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Mapping Ecosystem Services: Using Remote Sensing Data To Estimate Ecosystem Service Supply

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Introduction

Mapping ecosystem services (ES) has been mainly based on land cover approaches in combination with expert knowledge or in-situ measurements so far [1, 2]. Remote sensing (RS) enables rapid and continuous assessments, but also detection of changes of ecosystem properties at different scales. In particular imaging spectroscopy (IS) allows the retrieval of various ecosystem parameters including processes related to biogeochemical cycles and their changes in ecosystems. This study aims to map ecosystem services continuously across different ecosystem types using IS data. We modified the remote sensing approach of Homolová et al. [3], assessed additional ecosystem properties and derived them over different land cover types. Further, we provide a conceptual framework to combine individual ES maps according to the specific needs of stakeholders.

Methods

Test site and data

IS data of the Eastern part of Lake Geneva and surroundings (Switzerland) were acquired by the Airborne Prism Experiment (APEX) sensor on May 14th 2013 (Fig. 1a). The scene was radiometrically calibrated converting digital numbers to radiance values [4, 5], georectified using PARGE [6] and atmospherically corrected using ATCOR4 [7]. The GIS data of boat routes, harbours, accessibility to the lakeside and forest patches were digitized in ArcGIS.

Estimation of ecosystem properties and services

- Estimation of ecosystem properties based on spectral indices and GIS analyses using expert knowledge
- Total ES map based on weighting ecosystem properties and services to express stakeholder preferences (Tab. 1)
- Combination of ecosystem properties to estimate ES according to Lavorel et al. [2] (Tab. 2)

Table 1 Ecosystem service priorities of different stakeholders. Depending on stakeholder preferences ES can be weighted differently resulting in stakeholder specific individual and total ES maps.

Stakeholder	Provisioning ES				Regulating ES					Cultural ES	
	Crops	Timber	Forage	Freshwater	Air quality	Erosion control	Water purification	Climate regulation	Pollination	Recreation	Tourism
Farmer	++	+	++	0	--	+	--	--	++	0	+
Fisheries	--	--	--	++	--	+	++	--	--	0	0
Hydropower companies	0	+	0	+	0	++	+	0	0	0	0
Conservationists	--	--	--	++	++	++	++	++	++	0	-
Politicians	+	+	+	+	+	+	+	+	+	++	++
…											

Priorities:
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Results

- ES maps show high heterogeneity of ES supply within the landscape and its different ecosystems
- Total ES map with equal ES weightings displays overall ES supply. Depending on stakeholder priorities this map can look differently.

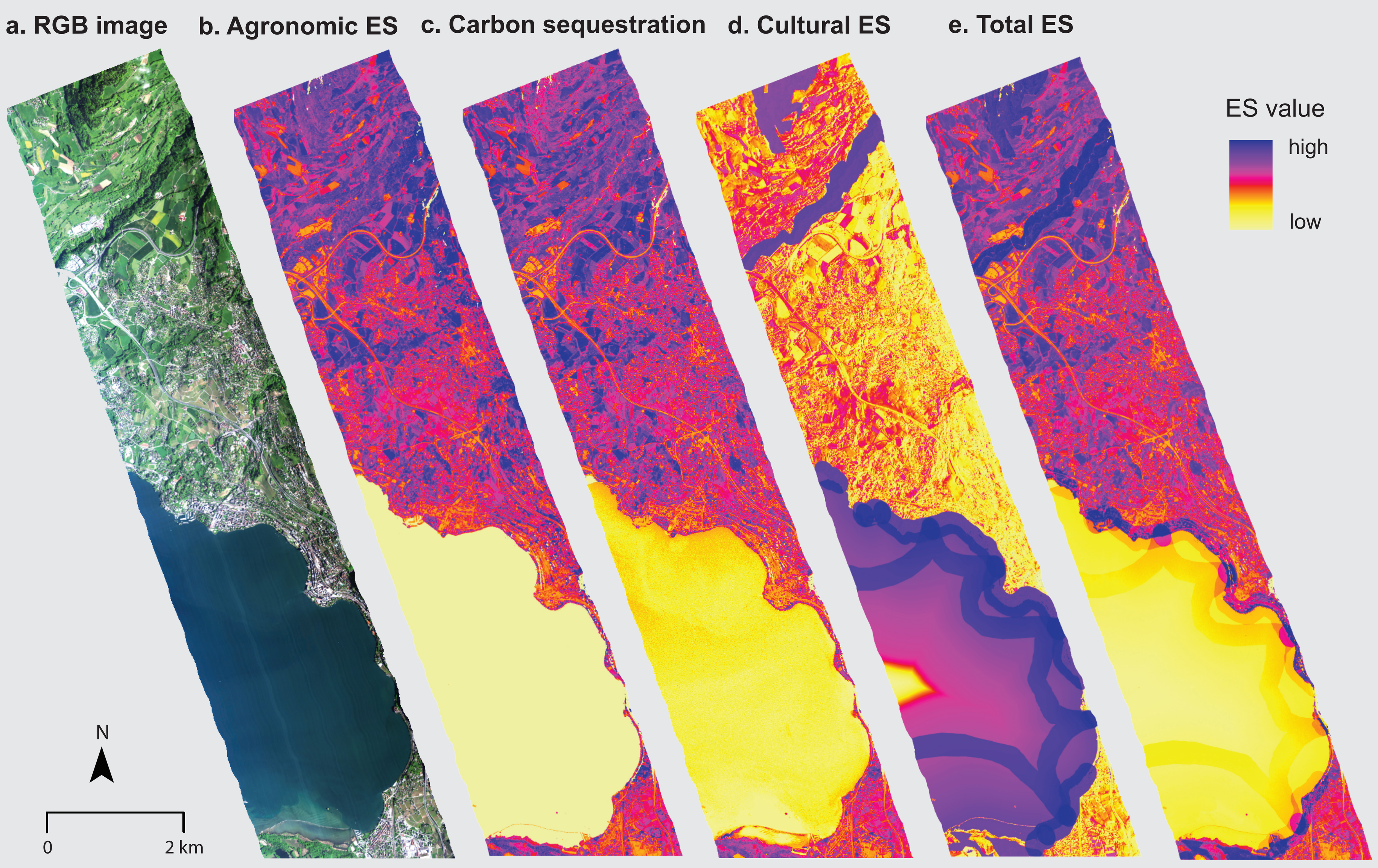

Figure 1 True colour composite and ecosystem service maps of the eastern part of Lake Geneva, Switzerland. Agronomic ES, carbon sequestration and cultural ES are products of ecosystem property combinations. They display spatial heterogeneity in ES supply within different ecosystems and Earth spheres (b-d). The total ES map shows overall ES supply (e). Areas of high overall supply match with forest areas and areas along the lakeside.The lake provides relatively few total ES, because there is little stakeholder requirements linked to an aquatic system.

Table 2 Approaches used to estimate ecosystem properties and their respective relation to agronomic ES, the ES of carbon sequestration and cultural ES. The individual ecosystem properties are aggregated to the three selected ES.

Ecosystem Service	Ecosystem property	Model type	Predictive equation	Literature
Agronomic ES	Green biomass	NDVI	Gbio=578.598*NDVI + 355.328 NDVI = $(R_{837} – R_{668})/(R_{837}+R_{668})$	Homolová et al. [3]
	Crude protein content	SML	CPC= $-0.3876*R_{2038} + 0.5639*R_{2346} + 34.085$	Homolová et al. [3]
Carbon Sequestration	Chlorophyll content	$CI_{red-edge}$	$CI_{red-edge} = 0.3418*(R_{856}/R_{724}) + 0.2075$	Clevers and Gitelson [8]
		AdChl	AdChl = $(35.75*(1/R_{666})*R_{709} - 19.3)^{1.124}$	Moses et al. [9]
Cultural ES	Species diversity	SML	SDiv= $7.945e^{-04}*R_{706}$ -5.031e-$^{04}*R_{2447}$ - 3.825e^{-02}	Homolová et al. [3]
	Boute routes	GIS	Buffer of 50 m surrounding boat routes	-
	Harbours	GIS	Buffer of 50 m surrounding harbours	-
	Access to lakeside	GIS	Buffer of 50 m to the lakeside	-
	Area of forest patches	GIS	Area of forest patches in m^2	-
	Distance to shore	GIS	Distance to the shoreline from the lake in m	-
	Litter mass	SML	Litt = $0.158*R_{868} – 0.180*R_{1160} + 0.242*R_{2306} – 73.153$	Homolová et al. [3]

NDVI = normalized difference vegetation index; SML=stepwise multiple linear regression; $CI_{red-edge}$ = Chlorophyll red-edge index; AdChl=Advanced chlorophyll index; R=reflectance.

Conclusion & Outlook

Our study demonstrates the usefulness of IS data for mapping ES continuously across different land cover types. We show the high heterogeneity of ES supply within a landscape and its different ecosystems. Further investigations in ES mapping are required. Key issues are the use of field data to verify the ES maps, the selection of additional ecosystem properties and services, retrievable from IS data, and the combination of ecosystem properties to estimate ES. Besides, stakeholders will be included in the definition and mapping process to generate deliverables that allow improving their decision-making.

References
1. F. Kienast, J. Bolliger, M. Potschin, R. S. de Groot, P. H. Verburg, I. Heller, D. Wascher, and R. Haines-Young, "Assessing landscape functions with broad-scale environmental data: insights gained from a prototype development for Europe," Environmental management, vol. 44, pp. 1099-120, 2009.
2. S. Lavorel, K. Grigulis, P. Lamarque, M.-P. Colace, D. Garden, J. Girel, G. Pellet, and R. Douzet, "Using plant functional traits to understand the landscape distribution of multiple ecosystem services," Journal of Ecology, vol. 99, pp. 135-147, 2011.
3. L. Homolová, M. E. Schaepman, P. Lamarque, J. G. P. W. Clevers, F. de Bello, W. Thuiller, and S. Lavorel, "Comparision of remote sensing and plant trait-based modelling to predict ecosystem services in subalpine grasslands," Ecosphere, vol. 5, 2014.
4. M. Jehle, A. Hueni, A. Damm, P. D'Odorico, J. Weyermann, M. Kneubühler, D. Schläpfer, M. E. Schaepman, and K. Meuleman, "APEX - Current status, performance and validation concept," 2010, pp. 533-537.
5. A. Hueni, K. Lenhard, A. Baumgartner, and M. E. Schaepman, "Airborne prism experiment calibration information system," IEEE Transactions on Geoscience and Remote Sensing, vol. 51, pp. 5169-5180, 2013.
6. D. Schläpfer and R. Richter, "Geo-atmospheric processing of airborne imaging spectrometry data. Part 1: Parametric orthorectification," International Journal of Remote Sensing, vol. 23, pp. 2609-2630, 2002.
7. R. Richter and D. Schläpfer, "Geo-atmospheric processing of airborne imaging spectrometry data. Part 2: Atmospheric/topographic correction," International Journal of Remote Sensing, vol. 23, pp. 2631-2649, 2002.
8. J. G. P. W. Clevers and A. A. Gitelson, "Remote estimation of crop and grass chlorophyll and nitrogen content using red-edge bands on sentinel-2 and-3," International Journal of Applied Earth Observation and Geoinformation, vol. 23, pp. 344-351, 2013.
9. W. J. Moses, A. A. Gitelson, S. Berdnikov, V. Saprygin, and V. Povazhnyi, "Operational MERIS-based NIR-red algorithms for estimating chlorophyll-a concentrations in coastal waters - The Azov Sea case study," Remote Sensing of Environment, vol. 121, pp. 118-124, 2012.

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