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Comparing Conservation Value Maps and Mapping Methods in a Rural Landscape in Southern Finland

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Appendix. Detailed description of materials and methods

Data and preprocessing

We used the following GIS and remote sensing datasets in mapping habitat types and ecosystem services: two different sets of aerial imagery, an airborne laser scanner (ALS) data from the National Land Survey (NLS) of Finland, 20 m resolution multisource National Forest Inventory (MS-NFI) from the Finnish Forest Research Institute from year 2009 (Tomppo et al., 2013), 1:20 000 resolution digital soil and 1:200 000 resolution digital bedrock maps from the Geological Survey of Finland, forestry planning polygons and polygons of Forest Act habitats from the Finnish Forest Centre Pirkanmaa from years 2000–2010, as well as a 1:10 000 resolution topographic database, and a 1:50 000 resolution SLICES land-use database from the year 2010 from the NLS Finland. Finally, we used a vascular plant species inventory data from the area. In the data, the presence of vascular plant species inside 286 quadrats with an area of one km² has been surveyed from 1983 to 2011 (Kuitunen, 2013).

The first set of aerial imagery was taken in summer, 2011 by Terratec for the Finnish Forest Centre Pirkanmaa. It consisted of three bands: green, red and near infra-red in 40 cm spatial resolution. The

other aerial image set was taken by the NLS Finland during springs 2010, 2011 and 2012. The spatial resolution of the data was 50 cm and it consisted of four bands: blue, green, red, and near infra-red.

The ALS data was taken in the springs 2008 and 2012 by the NLS Finland. Data had at least 0.5 points per 1 m² and the flying altitude was on average 2000 meters. Used scan angle was $\pm 20^\circ$ and the laser pulse footprint in terrain approximately 50 cm. The mean error in the elevation information is at maximum 15 centimeters and in the planar information at maximum 60 cm. The data was delivered as point clouds with automatic classification to ground hits, low vegetation hits, low error hits and unclassified hits.

From the ALS data, we constructed two primary layers. A digital terrain model was constructed by triangulating the points classified as ground. A digital surface model was constructed by triangulating the first hits only. Moreover, the unclassified or low points were excluded from the analyses. Before the triangulation, the surface was thinned to 1 m² resolution. A canopy height model (CHM) was constructed by subtracting the digital terrain model from the digital surface model. To eliminate unrealistic values, the CHM was further manipulated to include values only between 0 and 40 m. The ALS data was processed using LAStools (rapidlasso, Gilching, Germany).

The digital terrain model was not used in the analysis as such, but five different layers were derived from it. SAGA wetness index (SWI) models moisture conditions using local and neighborhood slope and upslope contributing area (Böhner & Selige, 2006). Terrain ruggedness index calculates the amount of elevation difference locally (Riley et al., 1999), topographic position index measures the relative altitudinal position of a pixel (Guisan et al., 1999) and multiresolution index for valley bottom flatness identifies the areas that are relatively low or flat (Gallant & Dowling, 2003). In a distance to water layer, a slope raster was used as a cost surface and, from each pixel, a cost distance to a stream or a water body was calculated (Murphy et al., 2007, 2009). The terrain ruggedness index was calculated using a 3×3 pixel window size, the topographic position index with a radius of 100 m, and the multiresolution index for valley bottom flatness using value 28 for initial threshold for slope as suggested by Gallant and Dowling (2003). Streams were modeled using D_{∞} flow direction and a 40 000 m² threshold value using TauDEM tools (Tarboton, 2012). The distance to water layer was calculated using ArcGIS 10.1 (Esri, Redlands, CA, USA) and the other topographic layers were calculated using SAGA-GIS 2.0.8.

Classification of habitat types

We classified different habitat types using two different classification workflow alternatives modifying the approach given in Räsänen et al. (2014). We did not want to test *per se* which one of the methods is better but to test what kind of effect habitat type maps which are based on different datasets have on final conservation value maps. In the alternative 1, we classified forest habitat types with ALS data and the aerial images in an Object-Based Image Analysis (OBIA) workflow. Other habitat types were obtained from ancillary datasets, i.e. other data than aerial imagery and ALS. In the alternative 2, only thematic GIS datasets were used (Table A1).

In the alternative 1, we mapped different forest habitat types using OBIA methodology.

Multiresolution Segmentation was performed in eCognition Developer 8.8 (Trimble, Sunnyvale, CA, USA) using a scale parameter value 10 together with a parameter value 0.5 both to color and to compactness. In segmentation, all aerial image bands were used together with the ALS-based CHM and SWI layers in 10 meter resolution. The aerial images were resampled to 10 m resolution using mean. Resampling was made in order to reduce noise such as shadows in the images as well as for data interoperability and computational reasons. All layers were given an equal weight.

For all segments, 122 features were calculated from the aerial imagery and the ALS data. From all 13 layers, mean value and standard deviation per segment were calculated. In addition, from all image layers and from the CHM, 12 Gray-Level Co-occurrence Matrix (GLCM) and Gray-Level Difference Vector (GLDV) texture features proposed by Haralick et al. (1973) were calculated using eCognition Developer 8.8. The following features were calculated to all directions using 8 bit quantization: GLCM homogeneity, contrast, dissimilarity, entropy, angular 2nd moment, mean, standard deviation, and correlation as well as GLDV angular 2nd moment, entropy, mean, and contrast.

From the total 98196 segments, whose size range was 100–19000m², 3790 were used as training data for a random forest classifier (Breiman, 2001) trained using the package randomForest (Liaw & Wiener, 2002) in R 2.15.2 (R Core Team, 2012). In random forest, a majority vote over several bootstrapped classification trees is made. When a tree is built, approximately 1/3 of the data is left out of the bootstrap sample and is called out of bag (OOB) data. The OOB data is used for error rate estimation, which is averaged over all trees. Because of the OOB, independent test data or cross-validation is not needed when random forest is used (Breiman, 2001; Breiman & Cutler, 2007).

For the training data segments, habitat types were obtained from the corresponding forestry planning polygons. The forestry planning data consisted of 4227 polygons, a total of 57.8 km², and had

Table A1: Different habitat types mapped and different datasets used in mapping them. Column OBIA refers to classification alternative 1, and column GIS to classification alternative 2.

Class	Habitat type	OBIA	GIS
1-4	Herb-rich and other deciduous forests (4 successional stages (open regeneration area, sapling stand, young, mature))	1	2
5-8	Esker forests (4 successional stages (open regeneration area, sapling stand, young, mature))	1,5	2,5
9-12	Dry upland forest sites (4 successional stages (open regeneration area, sapling stand, young, mature))	1	2
13-16	Moist upland forest sites (4 successional stages (open regeneration area, sapling stand, young, mature))	1	2
17	Rich fen	7	7
18-19	Open bogs (2 classes (drained, not drained))	3	2,3
20-21	Pine mires (2 classes (drained, not drained))	3	2,3
22-23	Spruce mires (2 classes (drained, not drained))	3	2,3
24	Oligotrophic lakes	3	2,3
25	Eutrophic lakes	3	3
26	Streams and rivers	3	3
27	Springs	3,7	3,7
28	Riparian habitats	3,7	3,7
29	Flooded areas	3,7	3,7
30	Beaches	3,5	3,5
31	Non-calcareous rocky areas	3	3
32	Calcareous rocks and quarries	3,6	3,6
33	Dry meadows	3,7,8	3,7,8
34	Wet meadows	3	3
35	Cultivated areas	3	3
36	Parks and gardens	3,4	2,3,4
37	Industrial and urban areas	3,4	2,3,4

1: OBIA classification using aerial imagery and ALS data

2: Majority vote using MS-NFI and SLICES

3: NLS topographic database

4: SLICES land use database

5: Soil map

6: Bedrock map

7: Forest Act habitats polygons

8: Forestry planning polygons

information, for instance, about the habitat type and tree stand. We classified the data into three different habitat types in four different successional stages based on habitat type, tree species and stand development class information in the dataset. Because of the recent open regeneration areas, we manually modified the habitat type of some forestry planning polygons and deleted some of the polygons altogether to match the aerial images. In some of the polygons, patch boundaries and stand development class information was still rather inaccurate, since there were age difference of maximum 12 years between the planning data and the remotely sensed datasets. In total, 49.3 km² of the data was used. All

those segments that had at least a 60 % share of area inside one habitat type based on the reference polygons were used as training data, while each segment was classified to one habitat type using the random forest classifier.

After the OBIA classification, we classified NLS topographic database forested peatland into spruce and pine mires based on predicted forest habitat type. If a peatland segment had over 50 % of its area inside 25 m buffers of topographic database ditches, it was classified as drained peatland. All segments, whose majority soil type was esker deposit, were classified as esker habitats to the respective

successional state. The rest of the habitat types were updated to this habitat type classification straight from ancillary datasets. In these habitat types, the following classifications were made. A lake was classified eutrophic if inside a 100 m buffer around the lake over 50 % of land-use was cultivated areas or meadows. Riparian areas were mapped using 15 meter buffers for lakes and streams as well as a 5 meter buffer for small streams, brooks, creeks, and ditches. In peatland areas, 5 meter buffers were not used. For 15 m lakeside buffers, all areas that were on a mineral soil were classified as beaches. For springs, a 5 m buffer was used. A rocky area was classified as calcareous, if the bedrock type was calcareous or mafic or intermediate based on classification by Kalliola (1973). A meadow was classified as a dry meadow, if it was on mineral soil (excluding clay) and if its mean SWI value was less than 15. When all habitat types had been classified, the vector dataset was converted into 10 m resolution raster.

In the habitat type classification 2, we classified forest and peatland habitat types based on MS-NFI dataset (Tomppo et al., 2013). In this classification, the same segmentation was used as in the classification alternative 1. To each segment, the majority MS-NFI habitat type (classes 1–12, 13, 15, 17) or SLICES land use class (classes 20, 31, 32, 33, 34) was assigned. Hence, this classification was a slight modification of the classification performed by Geneletti and Gorte (2003). All segments classified as peatland were reclassified as drained peatland in the respective class if over 50 % of their area was inside 25 m ditch buffers. All forested segments, whose majority soil type was esker deposit, were reclassified to esker forest in respective successional stage. Other habitat types were classified as in classification alternative 1, and the classification was converted into 10 m resolution raster.

The classification accuracies of alternatives 1 and 2 were calculated using forestry planning polygon based habitat type classification as reference data with simple pixel-based cross-tabulation matrices. All area that was mapped as forests in the classification as well as in the reference was used in the classification accuracy calculation. For the

alternative 1, an OOB error rate of the random forest classifier was also calculated on a segment level.

Valuation of habitat types

We valued different habitat types based on potential number of species and their rarity using six different methods (Table A2). We compared alternative methods, since there are many ways how habitat types and their species composition can be valued. We wanted to test, if the valuation of habitat types have an effect on the resulting maps. In calculating habitat type valuation alternatives, different datasets were tested. In all methods, we used a database by Rossi and Kuitunen (1996). In the database, all established vascular plant species in Finland are given primary, secondary, tertiary, and quaternary habitat type preferences based on the best available literature (Hämet-Ahti et al., 1986). The objective of the mapping based on this database is to show the potential species composition of different areas. Produced maps can be used to show the locations of potentially high-value areas, which can then be checked with field work. With the established species we mean that the recent exotic species, cultivated species, or escapes were not listed or used. In four of the six methods, we used only the species that are known to exist in the study area based on the 1 km² quadrat species inventory data. In the third method, we used all species that are known to exist in the southern boreal vegetation zone as listed in the database by Rossi and Kuitunen (1996).

In the first method, value given to a specific habitat type was the number of vascular plant species being potential to exist in the specific habitat type and that are known to exist in our study area. In the second method, we weighted the primary habitat type of each species with value 1, secondary with value 0.75, tertiary with value 0.5, and quaternary with value 0.25. Additionally in the second method, we weighted the different species by range size rarity calculations (Williams et al. 1996). In range size rarity, the species weight was 1 divided by the number of quadrats containing the species. In the third method, we valued habitat types as in method 2. However, we valued the species with the help

of their existence in the Finnish southern boreal vegetation zone and the Finnish red list status (Rassi et al., 2010) and a database of regionally threatened species (Ryttäri et al., 2012) as specified in Table A3.

We further used a fourth, fifth, and sixth habitat type valuation method in which we corrected the habitat type values of valuations 1–3 based on their naturalness and ecological condition, where

the habitat type values were reduced if they were not considered being natural or if it was considered that they were not in a good condition. First, forest successional stages were modified as follows: open regeneration area: 0.25 of value, sapling stand: 0.5, young: 0.75, and mature: 1. Drained peatlands were corrected with factor 0.25, meadows (class numbers 33–34) with factor 0.2, and human habitats (35–37) with factor 0.1.

Table A2: Values given to different habitat type classes based on six different valuation alternatives. 1: species in the area, 2: range size rarity & habitat preference corrected species in the area, 3: red list classification (Table A 3), 4–6: naturalness and integrity corrected versions of 1–3. Values are normalized, i.e. divided by the maximum value of each valuation, and color coded. Color codes are explained in the last row of the table. Habitat type class numbers are clarified in Table A1. Column Beauty refers to scenic beauty of the class which is used in recreational valuation with the value 5 being the highest scenic value.

Class	1	2	3	4	5	6	Beauty
1	0.68	0.41	0.58	0.18	0.15	0.22	2
2	0.68	0.41	0.58	0.37	0.31	0.43	3
3	0.68	0.41	0.58	0.55	0.46	0.65	4
4	0.68	0.41	0.58	0.73	0.61	0.86	5
5	0.13	0.21	0.24	0.04	0.08	0.09	2
6	0.13	0.21	0.24	0.07	0.16	0.18	3
7	0.13	0.21	0.24	0.11	0.24	0.27	4
8	0.13	0.21	0.24	0.15	0.32	0.35	5
9	0.16	0.02	0.22	0.04	0.01	0.08	2
10	0.16	0.02	0.22	0.09	0.01	0.17	3
11	0.16	0.02	0.22	0.13	0.02	0.25	4
12	0.16	0.02	0.22	0.18	0.03	0.34	5
13	0.37	0.13	0.20	0.10	0.05	0.07	2
14	0.37	0.13	0.20	0.20	0.10	0.15	3
15	0.37	0.13	0.20	0.30	0.15	0.22	4
16	0.37	0.13	0.20	0.40	0.19	0.30	5
17	0.27	0.21	0.60	0.30	0.32	0.90	5
18	0.20	0.14	0.20	0.05	0.05	0.08	2
19	0.20	0.14	0.20	0.22	0.21	0.30	5
20	0.09	0.07	0.01	0.03	0.03	0.00	2
21	0.09	0.07	0.01	0.10	0.10	0.01	5
22	0.54	0.17	0.32	0.15	0.06	0.12	2
23	0.54	0.17	0.32	0.59	0.25	0.48	5
24	0.11	0.06	0.08	0.12	0.09	0.11	4
25	0.24	0.19	0.28	0.26	0.28	0.42	4
26	0.17	0.07	0.07	0.19	0.10	0.10	4
27	0.18	0.20	0.38	0.19	0.31	0.57	5
28	0.92	0.53	0.67	1.00	0.80	1.00	4
29	0.10	0.10	0.26	0.11	0.15	0.39	4
30	0.08	0.04	0.16	0.09	0.07	0.24	5
31	0.52	0.66	0.46	0.57	1.00	0.69	5
32	0.08	0.08	0.31	0.09	0.12	0.47	5
33	0.73	1.00	1.00	0.16	0.30	0.30	2
34	0.41	0.26	0.44	0.09	0.08	0.13	2
35	1.00	0.78	0.50	0.11	0.12	0.07	1
36	0.68	0.95	0.16	0.07	0.14	0.02	1
37	0.94	0.93	0.45	0.10	0.14	0.07	1
valuation color codes:			< 0.2 or 1	0.2 to 0.39 or 2	0.4 to 0.59 or 3	0.6 to 0.79 or 4	> 0.79 or 5

Habitat type connectivity and complementarity calculations

After attaining the values for the specific habitat types explained above, we mapped the value for the different areas using two different methods which utilized widely used software packages. First, we calculated landscape metrics per patch and valued patches based on these metric values. Second, we used spatial conservation prioritization software for connectivity and complementarity calculations.

In the landscape metrics calculation, we first calculated two different landscape metrics for each patch: patch area and similarity index using FRAGSTATS 4.1 (McGarigal & Ene, 2012). These two metrics were selected so that large habitat type patches that have similar neighboring habitat types get the highest values. In other words, we wanted to give highest values to large contiguous and well connected areas as suggested e.g. by Hanski (2000) and Lehtomäki et al. (2009). Similarity index measures the similarity of the patch neighborhood inside a specific radius. In other words, the index gets larger values if there are (large) patches with similar habitat types in the patch neighborhood. For the similarity index, we calculated a matrix of habitat type similarities using a Bray-Curtis index with R package *vegan* (Oksanen et al., 2013) and vascular plant species data based on 1 km² quadrats and their habitat preferences. We modified the similarity index so that different

successional stages of forest types and drainage status of peatlands were less than 1.0. The values of 0.9, 0.8 and 0.7 were given to the closest, the second closest, and the third closest successional stage or different drainage status respectively. We used a radius of 2 km, which is suitable for some mobile vertebrate species and which has been previously used for instance by Lehtomäki et al. (2009). Both patch area and similarity index were divided into 20 quantiles so that largest value was 20. The quantile values were then multiplied with habitat type values. When the complementarity was taken into account, the lowest ranks (or the highest value) were given to the patches with the highest values within each habitat type. In other words, rank 1 was given to the patch with the overall highest value, and rank 2 was given to the patch with the highest value from other habitat types than patch with rank 1, and so on. Two alternatives were considered: in the first alternative, human habitats were regarded as other habitats. In the second alternative using only habitat type valuations 4 to 6, all human habitat patches were given the highest ranks (the lowest value). In the complementarity analyses, forest and peatland habitat types were considered as single classes, i.e. successional stages or management statuses were not separated from each other. In all, 30 different landscape metrics based calculations were made.

Second, we used spatial conservation prioritization software Zonation version 3.1 (Moilanen et al., 2005,

Table A3: Different values given to species with different conservation statuses used in habitat type valuations 3 and 6. A linear 1–100 valuation was used.

Value	Red list status / species abundance
0	Does not exist
1	LC in southern boreal vegetation zone in Finland
15.143	Regionally threatened/does not exist in parts of the Vegetation zone
29.286	Regionally threatened in the whole zone
43.429	NT
57.572	NT and regionally threatened in (parts of) the zone
71.715	VU
85.858	EN
100	CR

2009, 2012) for connectivity and complementarity calculations and for computing the conservation value for each cell in the landscape. Zonation is a spatial conservation prioritization program that ranks all cells in a landscape based on their value. It proceeds by iteratively removing cells with the lowest value, accounting for factors such as weight given to the features that occur in the cell, remaining occurrences of features and their connectivity. We used Zonation with basic core-area Zonation mode. We used habitat types as features in the analysis and weighted them with habitat type values. We regarded different forest and peatland habitat types as single classes, e.g. original habitat type classes 1–4 were one class and 5–8 another class in these analyses. For example, early successional stage and mature herb-rich forests were considered to be a single class, so that they won't be targeted separately in output conservation value maps. The successional stages and drainage statuses were implemented as a condition layer in valuations 4–6. In other words, early successional stage forests or drained mires were given lower habitat type condition than mature or non-drained mires as clarified in Tables A1 and A2. We also modified valuations 4–6 by giving all human habitats a value of 0, to primarily map only potentially important natural and semi-natural habitat areas. We calculated connectivity based on matrix connectivity in which multiple features can facilitate connectivity for each other. Previously matrix connectivity has been used, e.g., by Lehtomäki et al. (2009) and Arponen et al. (2012). We calculated a matrix of habitat type similarities using a Bray-Curtis index with R package *vegan* (Oksanen et al., 2013) and vascular plant species data based on 1 km² quadrats and their habitat preferences. A radius of 2 km was used in connectivity calculations as previously used by Lehtomäki et al. (2009). We did two rounds of calculations, using the matrix only as a connectivity matrix or also as a similarity matrix for transforming occurrences of the habitat types. In all, 36 different Zonation calculations were performed.

Mapping ecosystem services

We mapped three different ecosystem services from different ecosystem service main types, i.e., timber from provisioning services, carbon storage from regulating services, and landscape value of recreation from cultural services. We selected these three services, since these services represent different types of ecosystem services that landscapes can provide and since the services could be calculated easily from the datasets we had. First, using MS-NFI data, we calculated the monetary value of logs and pulpwood for forestry purposes. In MS-NFI data, the estimates of the volumes of logs and pulpwood are given for four major tree species groups (Tomppo et al., 2013). The volumes were converted to monetary values using average values for July 2013 given in MetINFO (2013). Secondly using MS-NFI, we estimated the amount of stored carbon to estimate carbon storage for climate regulation purposes. The biomass of trees, above and below ground, was taken from MS-NFI. For soil carbon estimations, we used average values for different forest types calculated by Liski and Westman (1997) and for peatland types we used values calculated by Turunen et al. (2002). In these calculations, MS-NFI data was resampled from 20 m to 10 m resolution to match with the other analyses.

In the third ecosystem service, the landscape value for recreation, we primarily located areas that have natural vegetation and are visible to most important recreation routes and resting places. Recreational value was mapped using Viewshed analysis in ArcGIS 10.1 (Esri, Redlands, CA, USA) from the most important recreation routes and resting places, used e.g. for hiking, canoeing and campfires, in the area. The Viewshed analysis was performed using the ALS-based digital surface model with 10 m resolution. The landscape that was visible from stops and routes was regarded as valuable for recreation as follows. First, the results of the Viewshed analyses were summed so that routes in total and all stops separately were considered as single observation points in order to get a numeric value for each landscape point, i.e., how many times that landscape point can be

seen. Second, these values were multiplied with habitat type class scenic beauty values which are given in Table A2. High scenic values were given to more natural environments and low scenic values to human environments. It has been found, that natural landscapes are usually preferred (Kaplan et al., 1972) especially by people with ecocentric value orientations (Kaltenborn & Bjerke, 2002). Third, the maximum recreational value per segment was given to all cells in the segment to have a smoother final output.

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