European cross-site comparison of place-based ecosystem services in multifunctional landscapes

Nora Fagerholm[1,2], Mario Torralba[1], Gerardo Moreno[3], Marco Girardello[4], Felix Herzog[5], Stephanie Aviron[6], Paul Burgess[7], Josep Crous[8], Nuria Ferreiro-Domínguez[8, 9], Anil Graves[7], Tibor Hartel[10], Vlad Măcicăsan[10,11], Sonja Kay[5], Anastasia Pantera[13], Anna Varga[14], Tobias Plieninger[1]

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[1]University of Turku, [2]University of Copenhagen, [3]University of Extremadura, [4]Universidade dos Açores, [5]Agroscope, [6]INRA Agrocampus, [7]Cranfield University, [8] University of Lisbon, [9]University of Santiago de Compostela, [10]Babes-Bolyai University, [11]Babes-Bolyai Unviersity, [13]TEI Stereas Elladas, [14]MTA Centre for Ecological Research

UNIVERSITY OF COPENHAGEN

Turun yliopisto
University of Turku

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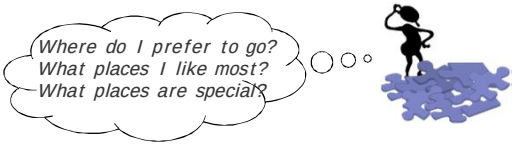
Ecosystem services and multifunctional landscapes

- *Landscape multifunctionality* has developed into a key management strategy to generate a diverse set of *ecosystem services (ES)* that are accessible to a broad range of beneficiaries
  - underpins *agricultural support and rural development policies* of the OECD member countries and also the Common Agricultural Policy (CAP) of the EU
- *People assign a variety of values to the everyday landscapes* in which they live, work, engage in recreational activities, encounter other people and search for relaxing and restorative experiences (Stephenson, 2008)
  - these perceived values are *place-specific* (Williams, 2014)
  - can be defined as the *benefits* that people derive from the structures and processes generated by nature, i.e. ecosystem services



Public participation GIS (PPGIS) approach to assess ecosystem services

- Recently, there has been an increased effort *to map place-based ES as perceived by people through Public Participation Geographical Information Systems (PPGIS)* (Brown & Fagerholm, 2015)
- Communicates *assigned values*, i.e. the judgement regarding the appreciation of objects such as places, ecosystems and species (Seymour et al., 2010, Van Riper & Kyle, 2014)
  - *focuses on the place-based personal perspective* that emerges from *everyday subjective experience* and *accumulated knowledge* (Stephenson, 2008; Williams & Patterson, 1996)
- PPGIS approaches highlight the *ecosystem benefits to the people that derive and demand them* and the *spatial heterogeneity of ES* demand (Termoshuizen & Opdam, 2009)
  - typically limited to studies that address specific socio-economic and landscape contexts

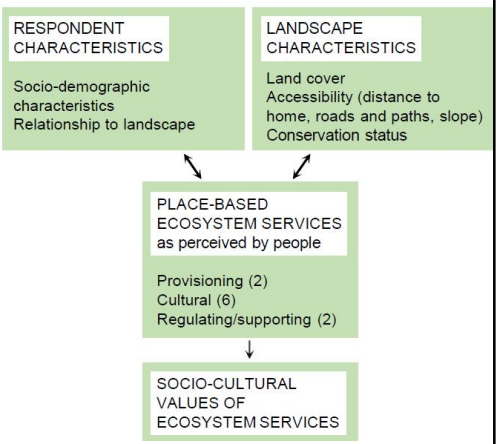
Objectives

It remains unclear *which ES are valued in different landscapes and by different people*

-> cross site comparison to improve understanding of the *linkages between multiple ES as perceived by different actors and multifunctional land use systems*

-> assessment of ES as perceived and mapped by residents across 13 multifunctional rural landscapes in Europe

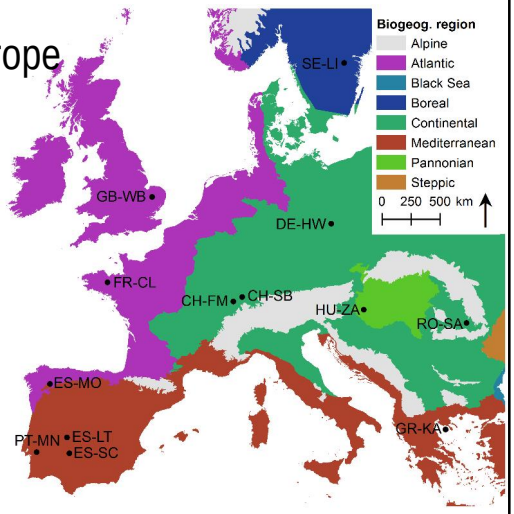
(cf. Scholte et al. 2015)



13 study sites across Europe

- Multifunctional farming landscapes
- A broad range of land-use systems
- Varying degrees of rurality and peri-urbanity
- Different levels of landscape protection

- 2301 respondents
- 28 878 mapped sites for ES



Indicators (landscape values and practices)

Ecosystem service category	Ecosystem service	Ecosystem service indicator	Operational definition (related survey question: Do you find some particular place or area special in this landscape?)
Provisioning	Food	Farm products	I appreciate, produce or can buy farm products here
	Food	Freely harvested wild products	I harvest fruits, berries, mushrooms, fish, game etc.
Cultural	Recreation	Outdoor activities	I practice outdoor sports, walking, hiking, biking, dog walking etc.
	Social relations	Social interaction	I spend time together with other people
	Aesthetic values	Beautiful landscape or landmark	I enjoy seeing this beautiful landscape or landmark
	Cultural diversity, cultural heritage values	Appreciation of local culture, cultural heritage or history	I appreciate the local culture, cultural heritage or history
	Inspiration, spiritual and religious values	Inspirational, spiritual or religious place, feeling or value	I am inspired by feelings, new thoughts, religious or spiritual meanings etc.
	Existence value	Appreciation of a specific place as such, independent of any benefit to humans	I appreciate this place just for its existence regardless of benefits for me or others
Regulating/ supporting	Provisioning of habitat, biodiversity	Appreciation of plants, animals, wildlife, ecosystems etc.	I appreciate the plants, animals, wildlife, ecosystems etc.
	Erosion control, soil fertility, water and climate regulation, air quality maintenance	Appreciation of environmental capacity to produce, preserve, clean, and renew air, soil and/or water	I appreciate the environmental capacity to produce, preserve, clean, and renew air, soil, and/or water

Method

Facilitated online survey platform with a mapping interface, purposive stratified sampling of residents

Informants and sampling

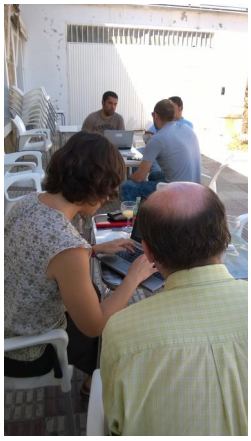
- Focus on practices, perceptions and values of *local inhabitants*
- *Facilitated on site recruitment of residents*
- *targeted n=170*
- Purposive stratified sampling based on three stratification criteria:
  1. *geographical balance within study area*
  2. *gender*
  3. *age* (young people/young adults 15-29 yrs, middle-aged 30-59 yrs, seniors =< 60 yrs
- Recruited *on site in different places in the study area*
  - e.g. in bars, cafes, parks, recreational routes, health care centres, pensioners' housing etc.

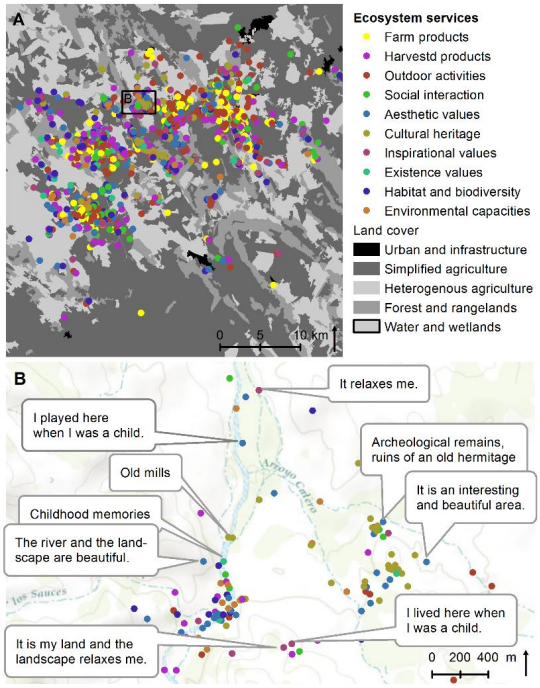
Facilitators

- Previous experience in survey data collection is not necessary –learning by doing
- *However, what makes a difference is a good attitude, willingness to approach people, genuine interest to listen to the informants and their stories about the landscape*

- Data collection is *most effective and motivating when working in pairs with two laptops/tablets or in teams*
  - allows interviewing two or more persons at the same time, e.g. friends sitting at a café
  - also, the other person(s) may look for informants when interviews are done

- *Instructions booklet for facilitators with*
- *detailed and practical instructions!*





Example from Serena Campiña, Spain (ES-SC)

181 respondents
2438 mapped places

Sample representativeness (age, gender)

- Overall the difference between the sample and census was good with less than 3.4% difference per age/gender group
- Except elderly women: 6.7% less represented compared to sample
- Men 30-59 yrs were challenging to interview in CH-FM, DE-HW, ES-LT and GB-WB (sample-census difference -6.3-14.8%), compensated with men of other age
- Young people less represented in CH-SB (sample-census difference men -14.8%, women -11.2%) but more represented in DE-HW (sample-census difference men 11.5%, women 9.2%) and SE-LI (sample-census difference men 8.3%, women 14.5%)

Results:
Identified place-based ES vary across Europe

- Key ES: *Outdoor recreation, aesthetic values and sites for social interactions*
- Average number of mapped places 12.5±5.2
- *Provisioning* services emphasized in regions with low GDP and population density and a high proportion of inhabitants working in agriculture (*Mediterranean and Eastern Europe*), while *cultural* services were more appreciated in regions with high GDP and population density (*Central and Northern Europe*)

E.S./Site	ALL 2139/29687	ES-LT 219/2594	FR-CL 146//2104	RO-SA 182/2036	SE-LI 172/2299	CH-FM 167/2574	GR-KA 173/2254	DE-HW 159/1551	GB-WB 174/1731	ES-SC 181/2438	CH-SB 221/2877	ES-MO 171/2640	PT-MN 174/2547	HU-ZA 167/2042
Farm pro	10.6	11.3	12.4	10.3	5.2	10.5	15.9	15.3	7.3	8.9	10.6	12.0	8.2	11.1
Harv pro	9.4	12.8	7.3	10.9	9.5	9.0	8.9	8.5	3.6	9.5	5.9	12.4	13.9	7.3
Outdoor	17.1	16.5	17.2	10.4	23.1	21.0	10.3	19.2	20.4	16.9	25.8	12.2	14.4	13.4
Social	12.2	10.4	11.5	9.9	19.4	10.4	12.7	10.6	14.6	16.4	8.9	9.7	11.5	13.8
Aesthetic	12.0	11.8	14.3	9.9	12.0	10.4	14.8	14.2	13.9	12.7	12.9	9.1	11.1	11.2
Cult her	9.1	9.8	8.0	9.6	6.1	9.0	9.8	7.0	6.3	13.4	8.8	11.3	8.3	8.8
Inspiration	6.3	5.2	6.5	8.2	4.3	7.4	7.4	5.0	6.4	6.6	5.5	5.9	5.4	8.7
Existence	5.1	3.9	7.1	5.9	4.0	4.1	5.7	3.0	6.2	4.2	4.3	6.3	4.9	7.3
Habitat	9.4	9.9	8.0	11.3	11.5	9.4	7.0	7.5	11.8	7.7	12.1	7.3	8.4	9.5
Env cap	6.1	5.4	6.7	9.7	3.9	5.0	7.5	6.1	7.9	3.6	3.2	7.6	6.2	9.0

Fig. Relative proportion (%) of mapped places in each study site with comparison to total for all sites.

How are ecosystem services distributed spatially? Clustering vs. dispersion (NN statistics)

- Ecosystem services are spatially clustered.
- Most clustered patterns are found for appreciation of local culture, cultural heritage or history, farm products and sites for social interaction.

Table S4. Nearest neighbour (NN) ratio and z-score for mapped ecosystem services for each study site. Results are significant at the level of p<0.001.

	CH-FM		CH-SB		DE-HW		ES-LT		ES-MO		ES-SC	
	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score	NN ratio	z-score
Provisioning services												
Farm products	0,19	-25,46	0,23	-25,66	0,37	-18,51	0,30	-22,78	0,24	-25,79	0,42	-16,38
Harvested products	0,31	-20,00	0,32	-16,81	0,38	-13,67	0,47	-18,15	0,32	-23,59	0,59	-11,95
Cultural services												
Outdoor activities	0,36	-28,43	0,50	-25,92	0,41	-19,51	0,27	-28,88	0,33	-22,99	0,38	-24,15
Social interaction	0,25	-23,38	0,34	-20,09	0,50	-12,31	0,35	-20,25	0,21	-24,20	0,27	-27,68
Aesthetic value	0,39	-19,14	0,50	-18,35	0,43	-16,19	0,48	-17,03	0,34	-19,57	0,35	-21,84
Culture and heritage	0,27	-21,31	0,28	-21,80	0,19	-15,90	0,23	-23,32	0,14	-28,25	0,16	-29,06
Inspirational, spiritual or religious values	0,39	-16,07	0,36	-15,22	0,38	-10,44	0,38	-13,80	0,40	-14,45	0,42	-14,18
Existence values	0,27	-14,27	0,39	-13,14	0,43	-7,47	0,43	-10,54	0,27	-18,02	0,35	-12,53
Regulating/supporting services												
Habitat and biodiversity	0,40	-17,77	0,40	-21,60	0,29	-14,43	0,41	-17,68	0,27	-19,34	0,44	-14,71
Environmental capacities	0,34	-14,21	0,34	-12,19	0,26	-13,58	0,46	-11,76	0,25	-20,37	0,27	-12,95

Results: Spatial patterns of ES facilitate the identification of landscape-level hotspots

- Appreciation of farm products, harvested products, outdoor activities closest to home
- *-> easy access to nature important*
- Habitat and biodiversity and aesthetic values are the furthest
- *-> 'unusual' landscapes with less built structures more attractive?*

- Most clustered patterns (nearest neighbour statistics)
- *-> well-known places, easily targeted in landscape management*
- Most dispersed patterns
- *-> individual preferences and experiences, risk that easily traded-off by development projects*

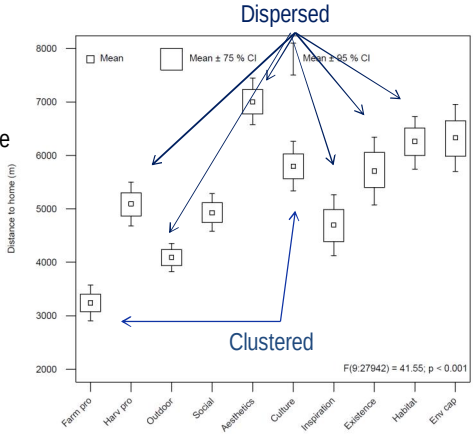


Fig. Mean distance (m) between respondent home location and mapped places for ES. CI=Confidence interval.

Results:
Respondent characteristics as determinants of ES

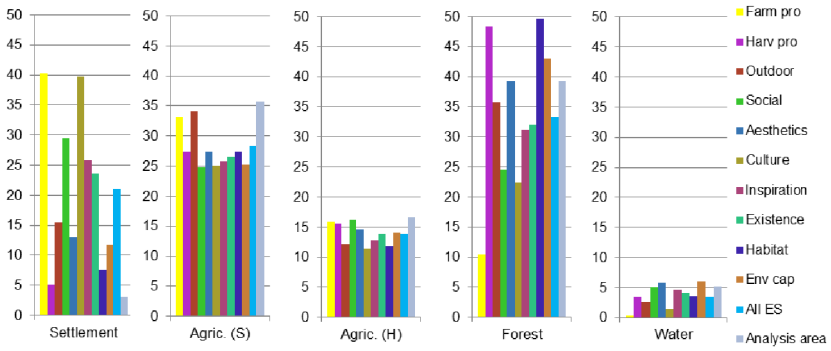
- Few relationships to gender, age, level of education and household income
- Respondents' *relationship to the study area* important:
- Appreciation for ES is higher among *landowners, land users, people who know the area well and long-term residents*

	Farm pro	Harv pro	Outdoor	Social	Aesthetic	Cult her	Inspiration	Existence	Habitat	Env cap
Field of work in agriculture	V=0.100	V=0.114	V=0.072	ns	ns	V=0.053	ns	ns	V=0.052	V=0.051
X2(df 1, N=2261)	22.53***	29.32***	11.56**			6.32*			6.21*	5.82*
No / Yes	84.6/92.3	66.1/81.5	95.6/91.1			76.0/82.4			81.4/87.2	62.6/69.9
Landownership[1]	V=0.272	V=0.098	ns	ns	V=0.050	V=0.128	V=0.123	V=0.102	V=0.051	V=0.100
X2(df 1, N=2048)	152.01***	19.68***			5.16**	33.75***	31.04***	21.41***	5.31**	20.52***
No / Yes	69.5/90.8	61.6/71.2			91.7/94.3	68.3/79.8	62.2/73.9	51.6/62.1	79.1/83.2	58.3/68.2
Self-estimated knowledge	V=0.093	V=0.162			V=0.104	V=0.090	V=0.080	V=0.100	V=0.092	V=0.101
X2(df4, N=2263)	19.62**	59.55**	ns	ns	24.36***	18.26**	14.56**	22.71***	19.16**	22.91***
Extrem. Good/Good/Moderate	84.6/84.2	72.1/70.9			94.3/93.7	79.5/74.3	69.7/68.8	56.7/57.8	85.9/81.1	67.5/62.7
Poor /Extrem. poor	78.1/70.4/83.3	60.2/42.9/25.0			90.9/86.7/66.7	78.9/63.3/66.7	65.4/52.0/58.3	59.5/38.8/16.7	78.6/73.5/66.7	60.2/48.0/33.3
Length of residency	V=0.126	V=0.140			V=0.068	V=0.145				
X2(df3, N=2144)	34.0***	42.0***	ns	ns	9.90*	45.30***	ns	ns	ns	ns
0-5 /6-15 yrs	73.3/75.6	52.4/61.4			89.5/93.7	59.2/71.9				
16-30/>31 yrs	83.6/86.6	69.1/73.4			91.5/94.6	76.0/80.7				

Table. Relationship between mapped values and respondent characteristics presented as percentage of respondents who mapped specific ecosystem service in each variable category with Chi square test of significance of association (***=p<0.001, **=p<0.01 and *=p=<0.05) and Cramer's V test measuring strength of association (0.0 to <0.1 negligible, ≥0.1 to <0.2 weak, ≥0.2 to <0.4 moderate association).

Results: Landscape characteristics as determinants of ES

Mapped places characterized mostly by forest (31.4% of area in mapped locations), simplified agricultural land (28.7%), urban and infrastructure land (21.1%) and heterogeneous agricultural land (14.8%). Only 4.0% of land in mapped locations are water and wetlands



Relative share (%) of each land cover class in 250 m buffer around each mapped location categorized per ecosystem service type. For comparison, the total share of all ecosystems services and each specific land cover class in the analysis area are also shown.

Results: Landscape characteristics as determinants of ES

Settlement areas are hotspots for all ES - particularly over-represented farm products, culture and heritage and social interaction

-> In terms of farm products sold in villages, settlement land cover is like an ambassador for ES produced in the surrounding agricultural land (ES flows)

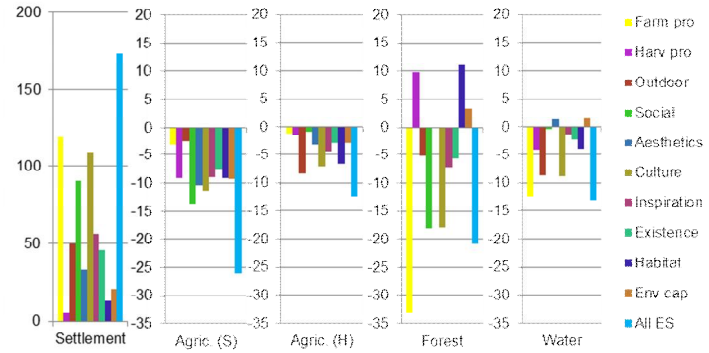


Fig. z-Scores (y-axis) of mapped ecosystem services by land cover class (x-axis) for each ecosystem service and all services together. Z-Score bars higher than +1.96 and lower than -1.96 indicate that the specific ecosystem service is statistically significantly ($p \leq 0.05$) over- or under-represented in a specific land cover class based on the proportion of that land cover class in the analysis area.

Results: Landscape characteristics as determinants of ES

- Generalized Linear Mixed Models (*GLMM*):
  - share of land cover class
  - land cover richness
  - share of conservation area
  - accessibility (distance to home, length of roads and paths, average slope)
- *Accessibility the most significant* predictor of the appreciation of ES
- ES sum and diversity increase with LC richness

  à *mosaic landscapes favored by people*, importance of multifunctionality and spatial patterns for generating socio-cultural values

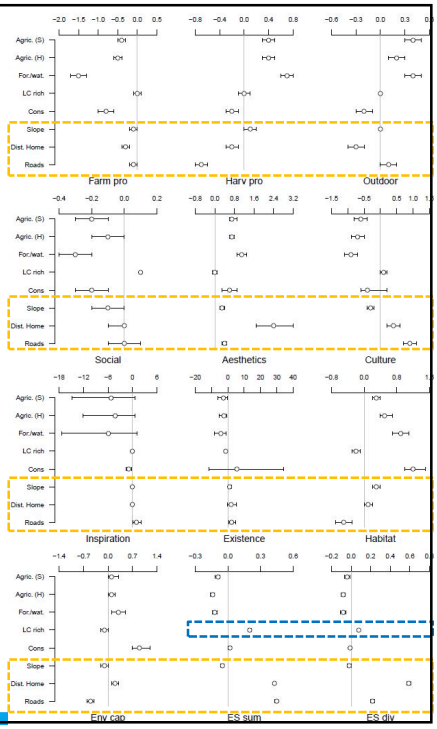
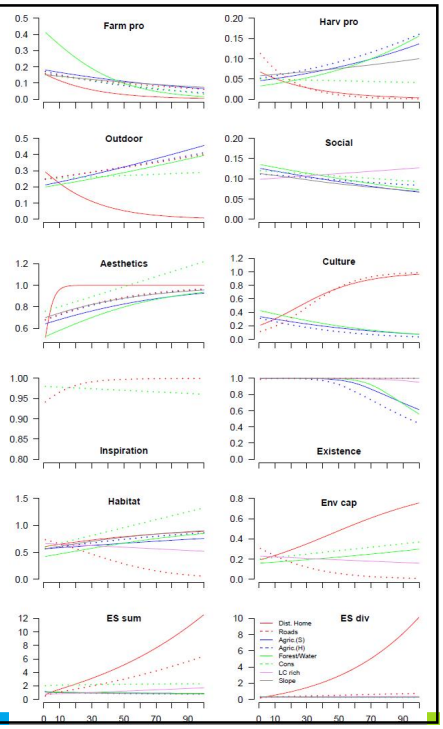


Fig. Parameter estimates for the GLMM based on summaries of the marginal posterior distributions of the predictors.

- Partial dependence plots between ES occurrence datasets and landscape characteristics predictors, as obtained from the GLMM analysis. Curves indicate how the probability that the response variables (individual ES, ES sum and ES diversity displayed on vertical axis) will occur varies in relation to landscape characteristics (share of land cover class (Agric. (S)=simplified agricultural land, Agric. (H)=heterogeneous agricultural land), land cover richness (LC rich), share of conservation area (Cons), average slope (Slope), distance to home (Dist. home), and length of roads and paths (Roads), displayed on horizontal axis, normalized to 0-100 range). The curves are only presented for the influential predictors (i.e. the bolded ones in Table S7). Partial dependence plots were created following the method suggested by Elith et al. (59).



Conclusions:
Socio-cultural ES assessment through PPGIS

- Participatory mapping provides a means of *assessing the less tangible, abstract, symbolic, and intrinsic values that landscapes and ecosystems provide to people*, the lack of which has been a recurring criticism of the ES framework (Daniel et al., 2012, Setten et al., 2014)
- *Complement biophysical and economic* valuation approaches
- Potential for identifying ES *trade-offs* and for *extrapolation* and *upscaling*
- *Subjective valuation* of landscapes and fostering *public participation* are also among *key priorities in landscape assessment* in Europe




Conclusions: Management of multifunctional landscapes

- Agricultural land (28-37% of the Earth's surface) has a key role in *safeguarding ES – multifunctional production systems* crucial
- Multifunctionality of rural areas globally promoted under *"integrated landscape management"* (ILM) (Denier et al., 2015)
  - emphasizes *local practices and values* on land and are a useful guide for the *sustainable stewardship* and *unique and contextual* sustainable landscape solutions
- *Participatory mapping of place-based ES* an *operational* model for planning and implementing ILM (Cowling et al. 2008, Sayer et al., 2013)
  - inclusion of *local-level perspectives* and *holistic landscape approach*
  - promoting *contextualized and socially acceptable* public policies for ES management
  - counteracting the development of simplified, productive, mono-functional landscapes in which *traditional activities* have been abandoned (IPBES, 2018)
  - reinforcing the weak link *from ES assessment to decision-making*

Participatory mapping of landscape values – so what?

- Operational model for planning and implementing Integrated Landscape Management
- Inclusion of local-level perspectives and holistic landscape approach
- Addition of a perception-based perspective into discussion of landscape multifunctionality
- Promotion of contextualized and socially acceptable public policies for landscape management
- Reinforcing the weak link from ecosystem services assessment to decision-making

Thank you!

Contact: Nora Fagerholm, Department of Geography and Geology, University of Turku, nora.fagerholm@utu.fi

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