It’s about time: Advancing spatial analyses of ecosystem services and their application

Louise Willemen

In October 2019 the Ecosystem Services Partnership (ESP) held its 10th World Conference in Hannover, Germany. An event attended by around 800 participants, quite a difference from the first ESP meeting in 2008, when a small group of ecosystem services experts gathered. This tenth ESP anniversary was good moment to take stock of what the international ecosystem services community has achieved during these years. For me personally, when preparing for a keynote presentation for this event, that reflection resulted in the realization that I have made many, and written a lot about, ecosystem service maps. And, that I since 2008 have a favourite way for ending a paper, typically with a sentence along the lines of ‘hey these maps are pretty neat, as they will “strengthen sustainable management of multifunctional areas” (Willemen et al., 2008)’. Surely, maps can contribute to sustainable area management, in assessments, as a canvas to plan for action, and to guide implementation of management action. But not just any map, only if a map is useful. I regard this as something the ecosystem service community has achieved: we are now well-aware what to put on a map and how (Willemen et al., 2015; Burkhard and Maes, 2017; van Oudenhoven et al., 2018). But once we have that user-relevant, robust, well-presented map; does that map have an expiration date? What moment does a map represent, and why does that matter? In this Commentary I argue that the ecosystem service community needs to better deal with time-aspects of ecosystem service information. Here I outline the importance of including ‘time’ and ‘timing’ to advance spatial ecosystem service analyses.

1. Time

When making statements about trends in ecosystem services, or the impact of area management, we need ecosystem service maps with an expiration date: maps that clearly depict a certain moment in time that allow for comparison. For example, in an Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessment that was all about change, we looked at land degradation -the loss of ecosystem services- and at restoration –a targeted increase the of ecosystem services- (IPBES, 2018). But is that loss of ecosystem services as compared to yesterday, the start of the industrial revolution, or the situation before modern humans were strolling around, pre-Holocene? That reference point in time is key (Kotiaho et al., 2016). It defines our perception of ecosystem degradation and the arguments about the causes, and it guides policy and action (IPBES, 2018). This IPBES assessment included a map of current soil carbon and species richness compared to the estimated original natural state, around 10.000 years ago. That map gives an idea of the impact people have had, but relevance for guiding practical decision making using a reference moment that long ago is very limited.

Defining and justifying the time period of interest is one step, but how can we collect information over time to inform statements about ecosystem service change? One can say that information on ecosystem services change can be gathered in ‘people-based’ to ‘technology-based’ ways. People-based ways capture people’s perspective on change through, for example, fact sheets, surveys, and participatory mapping (Fürst et al., 2014; Evans et al., 2018; Fagerholm et al., 2019). Technology-based approaches use field sensors, harvest information from the internet, or use satellite remote sensing (van Zanten et al., 2016; Schröter et al., 2017; Norton et al., 2018). All approaches, or combinations of those, have their advantages, disadvantages and complementarity, in relation to the scope, period, and spatial extent of monitoring interest. However, all approaches have one thing in common: the resulting ecosystem service information is prone to error and bias (Schulp et al., 2014; Willcock et al., 2019). These errors and bias stem from intentional or unintentional simplifications of reality, measurement errors, and are related to the large variation within social and ecological systems, the basis of ecosystem services. So there is uncertainty in ecosystem service information. To be able to make statements about ecosystem service change over time -is a difference a true change or a result of bias or error-, information about this uncertainty is needed and should be accounted for (Bryant et al., 2018).

To move forward, I would like to see that our ecosystem service community stores and shares ecosystem service information, including uncertainty statements, in such a way that these can be used to learn about change over time, building upon the experience of ecosystem accounting initiatives (Hein et al., 2020).

2. Timing

Ecosystem services do not only change between years but also within a year. Nature has a heartbeat (https://worldmapper.org/)
How much does ecosystem service supply change within a year? Does it matter when I do ecosystem service observations? How to capture this? To answer these questions even more time-explicit information is needed. Satellites continuously track the surface of the Earth in a consistent way. Currently 4,274 satellites are orbiting the Earth (UNOOSA 2020), including the two European Space Agency’s Sentinel-2 satellites collecting freely available, global high-resolution data of the Earth surface. For most places on Earth, Sentinel-2 passes by every five days. Satellite remote sensing information has started to be used in ecosystem service assessments, for example through indices describing vegetation condition, temperature, or soil moisture (Cord et al., 2017, Ramirez-Reyes et al., 2019). These examples are ecosystem characteristics that can be highly dynamic and drive ecosystem service supply. To define what ecosystem service elements or processes can be captured by remote sensing requires the identification and testing of ‘essential ecosystem service variables’ (Balvanera et al., 2016), for example by linking satellite imagery with ground observations (del Río-Mena et al., 2020a).

Only once the link between satellite imagery—a frequent and consistent information source—and ecosystem services is established, the variation in can be described. This variation, the timing of the ecosystem service flows, determines when nature contributes to our well-being. For example, if the ground is covered with vegetation when the major rains come, as such preventing erosion (del Río-Mena et al., 2020b), or if how well we can rely on a constant supply of food and forage (Vrieling et al., 2016). Accounting for fluctuations in ecosystem service supply and demand is needed, especially for ecosystem services that cannot be ‘stored’ to be benefited from later. Having good metrics that describe these fluctuations can inform the design of monitoring schemes, and will allow to plan for change, towards managing for resilience (Fedele et al., 2017).

3. To conclude
I would like to keep on writing that one sentence, that my ecosystem service maps and spatial analyses contribute to sustainable management of our surroundings. But to do so I would say I—and we as a community—need to do a better job in dealing with time. Partnerships will continue to important for sharing information, experiences, and addressing issues from diverse angles to ultimately advance spatial analyses of ecosystem services and application, by:

Capturing relevant moments in time. Temporal information on nature’s benefits to people is key to make statement of trends, give warnings, learn from successes, and to support scenarios modelling. For statements of trends and assessment of impact, we need to make and justify policy- and management-relevant comparisons.

FAIR diverse spatial data allowing for comparison over time. There is no one-size-fits-all for monitoring approaches. Currently, ecosystem service monitoring data are scattered and poorly documented. To better describe trends, we need to make a real effort in storing ecosystem service data in such a way that it is FAIR: Findable, Accessible, Inoperable, Reusable (Wilkinson et al., 2016). Systematic testing of diverse remote sensing indices. Satellite information is frequent, standardized, globally available and often freely-available. Testing is needed to find out how well remotely sensed information can capture variation ecosystem service supply and demand, and what other information sources can complement this.

Measuring fluctuation to plan for change. Nature and people are changing, also within a year. When managing and planning for sustainable management we have to account for these rhythms, explore how well supply and demand are aligned, and adjust our monitoring activities to this.

It’s about time.

Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References
Balvanera, P., A. F. Cord, F. DeClerck, E. G. Drakou, I. Geijzendorffer, G. N. Geller, D. Karp, B. Martin-Lopez, and T. Mwambwamba. 2016. Essential Ecosystem Service Variables. GEOBON Open Science Conference: Biodiversity and Ecosystem Services Monitoring for the 2020 Targets and beyond, Leipzig, Germany.
Bryan, B.P., Boruk, M.E., Hamel, P., Oleson, K.L.L., Schulp, C.J.E., Wilcock, S., 2018. Transparent and feasible uncertainty assessment adds value to applied ecosystem services modeling. Ecosyst. Serv. 35, 103-109.
Burkhard, B., Maes, J. (Eds.), 2017. Mapping Ecosystem Services. Pensof Publishers, Sofia.
Cord, A.F., Brauman, K.A., Chaplin-Kramer, R., Huth, A., Ziv, G., Seppelt, R., 2017. Priorities to Advance Monitoring of Ecosystem Services Using Earth Observation. Trends Ecol. Evol. 32, 416–428.
del Río-Mena, T., Willemen, L., Tesfamariam, G.T., Beukes, O., Nelson, A., 2020a. Remote sensing for mapping ecosystem services to support evaluation of ecological restoration interventions in an arid landscape. Ecol. Ind. 113, 106182.
del Río-Mena, T., Willemen, L., Vrieling, A., Nelson, A., 2020b. Understanding Intra-Annual Dynamics of Ecosystem Services Using Satellite Image Time Series. Remote Sensing 12, 710.
Evans, K., Guariguata, M.R., Brancalion, P.H.S., 2018. Participatory monitoring to connect local and global priorities for forest restoration. Conserv. Biol. 32, 525-534.
Fagerholm, N., Torralba, M., Meeren, G., Girardinello, M., Herzog, F., Aviron, S., Burgess, P., Crous-Duran, J., Ferreiro-Dominguez, N., Graves, A., Hartel, T., Mäćicsan, V., Kay, S., Pantera, A., Varga, A., Plieninger, T., 2019. Cross-site analysis of perceived ecosystem service benefits in multifunctional landscapes. Global Environ. Change 56, 134–147.
Fedele, G., Locatelli, B., Djoudi, H., 2017. Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosyst. Serv. 28, 43–54.
Fürst, C., Opdam, P., Inostroza, L., Luque, S., 2014. Evaluating the role of ecosystem services in participatory land use planning: proposing a balanced score card. Landscape Ecol. 29, 1435–1446.
Hein, L., Bagstad, K.J., Obst, C., Edens, B., Schenau, S., Castillo, G., Soulard, F., Brown, C., Driver, A., Bordi, M., Struerer, A., Harris, R., Caparrós, A., 2020. Progress in natural capital accounting for ecosystems. Science 367, 514–515.
IPBES, 2018. The IPBES assessment report on land degradation and restoration. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.
Kotiaho, J.S., ten Brink, B., Harris, J., 2016. A global baseline for ecosystem recovery. Nature 532, 37.
Norton, L.R., Smart, S.M., Maskell, L.C., Henny, P.A., Wood, C.M., Keith, A.M., Emmett, B.A., Cosby, B.J., Thomas, A., Scholefield, P.A., Greene, S., Morton, R.D., Rowland, C.S., 2018. Identifying effective approaches for monitoring national natural capital for policy use. Ecosyst. Serv. 30, 98–106.
Ramirez-Reyes, C., Brauman, K.A., Chaplin-Kramer, R., Galiford, G.L., Adamo, S.B., Anderson, C.B., Andersen, C., Allington, G.R.H., et al., 2019. Reimagining the potential of Earth observations for ecosystem service assessments. Sci. Total Environ. 665, 1053–1063.
Schröter, M., Kraemer, R., Mantel, M., Kabisch, N., Hecker, S., Richter, A., Neumeier, V., Bona, A., 2017. Citizen science for assessing ecosystem services: Status, challenges and opportunities. Ecosyst. Serv. 28, 80–94.
Schulp, C.J.E., Burkhard, B., Maes, J., Van Vliet, J., Verburg, P.H., 2014. Uncertainties in Ecosystem Service Maps: A Comparison on the European Scale. PLoS ONE 9, e109643.
UNOOSA, 2020. Online Index of Ecosystems Launched into Outer Space. United Nations. Office for Outer Space Affairs.
von Oudenhoven, A.P.E., Schroer, M., Drakou, E.G., Geijzendorffer, I.R., Jacobs, S., van Bodegom, P.M., Chavee, L., Czicz, B., et al., 2018. Key criteria for developing ecosystem service indicators to inform decision making. Ecol. Ind. 95, 417–426.
von Zanten, B.T., Van Berkel, D.B., Meentemeyer, R.K., Smith, J.W., Tieskens, K.F., van Zanten, B.T., Van Berkel, D.B., Meentemeyer, R.K., Smith, J.W., Tieskens, K.F., 2014. Uncertainties in ecosystem services modeling. Ecosyst. Serv. 33, 103–109.
Vrieling, A., Mersoni, M., Mudge, A.G., Chantarar, S., Unmehosen, C.C., de Bie, K., 2016. Early assessment of seasonal forage availability for mitigating the impact of drought on East African pastoralists. Reg. Environ. Change, 174, 44–55.
Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.W., et al., 2016. The FAIR Guiding Principles for scientific data management and stewardship. Sci. Data 3, 160018.
Wilcock, S., Hootman, D.A.P., Balbi, S., Blanchard, R., Dawson, T.P., O’Farrell, J.P., Hickler, T., Hudson, M.D., Lindeskov, M., Martínez-Lopez, J., Mulligan, M., Rayers, B., Shackleton, C., Sitons, N., Villa, F., Watts, S.M., Eigenbrod, F., Bullock, J.M., 2019. A Continental-Scale-Scale Quantification of Ecosystem Service Models. Ecosystems 22, 1418–1517.
Willemen, L., Burkhard, B., Crossman, N., Drakou, E.G., Palomo, I., 2015. Editorial: Best practices for mapping ecosystem services. Ecosyst. Serv. 13, 1–5.
Willemen, L., Verburg, P.H., Hein, L., Van Mensvoort, M.E.F., 2008. Spatial characterization of landscape functions. Landscape Urban Plann. 88, 34–43.