic beauty. Ecol Ind 32:222–231

Girvetz EH, Thorne JH, Berry AM, Jaeger JAG (2008) Integration of landscape fragmentation analysis into regional planning: a statewide multi-scale case study from California, USA. Landsc Urban Plan 86(3–4):205–218

Haines-Young R (2011) Exploring ecosystem service issues across diverse knowledge domains using Bayesian Belief Networks. Prog Phys Geogr 35(5):681–699

Haines-Young R, Potschin M (2013) Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August–December 2012. EEA Framework Contract No EEA/IEA/09/003

Jaeger JAG, Bertiller R, Schwick C (2008) Implementing landscape fragmentation as an indicator in the Swiss Monitoring System of Sustainable Development (MONET). J Environ Manag 88(4):737–751

Kuttner M, Hainz-Renetzeder C, Hermann A, Wrbka T (2012) Borders without barriers: structural functionality and green infrastructure in the Austrian–Hungarian transboundary region of Lake Neusiedl. Ecol Ind 31:59–72

Kyttä M, Kahila M (2011) SoftGIS methodology: building bridges in urban planning. GIM Int 25(3):37–41

Kyttä M, Broberg A, Tzoulas T, Snabb K (2013) Towards contextually sensitive urban densification: location-based softGIS knowledge revealing perceived residential environmental quality. Landsc Urban Plan 113:30–46

LaFortezza R, Davies C, Sanesi G, Konijnendijk C (2012) Green infrastructure as a tool to support spatial planning in European urban regions. iForest 6:102–108

Lankia T, Kopperoinen L, Pouta E, Neuvonen M (2012) Mapping outdoor recreation benefits in Finland using national inventory data. In: Fredman P, Stenseke M, Liljendahl H, Mossing A, Laven D (eds) Proceedings of the 6th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas. Outdoor Recreation in Change: Current Knowledge and Future Challenges, Stockholm, Sweden, August 21–24, 2012

Larondelle N, Haase D (2013) Urban ecosystem services assessment along a rural-urban gradient: a cross-analysis of European cities. Ecol Ind 29:179–190

Maes J, Hauck J, Paracchini M et al. (2012) A spatial assessment of ecosystem services in Europe: methods, case studies and policy analysis-phase 2. Full report. Partnership for European Environmental Research, Ispra

Minor ES, Urban DL (2008) A graph-theory framework for evaluating landscape connectivity and conservation planning. Conserv Biol 22(2):297–307

Naidoo R, Balmford A, Costanza R et al (2008) Global mapping of ecosystem services and conservation priorities. Proc Natl Acad Sci 105(28):9495–9500

Naumann S, McKenna D, Kaphengst T (2011) Design, implementation and cost elements of Green Infrastructure projects. Final report to the European Commission, DG Environment, Contract no. 070307/2010/577182/ETU/F.1. Ecologic institute and GHK Consulting

Pauleit S, Breuste JH (2011) Land-use and surface-cover as urban ecological indicators. In: Niemelä J (ed) Urban ecology: patterns, processes, and applications. Oxford University Press, Oxford, pp 19–30

Raymond CM, Bryan BA, Hatton MacDonald D et al (2009) Mapping community values for natural capital and ecosystem services. Ecol Econ 68:1301–1315

Söderman T, Kopperoinen L, Yli-Pelkonen V, Shemeikka P (2012) Ecosystem services criteria for sustainable development in urban regions. J Environ Assess Policy Manag 14(2):1250008-1–1250008-48

Vihervaara P, Kumpula T, Ruokolainen A, Tanskanen A, Burkhard B (2012) The use of detailed biotope data for linking biodiversity with ecosystem services in Finland. Int J Biodivers Sci Ecosyst Serv Manag 8(1–2):169–185

Vogt P, Ferrari JR, Lookingbill TR, Gardner RH, Riitters KH, Ostapowicz K (2009) Mapping functional connectivity. Ecol Ind 9(1):64–71