METHOD FACTSHEET

ADVANCED MATRIX APPROACH (GREENFRAME)

Introduction

Matrix Approaches are quick and simple ways to get an overall spatially-explicit picture of the ES in case study areas. The method is based on the idea of linking tabular spreadsheet data and spatial data together, i.e. joining external datasets to spatial units to create maps. The spreadsheet format data can be collected, for example, as expert evaluation or constructed from indicators or statistics. Simple application of the approach typically involves land use or land cover (LULC) datasets, although other datasets can be used.

An advanced version of the matrix method has been suggested to improve representation of the transdisciplinary issues that are often related with ES studies (Jacobs et al. 2015). A modified, transdisciplinary version of the spreadsheet-type method is GreenFrame, which uses an extensive set of spatial datasets grouped into themes (instead of using solely LULC data) combined with both scientific experts' and local actors' scorings (Kopperoinen et al. 2014). The method was developed to assess spatial variation in ES provision potential of green infrastructure in spatial planning.

This document details the ***Advanced Matrix Approach***. To get an understanding of the methodology on which this builds it may help to read the "*Simple Matrix Approach*" factsheet prior to this.

Keywords

GIS, ecosystem services, spreadsheets, matrix, expert scoring, stakeholder engagement, semi-quantitative methods.

Why would I chose this approach?

The advanced matrix approach adds two additional advantages to the main advantages of the simple approach. The advantages of the simple matrix approach are:

1) To get a quick overview of the potential supply of, demand for and budgets of ecosystem services.
Burkhard et al. (2012) used spreadsheets for creating a scored ES reclassification table (also often called an expert knowledge table) which was coupled with the CORINE Land cover (CLC) database to produce ES supply, demand and budgets maps. By linking expert evaluation of the ability of each LULC class to supply ES as well as the demand for various ES within the same LULC classes, overview maps of both supply and demand were quickly derived. When supply and demand were calculated together, budgets were created.

2) To detect possible areas of conflict where multiple land use interests or needs for biodiversity conservation exist.

A spatially-explicit ES mapping exercise can be used for detecting possible areas of conflict where multiple land use interests or needs for biodiversity conservation exist (e.g. Vihervaara et al. 2010; 2012). In addition, optimising multiple ES and conservation needs is possible. Potentially relevant biodiversity datasets include for example EUNIS (e.g. Natura 2000 habitats), agricultural parcels (e.g. grasslands, pastures) and multi-source forest inventories. In general, ES assessments can be extended by using additional datasets related to land cover types, such as statistics (e.g. Kandziora et al. 2013), modelled data (e.g. Nedkov & Burkhard 2012) or monitoring data (Baral et al. 2013).

The advanced matrix approach brings the following additional advantages:

3) To help spatial planning in assessing green infrastructure based on ES supply and demand.
By using GreenFrame it is possible to get a more comprehensive map of the spatial variation in ES provision potential of green infrastructure. This helps to identify the key areas of green infrastructure in spatial planning (see procedure in Itkonen et al. 2015). Coupled with spatial assessment of potential and actual ES demand, as well as the connectivity of green infrastructure, spatial planners obtain valuable information on what type of ecological and social values are attached to different areas and are better informed for making decisions of land allocation for different purposes.

4) To engage stakeholders and local and regional actors in decision-making, to enhance joint understanding and to raise awareness of the various benefits that nature provides to us.
GreenFrame, which involves focus groups and the active involvement of local and regional stakeholders, raises awareness of the benefits of the ES approach. To enable the scoring of different data themes based on whether they are likely to positively or negatively affect ES provision potential, the concept of ES, content of the spatial datasets and the principles of scoring must be presented and explained in detail. In addition, by bringing stakeholders (local and regional actors) around the same table for discussion, different viewpoints are shared and common understanding is usually enhanced. The process itself can be as important as the maps resulting from the analyses when applying GreenFrame.

What are the main advantages of the approach?

- Relatively easy and fast to perform;
- Draws on existing data, can handle missing data, and expert knowledge can be included;
- Basic knowledge of spreadsheets and GIS is usually enough;
- **(Advanced) Takes also into account features that reduce the provision potential;**
- Open source software can be used;
- Simultaneous assessment of multiple ES;
- Applicable at different scales: best possible datasets of appropriate resolution need to be used accordingly;
- Naturally an integrative / holistic approach;
- Suitable for transdisciplinary research problems;
- **(Advanced) Useful in a participatory approach with stakeholders;**
- Easily adoptable, transparent and flexible.

What are the constraints/limitations of the approach?

- Availability of the background data might be a restraint;

- If a matrix using LULC data is applied, the data might be too coarse to study small case study areas;
- Data preparation can be quite a long and demanding task when a wide array of spatial datasets is used (GreenFrame);
- Possibly biased answers by the experts;
- Reliability of the results should always be evaluated;
- Wide matrices can be quite exhausting to fill in with scores and loss of concentration can result in errors in scores.

What types of value can the approach help me understand?

The approach can be used for both the supply and demand of ecosystem services. It can provide outputs across all ecosystem service types and represent both biophysical and socio-cultural values. It is not designed to provide information on monetary values.

How does the approach address uncertainty?

Spreadsheet-type methods do not generally address uncertainty explicitly.

How do I apply the approach?

The following steps need to be undertaken to apply the Advanced Matrix method within a case study:

Step 1: What is your problem?

- To identify and spatially locate different elements and key areas of green infrastructure based on the provision potential of ES?
- To aid a land use planning process by identifying the most important areas from the ES point of view?
- To get an overall picture of the ES supply of an area?
- To assess supply of, demand for and flows of ES?
- For detecting possible areas of conflict where multiple land use interests or needs for biodiversity conservation exist?

Step 2: Define the limits / borders of the study area

- The extent of the study area defines what should be taken into account in the analysis.
- If you work with, for example, a land use planning area, that defines what type of spatial datasets are needed.
- To avoid border effects, create a wide enough buffer around the study area and do the analysis using a union of the area and the buffer.

Step 3: Based on your problem

- Identify the set of ES you are targeting in the analysis.
- Decide on the ES classification you want to use. Modify it to fit your case by leaving out non-relevant classes or groups, and leaving out other ES classes or groups that you do not want to examine (but do not forget them).

Step 4: Identify the participants of the first focus group

- People who can help you identify the relevant scientific experts and key local stakeholders or actors to be invited to the scoring focus groups.
- People who can help you identify and locate the best available spatial datasets with regard to the set of ES in focus:
  - The level of detail of spatial datasets depends on the scale of the study area. -> The bigger the area examined, the coarser the scale.
  - Scale and resolution of spatial data matters when choosing datasets for evaluation:
    - National level analysis: a very general overview which should not be zoomed in;
    - Regional level analysis: local details cannot be taken into account;
    - Local level analysis: need for more detailed data;
    - Block / plot level analysis: data on small features, such as individual trees, bushes, green walls, etc., is needed.

Step 5: Arrange the first focus group

- Explain the context of your research and the key concepts carefully and objectively, including green infrastructure and ES with the help of a (simplified) ES classification. It can also be helpful to use the ES cascade to present the ES concept to land use planners, governance and management staff and other actors in an understandable way.
- Facilitate a discussion on:
  - Identification of relevant scientific experts (people attending the focus group can belong to them!).
  - Identification of local and regional experts if applicable.
  - The best existing spatial datasets (type, content, collected by whom, spatial extent, quality, update period, consistency, availability, administrator).

Step 6a: Compilation and preprocessing of data

- Collect the spatial datasets taking into account costs, individual researcher's 'property', privacy questions (e.g. socio-economic data) and dataset sensitivity (e.g. threatened species, valuable natural features in private land).
- Examine the extent and quality of the spatial data (does it cover the whole study area, is it available at reasonable cost for research purposes, is it up-to-date, is it of good quality, does the resolution of the data match the scale of the case study). Note any shortcomings of the data for later use and understanding. If the quality is good enough, proceed to preprocessing.
- Preprocess the datasets into comparable formats by extracting data subsets (e.g. groundwater areas of good quality) and combining different data layers into themes (see**Error! Reference source not found.**). Data may need to be converted from feature to raster format and the raster layers resampled to a common pixel size to ensure that the raster layers align with each other spatially. Thematic layers are assigned a binary value of 0 or 1 indicating the presence or absence of the theme in a pixel.
- Preprocessing of quantitative datasets:
  - The data layers are converted into continuous raster layers, where the quantities of the original data are rescaled between 0 and 1.
  - As in the case of qualitative data, pixel value 0 represents the lowest, and pixel value 1 represents the highest provision potential within the study area.

- Therefore, when quantitative datasets are available it is useful to denote pixels outside 'service providing units' as 0 and rescale the quantities of the service providing areas between e.g. 0.5 and 1 (the lowest value depends on how low the quantity is in regard to the highest value).

Step 6b: Scoring of the themes affecting ES provision potential

- The data themes are assessed in focus groups where participants assess the effect of each theme on the provision potential of each ES group and score the themes accordingly. The relevance of the themes to the provision potential of ES is summarized as median scores. Each theme has to be considered in relation to each ES group, because all themes are not equally relevant for all ES.
- This done by asking 'what effect does the theme in question have on the prerequisites of ES provision potential? For example, does the presence of a conservation area have a favourable or harmful effect on the ES 'Habitat and gene pool protection'? If the effect is favourable, the effect is scored as: very favourable (3); favourable (2); or slightly favourable (1). If the effect is neutral or the theme is irrelevant for the specific ES, a score of zero (0) is given. If the effect is harmful, the effect is scored as: slightly harmful (-1); harmful (-2); or very harmful (-3). Respondents are also allowed to respond as 'I don't know'. An example scoring is given in ~~the~~ Table 1 below.

Table 1. Example of scoring of data themes on ecosystem service provision

DATA THEME	ES GROUP CODE																				
	P1	P2	P3	P4	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	C1	C2	C3	C4	C5
1. Conservation areas	0	2	2	2	0	1	2	3	2	2	3	2	2	2.5	2	2.5	3	3	2	3	3
2. Valuable landscapes	3	1.5	1	1	1	2	1	1	1	2	2	1	1	1	0	1	2	2	3	2	2
3. Valuable cultural heritage environments	2	1	0	1	0	1	1	1	0	2	1	1	1	1	0	1	3	1.5	3	2	2
4. Traditional agricultural biotopes	2	2	0	1	0	1	1	1	1	3	3	1	2	1	0	1	2	2	3	2	3
5. Important forest habitats	0	2	1.5	1.5	1	1	1	2	1	2	3	1	2	2	1	1	2	3	2	2	3
6. Undrained peatlands	0	2	2	2	1	0	1	3	1	1	3	1	2	2.5	1	2	2	3	2	3	3
7. Important bird areas	0	1	0	1	1	1	1	1	0	1	3	1	1	1	0	1	2	3	2	2	3
8. Valuable geological features	0	1	3	2	1	2	1.5	2	1	1	1	1	2	3	0	1	2	2	2	2	3
9. Groundwater areas	0	1	3	3	0	1	1	3	1	1	1	0	2	3	0	1	1	1	1	1	2
10. High Nature Value farmlands	3	1	0	0	0	1	1	1	0	2	2	1	1	1	0	1	2	2	2	2	2
11. Good and continuous agricultural areas	3	2	0	0	1	1	0	0	0	1	0	0	1	0	0	1	0	1	2	0	0
12. Surface waters of high or good ecological status	0	2	3	3	0	0	0	2	0	0	3	2	0	3	0	0	3	3	2	2	3
13. Surface waters with low or very low level of human-induced alterations	0	2	2	3	0	0	0	2	0	0	2	1	0	3	0	0	2	2	2	2	3
14. Regional recreation areas	1	2	1	1	0	2	1	1	1	1	1	1	1	1	0	1	3	2	2	2	2
15. Groundwater areas at risk	-2	-1	-3	-2	-3	0	0	-1	0	0	0	0	0	-3	0	0	0	0	0	0	-1
16. Sealed surfaces	-3	-3	-3	-3	-2	-1	-2	-3	-2	-2	-3	-1	-3	-2	-1	-2	-3	-3	-3	-3	-3
17. Land extraction sites	-2	-3	-2	-2	-2	-3	-2	-2	-1	-2	-2	-1	-3	-2	-1	-1	-3	-2	-2	-3	-3
18. Peat extraction sites	-2	-3	-2	-2	-2	-2	-2	-2	-1	-1	-2	-1	-3	-3	-2	-1	-3	-3	-3	-3	-3
19. Surface waters of moderate, poor or bad ecological status	-1	-1	-2	-2	-1	0	0	0	0	0	-1	-1	0	-2	0	0	-2	-1	-2	-2	-2
20. Sites of frequent algal bloom observations	-2	-2	-2	-2	-1	0	0	0	0	0	-1	-1	0	-2	0	0	-2	-1	-2	-2	-2
21. Surface waters with moderate or high level of human-induced alterations	0	-2	-2	-2	-1	0	0	-1	0	0	-1	-1	0	-2	0	0	-2	-2	-2	-2	-2

3: *Very favourable effect*, 2: *Favourable effect*, 1: *Slightly favourable effect*, 0: *No effect / neutral effect*, -1: *Slightly harmful effect*, -2: *Harmful effect*, -3: *Very harmful effect.*

Step 6c: Criteria for summarising the scores

- Unanimous answers: The median value of the answers is used in the summary if all respondents agree upon the direction of the causal relationship between the theme and the ES in question, for example, if all respondents give either a positive value [or zero] or all respondents give a negative value [or zero].
- Slight disagreements: Differing answers are excluded from the summary if less than 20% of the respondents disagree with the majority's opinion of the favourableness or harmfulness of the effect. Slight disagreements might result from misinterpreting the question and concepts involved.
- Clear disagreements: Value zero is used, if over 20% of the respondents disagree with the majority's opinion of the favourableness or harmfulness of the effect. This way the theme in question is interpreted not to have a clear effect on the provisioning potential of the specific ES in the analysis. Clear disagreements might result from a lack of unambiguous understanding of the causal effect between the theme and the ES or from significant complexities / uncertainties related to them.

Step 7: Analysing the spatial variation in ES provision potential using a GIS

- The pre-processed and rescaled quantitative data layers already represent the spatial variation in the provision potential of certain ES within the study area (e.g. groundwater supply, timber volumes of forests). Therefore, using the expert scores and overlaying qualitative data themes is not required to assess these ES.
- For other ES, the spatial variation in the provision potential is assessed using the pre-processed data themes and median scores (weights) obtained from the expert assessments in GIS software. First, each ES group is assessed individually by calculating a weighted sum of the preprocessed binary raster layers. The median scores for each data theme for the given ES are used as weights. Thus, a median score of 0 omits a data theme from the assessment of the ES group in question. The weighting can be implemented for example with the Weighted Sum tool in the Spatial Analyst extention of ArcGIS (version 10.1). The tool allows weights to be assigned to each layer and sums overlaying pixels into an output layer.
- The resulting layers for each ES are rescaled to a range of 0 – 1. In the output, the pixel value 1 represents the area with the highest provision potential for the ES in question, and pixel value 0 represents the lowest provision potential within the study area. A value of 0 does not necessarily indicate that the location has no provision potential for the given ES, but it indicates that within the study region, other locations have greater potential for the provision of this particular service.
- The spatial patterns of each ES section (provisioning, regulating and maintenance, and cultural) can be analysed by summing the results of related ES groups according to the section they belong to, and normalising the results to a common range of 0 – 1. All ES can be included as equally important in the synthesis, or weights can be assigned according to the importance of different layers.
- A full synthesis of the analysed ES can be created by summing up the layers for each ES section and rescaling the resulting values to a range of 0 – 1. An example of such an ES synthesis map is shown in Figure 2.1.7).

Step 8: Visualisation of the results

- Once all desired ES groups are assessed individually and syntheses of different ES sections and all ES are made, the results are ready for visualisation. An intuitive way to present the results is to use a sequential monochromatic color scheme, where areas with highest potential are visualised with darker tones and areas with lower potential are visualized with lighter tones (**Error! Reference source not**

found.). Depending on the distribution of the pixel values, different classifications of the pixel values can be used. Often, but not necessarily always, the pixel values are somewhat normally distributed. In this case, it is good to apply standard deviations stretch or quantile classification of the pixel values.

Step 9: Validation of the results

- After carrying out the analyses, it is recommended to validate the results with stakeholders and/or scientific experts who have expertise on the study area. Among possible methods for obtaining feedback on the results are individual fill-forms, focus group discussions, interviews, and interactive workshops.
- It is advisable to collect the feedback in such a way, that the comments can be attached to specific locations. This enables a more detailed analysis on the factors that affect the results in these locations. An easy way to collect this information is to use hard-copy paper maps and ask the respondents to pinpoint locations where they find the results either plausible or unconvincing / inconsistent etc. The targets can be marked with numbers, and justifications for each pinpointed target can be written down. These paper maps can then be scanned and georeferenced. In order to avoid digitizing paper copy maps, also online map surveys, or for example Google Earth can be used to get the feedback directly in GIS format.

Requirements

Data	☑ Data is available ☑ Need to collect some new data ☑ Need to collect lots of new data	The need to collect new data depends on: (i) the objectives of the case study; (ii) the matrix-type method selected (based solely on LULC or based on a wide variety of spatial datasets as in GreenFrame method); and (iii) on the availability of data from the case study area.
Type of data	☑ Qualitative ☑ Quantitative	Spatially-explicit datasets (vector or raster) and additional information are needed.
Expertise and production of knowledge	☑ Work with researchers within your own field ☑ Work with researchers from other fields ☑ Work with non-academic stakeholders	Basic knowledge in spreadsheets and GIS are needed to conduct the assessment successfully. Facilitating expert evaluations and focus groups needs social and stakeholder engagement skills as well as the ability to clarify the ES concept, ES categories, the content and quality of various spatial datasets, and the scoring task in an understandable and uniform way.
Software	☑ Freely available ☐ Software licence required ☐ Advanced software knowledge required	Any general spreadsheet software (e.g. Excel, Lotus123, Google Spreadsheets) is suitable to collect data in tabular form. Before the data is imported into a GIS programme, the data must be saved to a database IV file (*.dbf) or Excel format (*.xls). The method can be applied using any type of GIS software, licensed (ArcGIS) or open source (GRASS, QGIS, R, etc). The LULC data should be in Shapefile format (*.shp) or a raster image (e.g. *.tiff, *.img), with LULC coding. The GIS software is needed to join the tabular data to the spatial data for the spatial analysis and creating output maps.

Time resources	☑ Short-term (< 1 year) ☑ Medium-term (1-2 years) ☐ Long-term (more than 2 years)	Time and economic resources depend on the availability and accessibility of spatial datasets, on the need for pre-preparing the datasets for analysis, and on the expertise of the researchers and GIS specialists.
Economic resources	☑ < 6 person-months ☑ 6-12 person-months ☐ > 12 person-months	Similar to time resources.
Other requirements	When using GreenFrame, expertise is needed in carrying out focus groups and working together with researchers from other fields as well as with local and regional actors. Basic knowledge of statistics is also needed (understanding variation, mean, median, etc.).	

Where do I go for more information?

Burkhard, B., Kandziora, M., Hou, Y. and F. Müller (2014), 'Ecosystem service potentials, flows and demands–concepts for spatial localization, indication and quantification'. Landscape Online, 34, 1-32.

Burkhard, B., Kroll, F., Nedkov, S. and F. Müller (2012), 'Mapping ecosystem service supply, demand and budgets', Ecological Indicators, 21, 17-29.

Kopperoinen, L., Itkonen, P. and J. Niemelä (2014), 'Using expert knowledge in combining green infrastructure and ecosystem services in land use planning: an insight into a new place-based methodology'. Landscape Ecology, 29 (8), 1361-1375.

Vihervaara, P., Kumpula, T., Ruokolainen, A., Tanskanen, A. & B. Burkhard (2012), 'The use of detailed biotope data for linking biodiversity with ecosystem services in Finland', International Journal of Biodiversity Science, Ecosystem Services & Management, 8 (1-2), 169-185.

Vihervaara, P., Kumpula, T., Tanskanen, A. and B. Burkhard (2010), 'Ecosystem services – A tool for sustainable management of human-environment systems. Case study Finnish Forest Lapland', Ecological Complexity, 7, 410-420.

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