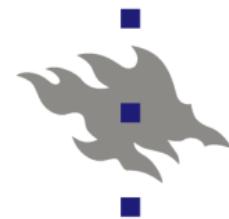


Predicting the provisioning potential of forest ecosystem services using airborne laser scanning data and forest resource maps



UNIVERSITY
OF EASTERN
FINLAND



UNIVERSITY OF HELSINKI

Dr. Jari Vauhkonen

Forest Ecosystems Spring Workshop 2018

Ekosysteemipalveluindikaattoreita hilamuotoisista metsävara-aineistoista!

- Ekosysteemipalvelut – hilamuotoisista metsävara-aineistoista
 - Vauhkonen J., Ruotsalainen R. (2017a). Assessing the provisioning potential of ecosystem services in a Scandinavian boreal forest: suitability and tradeoff analyses on grid-based wall-to-wall forest inventory data. *Forest Ecology and Management* 389: 272–284.
<https://doi.org/10.1016/j.foreco.2016.12.005>
- Laserkeilaus ja ekosysteemipalvelut
 - Vauhkonen J. (2018). Predicting the provisioning potential of forest ecosystem services using airborne laser scanning data and forest resource maps. *Forest Ecosystems* 5:24.
<https://doi.org/10.1186/s40663-018-0143-1>
- Laserkeilaus ja maisema
 - Vauhkonen J., Ruotsalainen R. (2017b). Reconstructing forest canopy from the 3D triangulations of airborne laser scanning point data for the visualization and planning of forested landscapes. *Annals of Forest Science* 74:9. <https://doi.org/10.1007/s13595-016-0598-6>
- Pohdintaa

Forest ecosystem services?

- Synonyms to “multiple uses” of forest (e.g. Kangas 1992, 1994)
- Management objectives in multi-criteria forest management planning
- Based on proxy variables
- Different scales,
- Different units



Image source: <http://www.metsa.fi/web/en/ecosystemservices>

Proxy values?

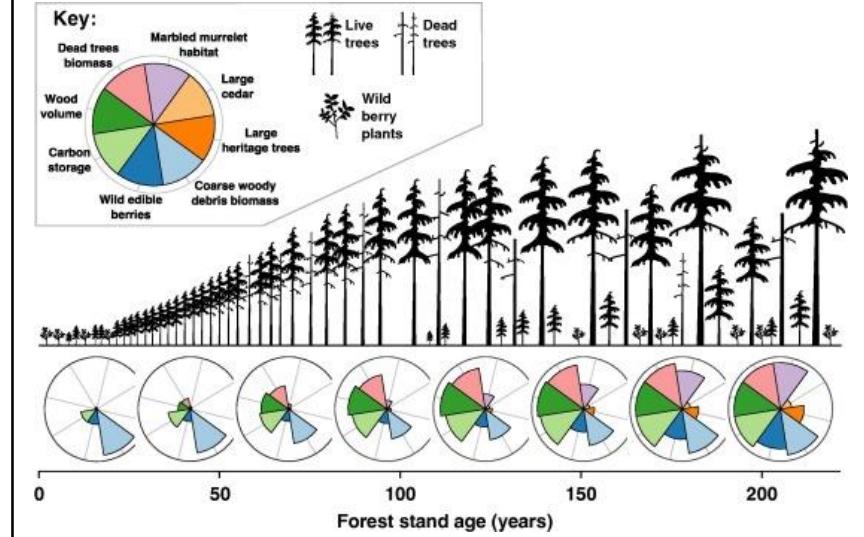
- The provisioning potential of ecosystem services, based on existing models:

Service category	Example service (indicator; unit)	Stand-level forest attributes used for modeling
Supporting	Biodiversity management (conservation value based on expert opinion; index value)	Species composition, mean diameter, growing stock volume, site fertility (Lehtomäki et al., 2015)
Provisioning	Timber production (soil expectation value; €/ha)	Mean diameter, basal area, age, site fertility, species-specific growing stock volume, number of trees, operational environment (temperature, interest rate, timber prices) (Pukkala, 2005)
Regulating	Carbon storage (estimated amount of carbon; t/ha)	Total biomass converted to carbon (IPCC, 2003)
Cultural	Recreation value (recreational amenity and suitability for berry picking; index values)	Mean diameter, basal area, age, site fertility, species-specific growing stock volume, number of trees (Pukkala et al., 1988; Ihalainen et al., 2002)

Source: Sutherland et al. 2016, doi: [10.1016/j.foreco.2016.04.037](https://doi.org/10.1016/j.foreco.2016.04.037)

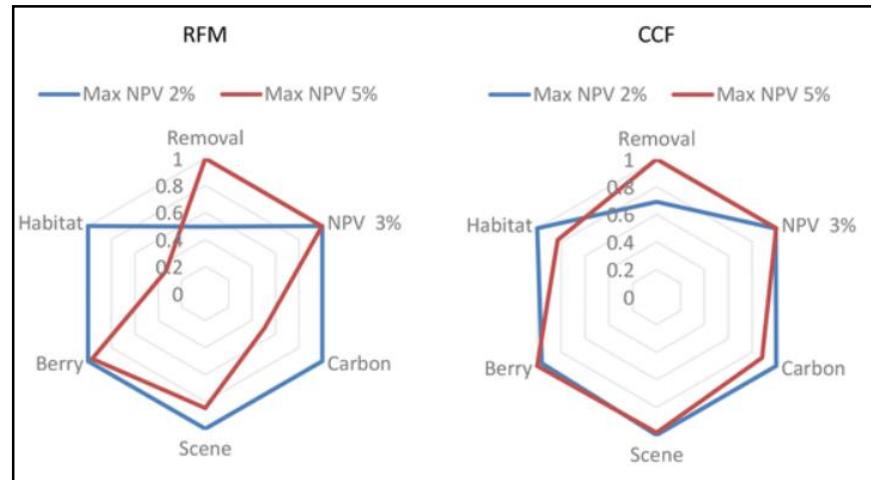
Provisioning potential?

- “The potential of each forest patch to provide selected ecosystem services” (relative to the entire landscape)
 1. Related to the prevailing for. structure
 2. Can be affected by forest management
 3. Making forest management decisions at the level of pixels is expected to allow more efficient use of the production possibilities of the forest.



Provisioning potential?

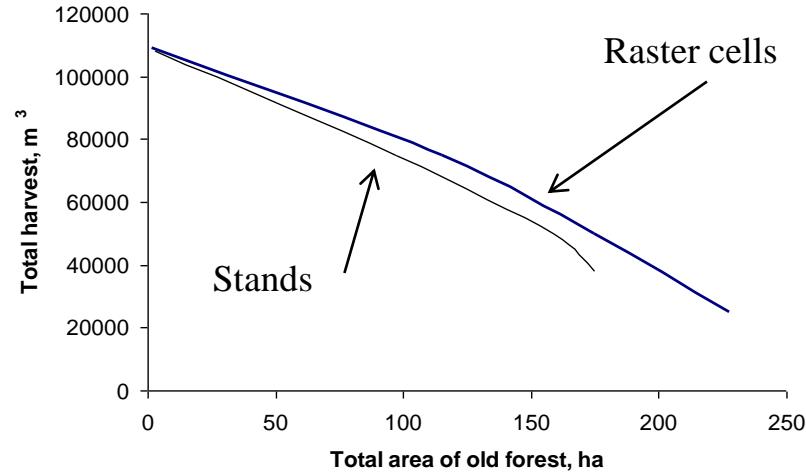
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Provisioning potential?

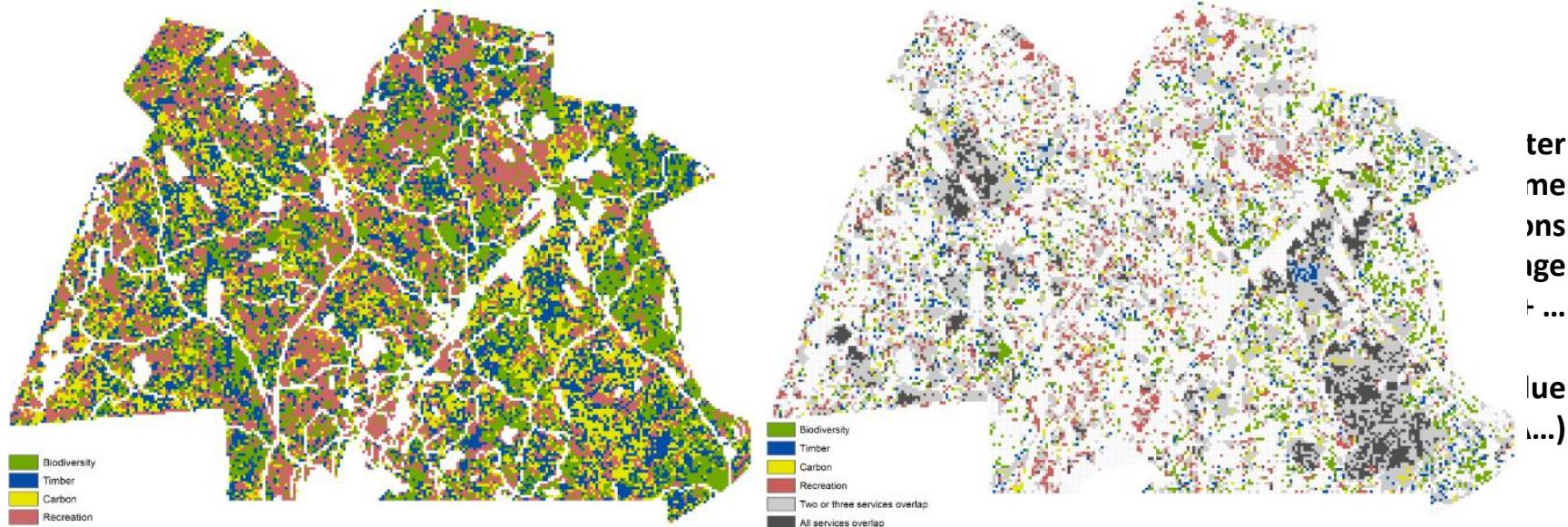
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 3. Making forest management decisions at the level of pixels is expected to allow more efficient use of the production possibilities of the forest.

Source: Heinonen et al. 2007, doi: [10.14214/sf.474](https://doi.org/10.14214/sf.474)



Mapping of forest ecosystem services?

- Using land-cover maps, public databases & expert models
- ➔ Spatial prioritization for forest management decision analyses *



* Vauhkonen, J. & Ruotsalainen, R. 2017. Assessing the provisioning potential of ecosystem services in a Scandinavian boreal forest – Suitability and tradeoff analyses on grid-based wall-to-wall forest inventory data. Forest Ecology and Management 389: 272-284.

Improvement needs

- Publicly available databases and (2D) forest resource maps might not be ideal data sources
- Uncertainties? Propagation of errors?

OBJECTIVES

1. Test (3D) airborne laser scanning data for modelling the provisioning potential of forest ecosystem services
 - ➔ Models for proxy values based on 3D forest structure indices
 - ➔ Integrate model errors as uncertainties in decision making

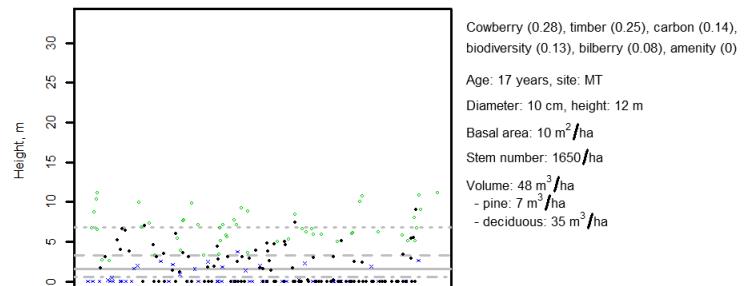
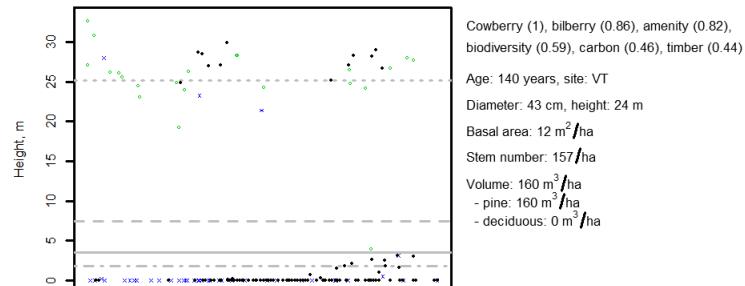
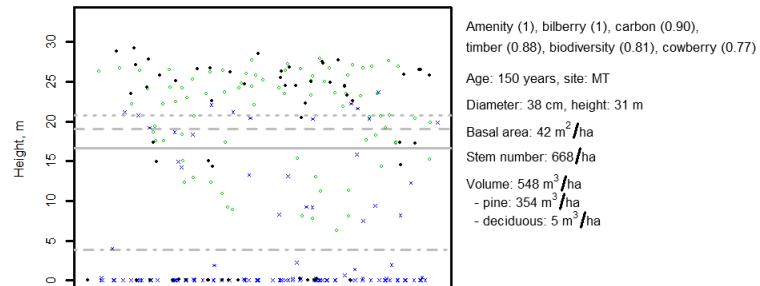
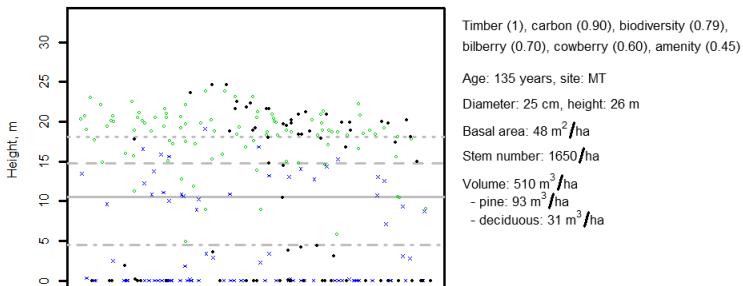
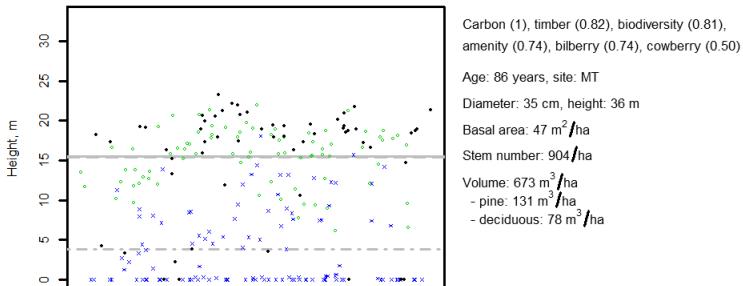
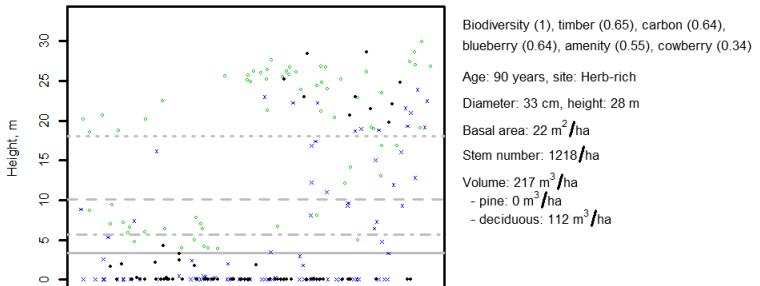
Experimental set-up

- Compare proxy values obtained from:
- Field plots
- Multi-source forest resource maps
- Airborne laser scanning (ALS)
 - Acquired by National Land Survey for terrain elevation modeling
 - Sparse data (0.8 hits per m²)



ALS POINT CLOUDS vs. FIELD OBSERVATIONS

-plots with highest provisioning potential of ecosystem services



ALS-BASED MODELS FOR THE PROVISIONING POTENTIAL

- Non-linear regression models
- Seemingly Unrelated Regression for model fitting
- Different number of predictor variables per ES
- Always interactions and multiple heights & echo types

Table 2. The features and performance of ALS-based models for predicting ratio-scaled ES proxy values. W – Shapiro-Wilk test statistic.

ES	Predictor	W ¹	RMSE	RMSE _{LOOCV}
BIOD	ccshrub × h40 _{first}	0.965***	0.259	0.266
	+ propfirstFP_ground × d50 _{first}	0.981	0.235	NA
	+ diffonly-LP × hstd _{LP}	0.986	0.217	0.226
	+ h95 _{first} × h10 _{LP}	0.977*	0.203	NA
TIMB	cconly_ground × hmeanFP	0.977*	0.220	0.228
	+ h40 _{last} × cCLP_ground	0.970**	0.202	0.213
	+ h05 _{last} × d05 _{first}	0.989	0.182	NA
	+ cconly_ground × h10FP	0.988	0.174	NA
CARB	ccshrub × h60 _{first}	0.980	0.158	0.163
	+ h20 _{last} × cconly_ground	0.988	0.144	0.152
	+ d60 _{first} × d30 _{LP}	0.987	0.138	0.148
	+ propfirstFP_ground × d05 _{first}	0.984	0.132	NA
BILB	h60 _{first} × h70 _{LP}	0.987	0.279	0.286
	+ d50only × cCFP_ground	0.984	0.255	0.274
	+ tunderstory × d05FP	0.982	0.238	NA
	+ d70 _{first} × d50only	0.984	0.222	0.267
COWB	d20 _{LP} × h40FP	0.966***	0.281	0.295
	+ diffonly-FP ²	0.981	0.250	NA
	+ propfirstFP_ground × d05 _{first}	0.983	0.233	NA
	+ d60 _{first} × h05only	0.971**	0.217	NA
AMEN	h10 _{first} × hmeanFP	0.993	0.239	0.246
	+ d30 _{last} × d70 _{first}	0.991	0.219	0.229
	+ h20 _{last} × cCFP_ground	0.994	0.204	NA
	+ hstd _{first} × hmean _{LP}	0.991	0.187	NA

¹ The asterisks refer to the significance of the test statistic at the 90%(*), 95% (**), and 99% (***) confidence level.

MODEL PERFORMANCE:

Scatter plots with 0-1-line

Biodiversity

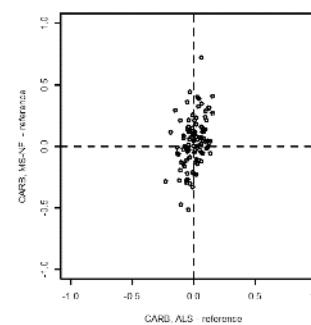
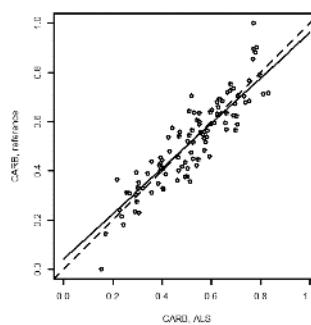
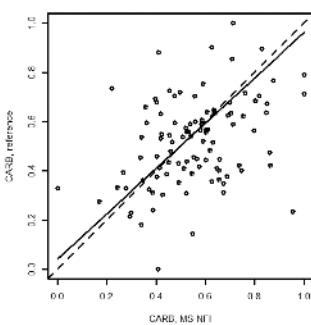
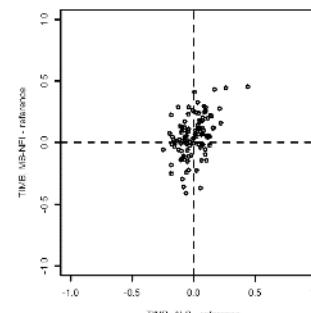
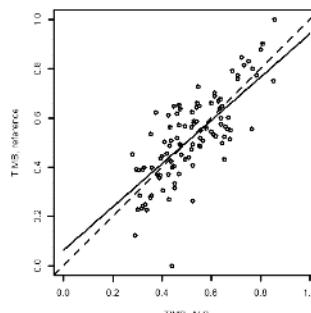
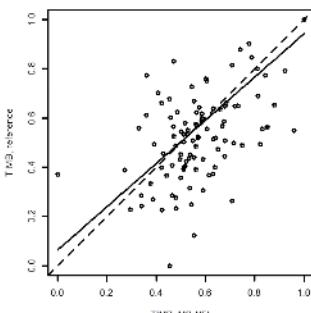
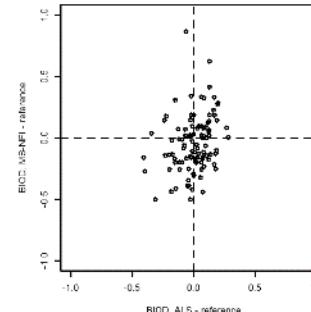
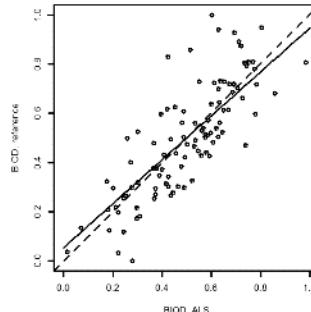
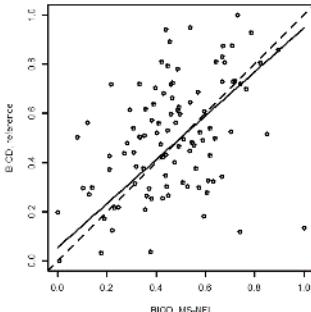
Timber

Carbon

Multi-source

Laser

Errors

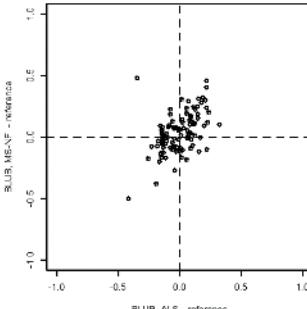
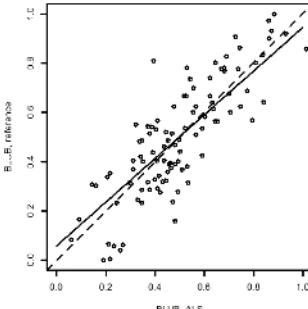
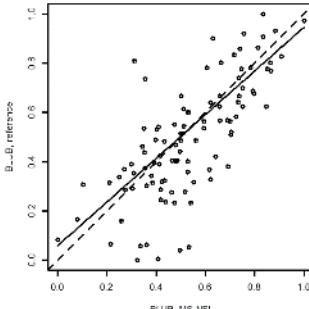


MODEL PERFORMANCE:

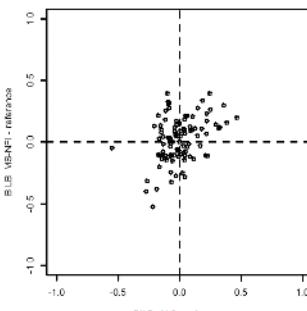
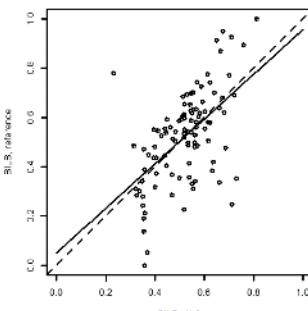
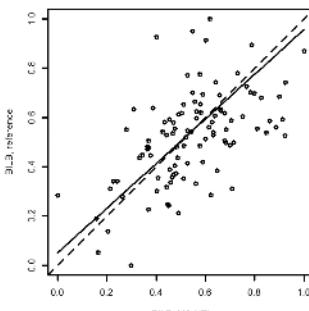
Scatter plots with 0-1-line

Blueberry

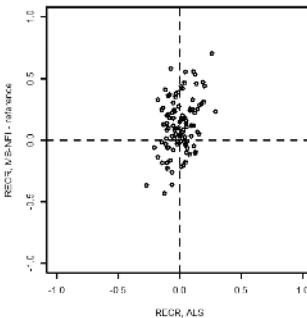
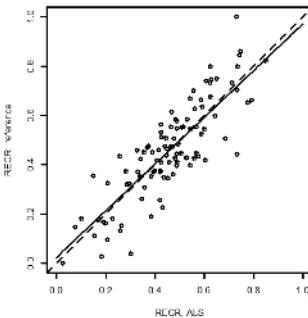
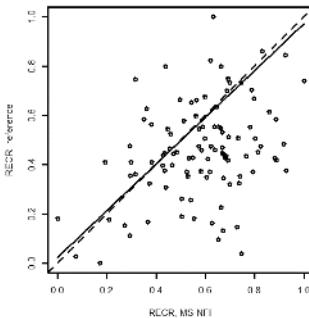
Multi-source Laser Errors



Bilberry

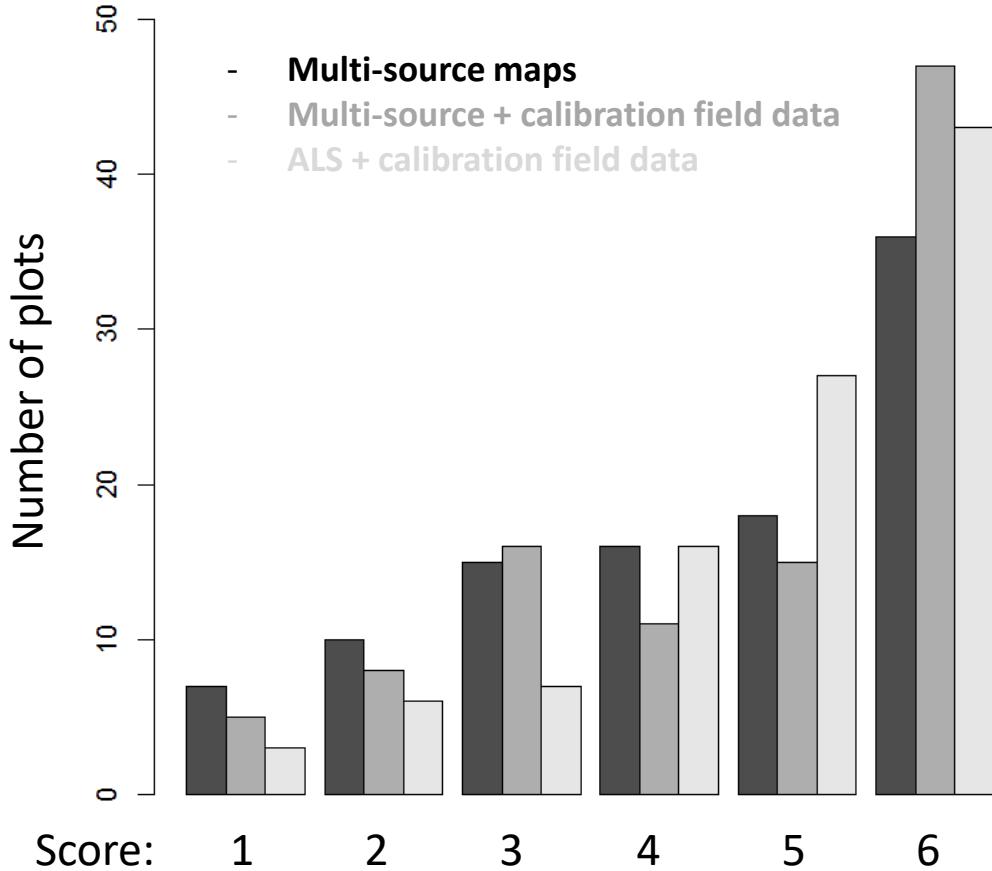


Visual
Amenity



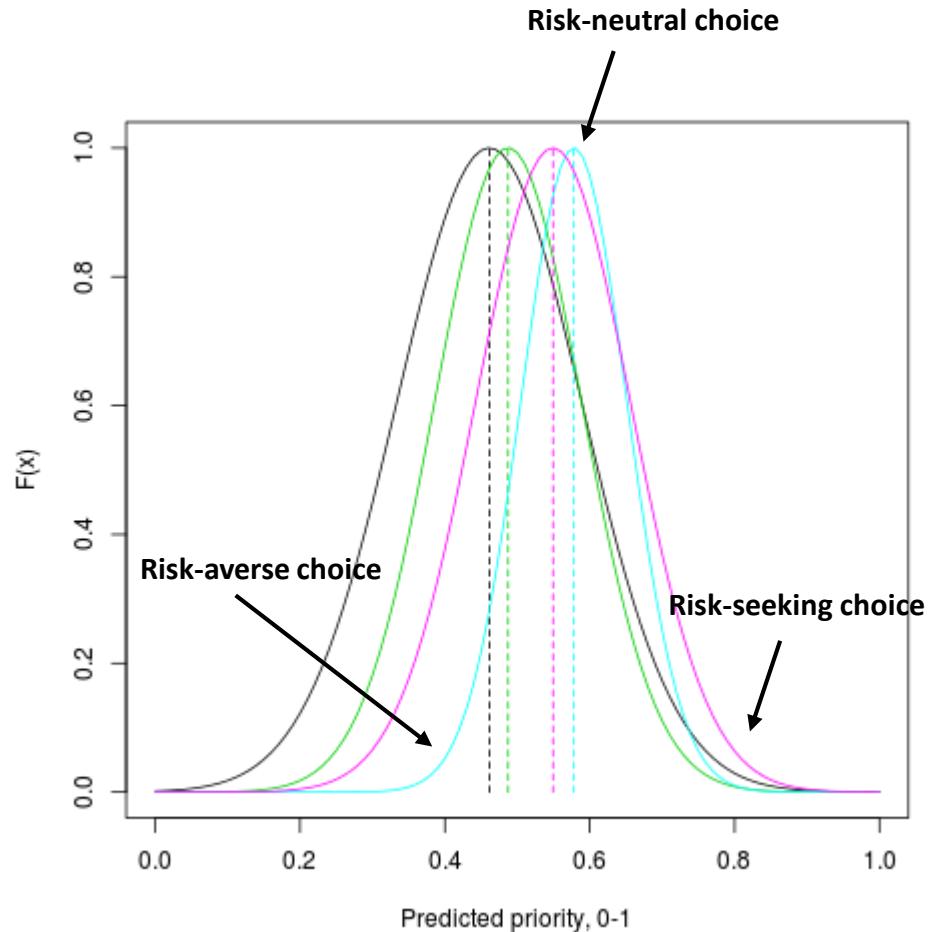
QUALITY OF PRIORITIZATION DECISIONS

- Prioritize management with the proxy values
- The ecosystem service with the highest priority was assumed most suitable for the specific plot.
- The RS-based decision was correct if it equaled the field-based decision.
- A correctness-score was given for every decision:
 - 6 = RS and field data resulted in the same decision
 - 5 = RS-based service was 2nd best according to field data
 - ...
 - 1 = RS-based service was the worst according to field data



”Risk resilient mapping”?

- The decisions presented earlier were based on *deterministic, risk-neutral* predictions
 - Priority ranking based on expected values
- Prediction models of different ecosystem services have different error structures
 - Expected values + standard errors
- Decisions based on extreme values of the error distributions may lead to different conclusions
 - Decision maker's risk aversion



Maiseman visualisointi ja parivertailut / ALS-data

- Roope Ruotsalaisen kandidaatintutkielma, UEF 2015
- Vauhkonen & Ruotsalainen, [Annals of Forest Science 2017](#)

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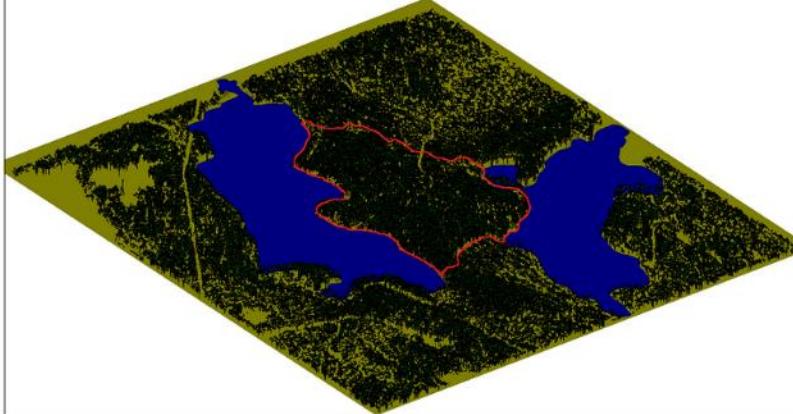
Tervetuloa kyselytutkimukseen!

Taustatietoja ennen kyselyn aloitamista:
Metsämaiseman keskiosassa sijaitsevalle metsikkökuviolle on suunnitellua harvennushakkuu. Harvennettavan kuvion läpi kulkee vaellusreitti ja lisäksi kuvioilla sijaitsee laavu.
Harvennusvoimakkaiden suuruutta ei ole vielä päättetty, mutta harvennuksessa pyritään sailyttämään alueen hyvyyssä virkistyskäytöön mahdollisimman korkeana.

Kyselyssä sinun tulee verrata kerrallaan kahta erilaista maisemakuvaaa keskenään ja valita, kumpi harvennusvoimakkuuksista on mielestäsi parempi metsääalueen virkistyskäytön ja maisema-arvojen kannalta.

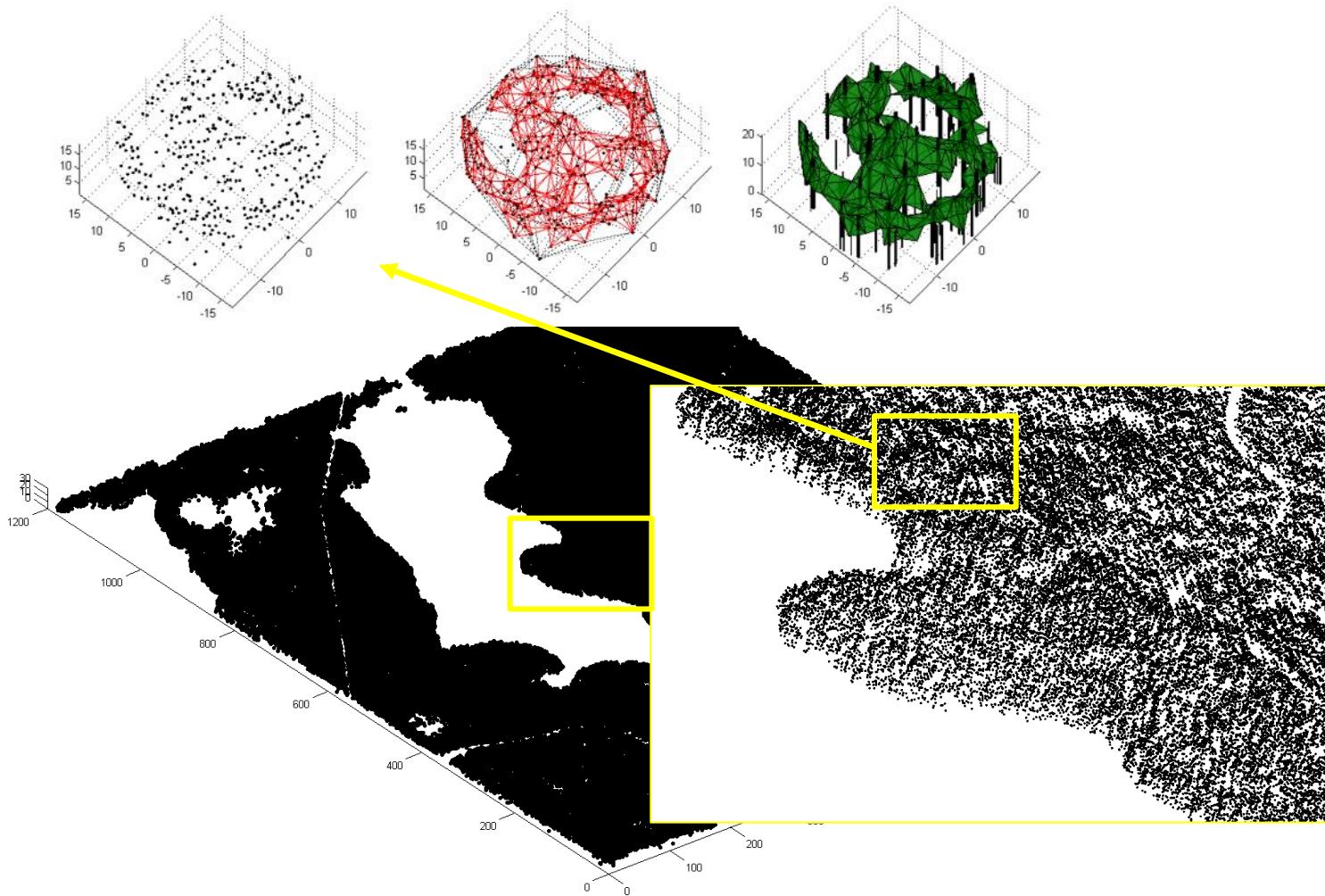
Alla olevaan kuvaan on rajattu harvennettava metsikkökuvio punaisin äärivivoin. Muuta osaa metsääalueesta ei käsitellä.

Kysely alkaa kun painat sivun alalaidassa olevaa "Seuraava kuvapari"-painiketta.

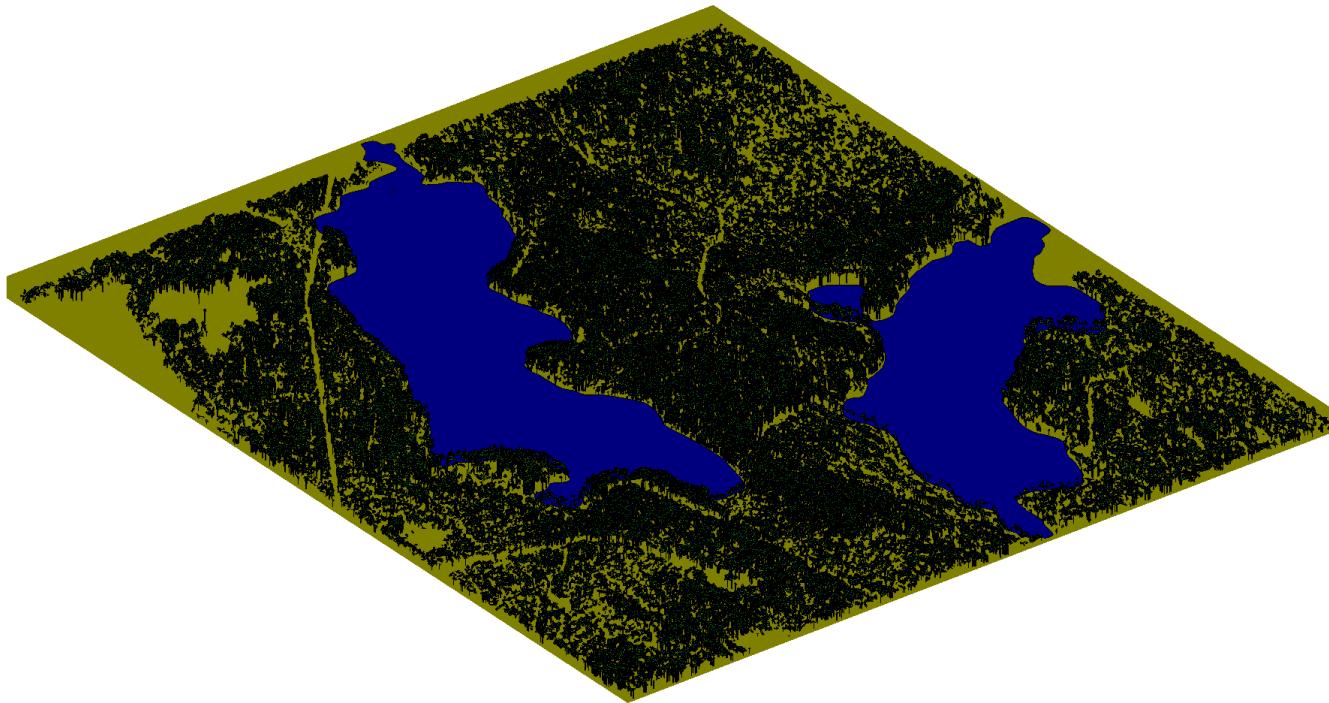


1 / 12 | 8%

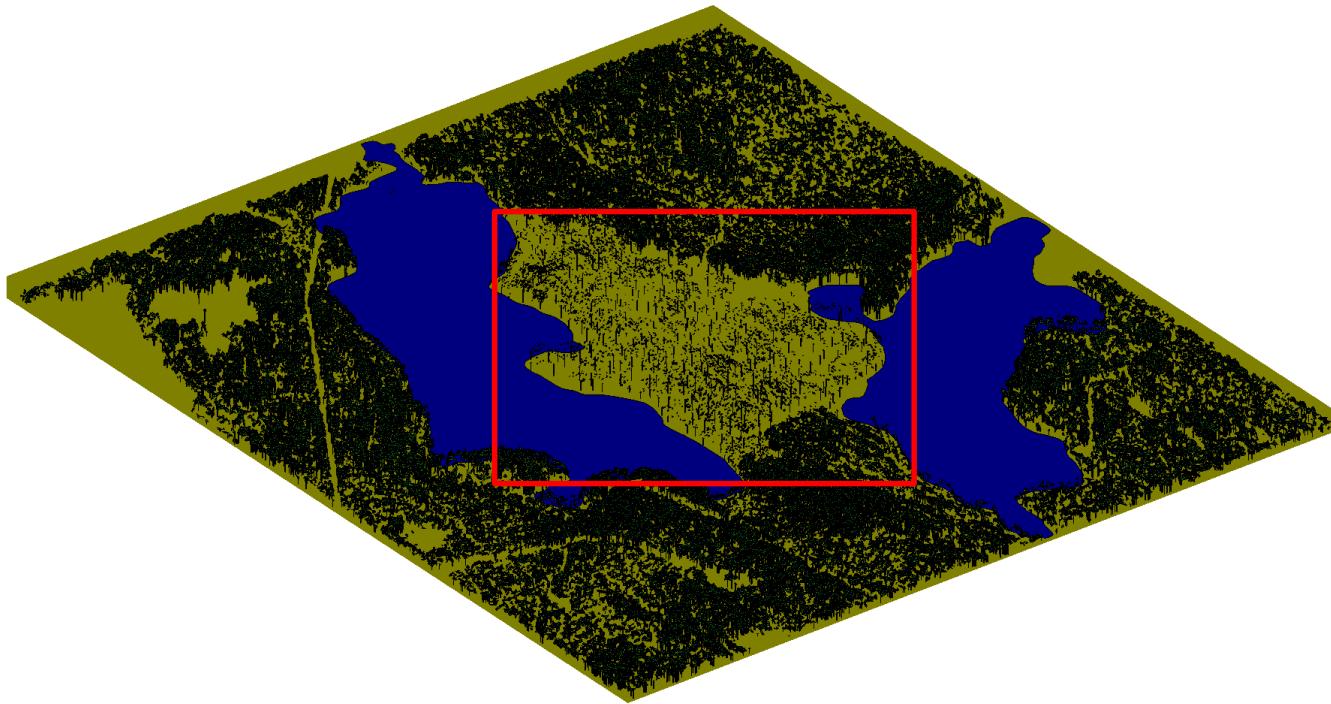
Seuraava kuvapari

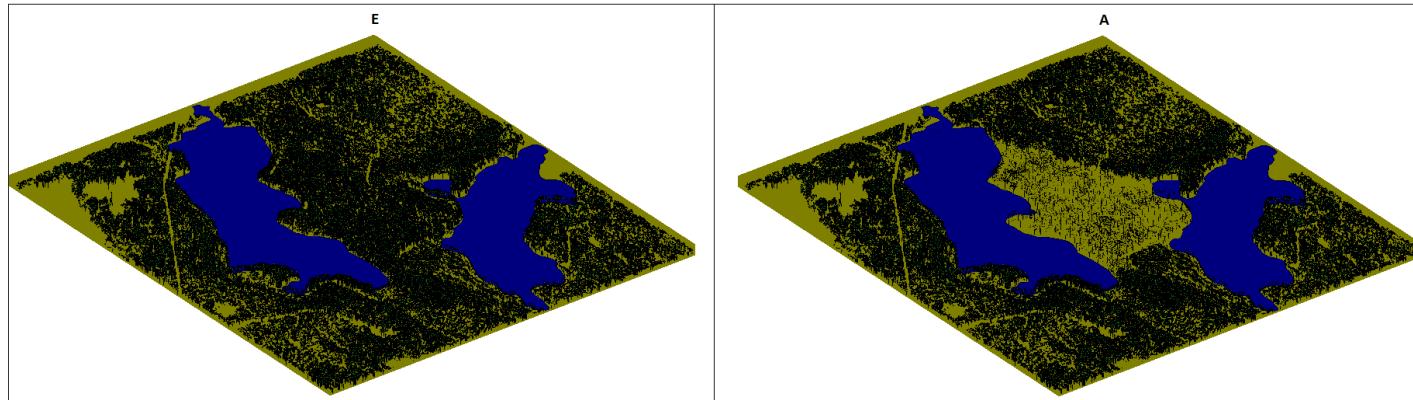


Maiseman visualisointi laserkeilausaineistolta



Maiseman ja hakkuuvoimakkuuden visualisointi





8. Kumpi harvennusvoimakkuudesta on mielestäsi parempi metsäalueen virkistyskäytön ja maisema-arvojen kannalta?

<input type="radio"/> E on erittäin paljon parempi	<input type="radio"/> E on hyvin paljon parempi	<input type="radio"/> E on paljon parempi	<input type="radio"/> E on hieman parempi	<input type="radio"/> E ja A ovat yhtä hyviä	<input type="radio"/> A on hieman parempi	<input type="radio"/> A on paljon parempi	<input type="radio"/> A on hyvin paljon parempi	<input type="radio"/> A on erittäin paljon parempi
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9 / 12 75%

[Edellinen kuvapari](#) [Seuraava kuvapari](#)

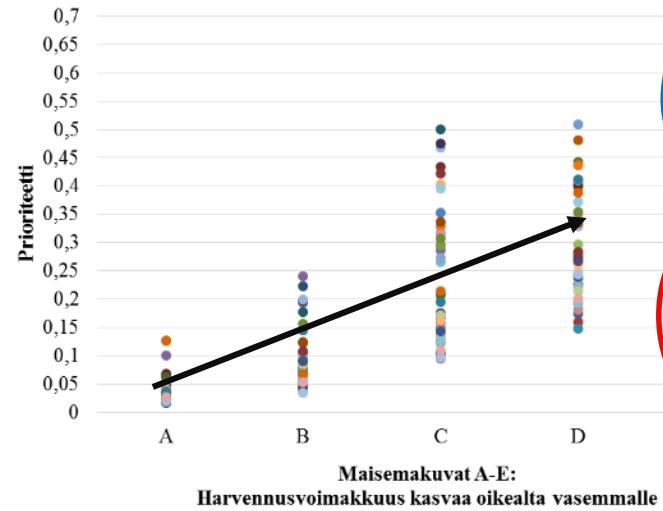
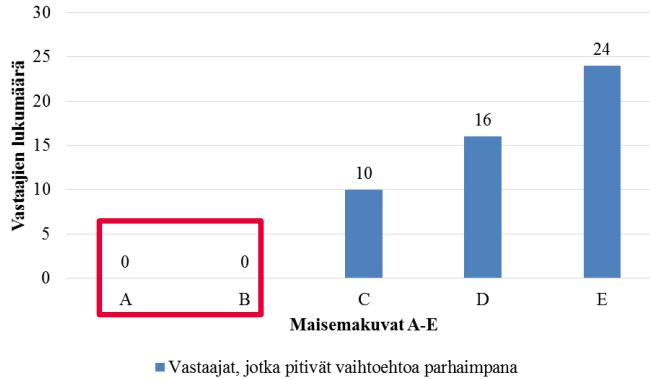
Esim. prioriteetit järjestyksessä A-E: $0.03 + 0.08 + 0.14 + 0.24 + 0.51 = 1$

Verbaalinen asteikko	Suhdeluku (Satty)
Yhtä hyvä	1/1
Hieman parempi	3/1
Paljon parempi	5/1
Hyvin paljon parempi	7/1
Erittäin paljon parempi	9/1
Väliarvot	2/1, 4/1, 6/1, 8/1

	A	B	C	D	E
A	1	1/3	1/5	1/7	1/9
B	3	1	1/3	1/5	1/5
C	5	3	1	1/3	1/5
D	7	5	3	1	1/5
E	9	5	5	5	1

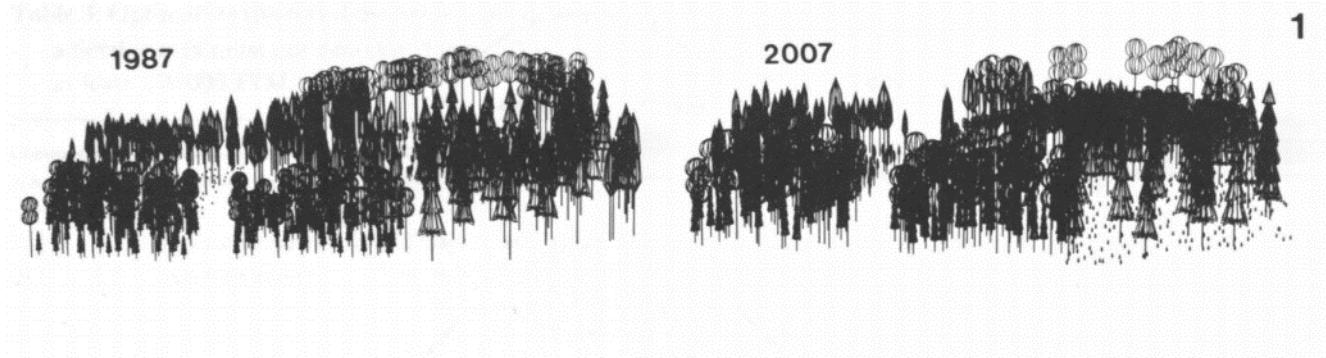
3. Tulokset

Prioriteettien jakauma



Maiseman visualisointi

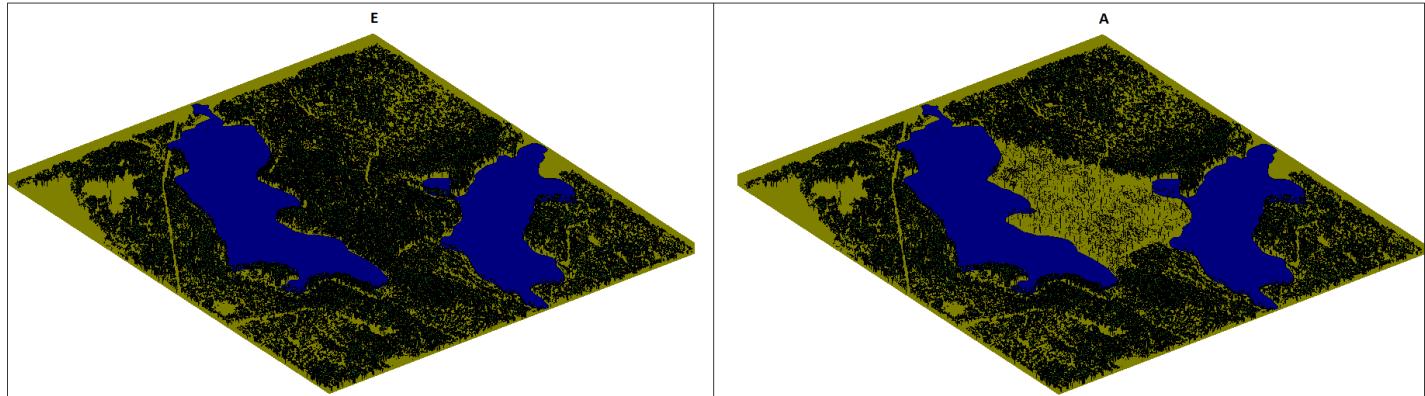
Pukkala 1988



Vauhkonen &
Ruotsalainen
2017

Uusien
aineistojen
hyödyt???

- VR?



8. Kumpi harvennusvoimakkuudesta on mielestäsi parempi metsäalueen virkistyskäytön ja maisema-arvojen kannalta?

- E on erittäin paljon parempi E on hyvin paljon parempi E on paljon parempi E on hieman parempi E ja A ovat yhtä hyviä
A on hieman parempi A on paljon parempi A on hyvin paljon parempi A on erittäin paljon parempi

- Rasterikarttojen käyttö samaan tapaan?

Parivertailut ja asiantuntijanäkemys

Kangas et al. 1993

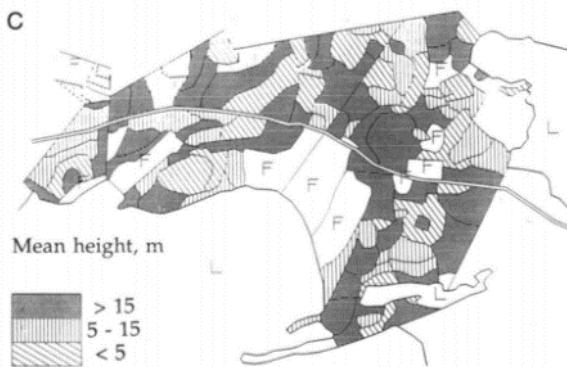
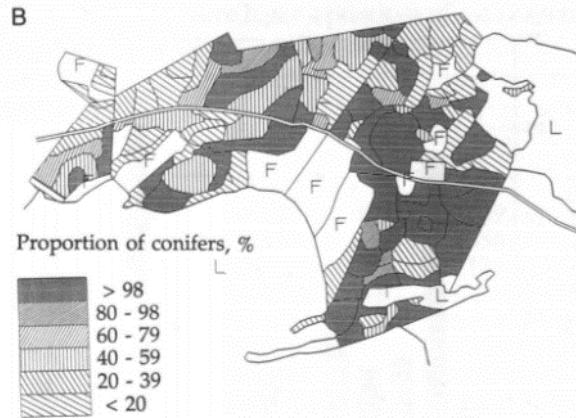
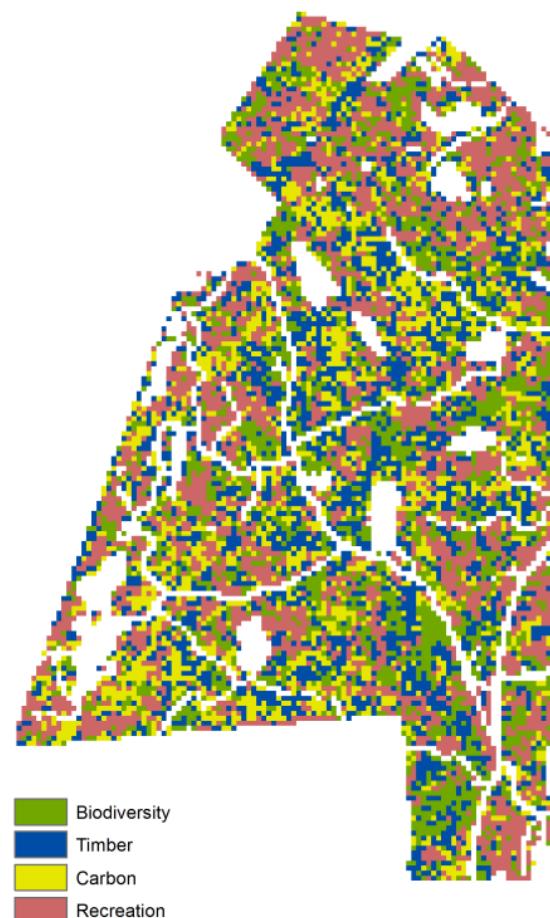


Fig. 1. Examples of thematic maps which were presented to experts; plan number 3. White compartments in maps B and C are lakes (L), fields (F), or peatlands without tree cover.

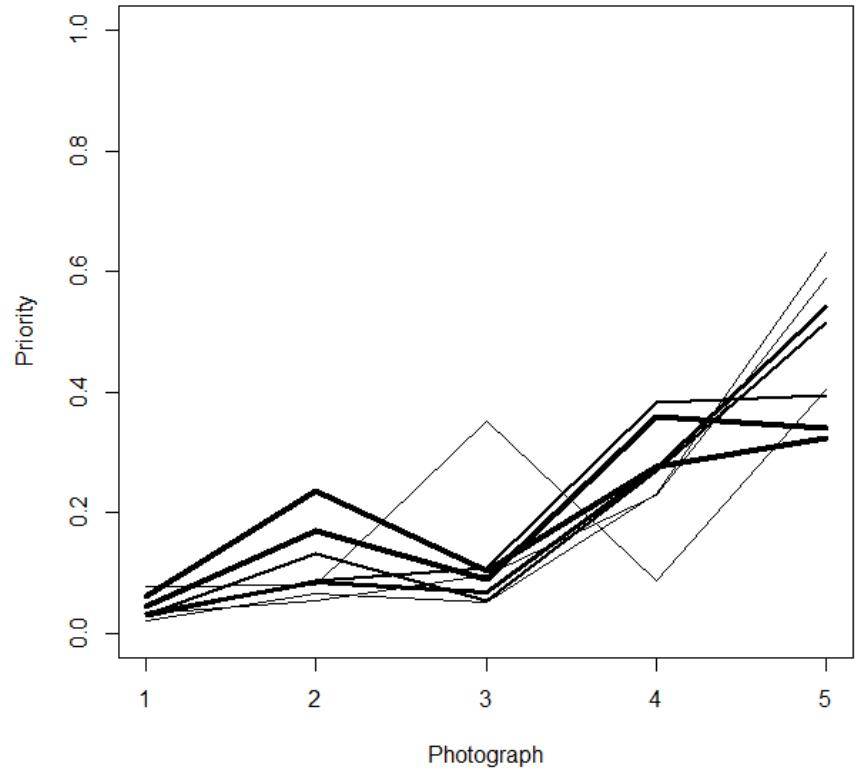
Map A: Stands where the share of birch is at least 50 % of stand volume, or the share of birch is at least 10 % and birch is the tallest tree species; stands fulfilling the conditions shaded.

Map B: Proportion of conifers of the stand volume.

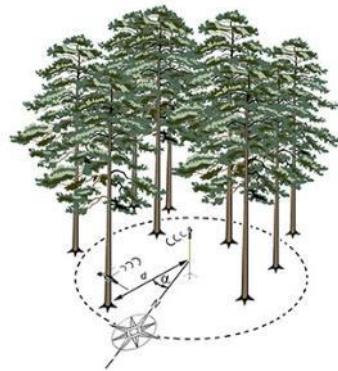
Map C: The mean tree height.



- Hyviä aineksia (asiantuntija-)mallien kehitykselle
 - Hila-aineistot
 - Paljon muita aineistoja
- Hyvin lokaalia tietoa (esim. pikselitaso) voisi tuottaa vaikka kuinka paljon
 - Mallien ennusteet – stokastisina – jakaumat
 - Päättöksentekijän preferenssit
 - ...
- Mutta onko tarvetta?
- Onko tämä jo TOO BIG DATA?



Forest data

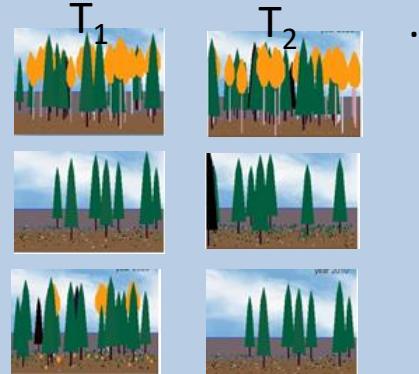


Simulations of management alternatives

CURRENT STATE



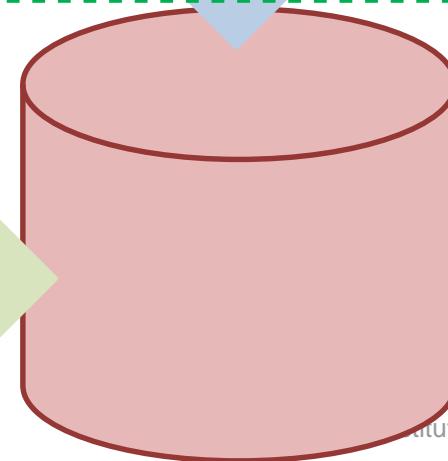
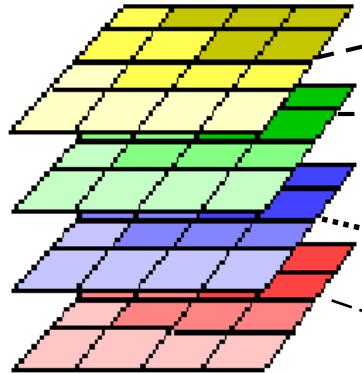
M_1
 M_2
 M_3
 M_n



SELECT OPTIMAL

CONVENTIONAL SIMULATION-OPTIMIZATION

DESIMAP PROPOSAL



SELECT OPTIMAL
SII LUKE
NATURAL RESOURCES INSTITUTE FINLAND

Thank you!

