Ecosystem service bundles

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Introduction and 'State-of-the-art'

As stated in the OpenNESS DOW, further conceptual and empirical work is needed "to translate the concepts (of Ecosystem Services (ES) and Natural Capital) into operational frameworks …. and to understand how the concepts can be embedded in existing practice, or used to transform current management and policy approaches". Much research has focused on how certain ecosystems are linked in practice to the delivery of a particular service; but in reality, given the multifunctionality of ecosystems, they are responsible for the delivery of multiple ES. Multifunctionality is also gradually being acknowledged at the conceptual level in several land-use policies, such as spatial planning, water management, forestry, green infrastructure. 'ES bundles' can make the multifunctionality concept more concrete.

The terminology found in the literature related to this topic is quite confusing. ES bundles, multifunctionality, trade-offs, synergies are often used interchangeably, so this Synthesis Paper (SP) will explore the distinction between ES bundles and multifunctionality, while another SP (Turkelboom et al., 2015) focus on trade-offs and synergies.

- Most definitions of ES **bundles** (explicit or implied) focus on the spatial coincidence of the delivery of a range of services. Some authors expand the definition: Raudsepp-Hearne et al. (2010) suggest that they are "sets of ecosystem services that repeatedly appear together across space or time", while García-Nieto et al. (2013) extend the idea to the relationships between ES supply and ES demand bundles. In the context of OpenNESS it is proposed that ES bundles are defined as "a set of associated ecosystem services that are linked to a given ecosystem and that usually appear together repeatedly in time and/or space". This definition applies to the ES supply bundles, as those on the demand side have a different nature and we define them as "A set of associated ecosystem services that are demanded by humans from ecosystem(s)". In an ecosystem or landscape, this set of services could be demanded by different groups of stakeholders. For example, in the Sierra Nevada, Iniesta-Arandia et al. (2014) found that a bundle of ecosystem services (i.e. water regulation, erosion control, soil fertility, food from traditional farming) mostly demanded by farmers who manage the land extensively, while tourists mostly demanded other bundles (recreation, aesthetic values, air purification, carbon sequestration). The first bundle is more related to agroecosystems and the second one is more related to forests, although both take place in the same multifunctional landscape.
- **Multifunctionality** is closely related to bundles, but is not the same. Multifunctionality is defined in this SP as "the characteristic of ecosystems to simultaneous perform multiple functions, that might be able to provide a particular ES bundle or bundles".

The ES within these bundles can interact with each other, potentially leading to **synergies** and **trade-offs**, although there may be limits on the extent of realisation of the synergies due to constraints on the ability of the ecosystem to deliver each service to the desired level and/or management practices and/or the negative interactions between certain ES (Table 1).

A synergy is can be viewed as where the use of one service increases the benefits supplied by another and a trade-off as a situation in which the use of one service decreases the benefits supplied by another service, now or in the future (after Bennett et al., 2009; Lavorel et al., 2011). ES synergies and trade-offs are causally linked (i.e. respond to the same driver or truly (functionally) interact), but it is not essential that they occur in the same location (e.g. upstream land-use conversion versus downstream flood risk).

Table 1: Summary of characteristics of related concepts: multifunctionality, ecosystem service bundles, ES synergies and trade-offs.

Characteristics	Multifunctionality	ES bundles	ES synergies & trade-offs
Spatial coincidence of ES	Yes	Yes	Not essential
Temporal synchronicity of ES	Yes	Yes	Not essential
Causal interrelationship between ES	Not necessary	Not necessary	Essential
Potential vs actual ES delivery	Potential	Potential	Actual

A number of **advantages** of bundling of ES have been identified including (based on UNEP, no date)[1]:

1. Identification of bundles can help to speed up ES assessments, especially of new areas: when previous assessments have shown that certain ES usually come as a bundle with other ES in a particular ecosystem, then an educated guess can be made that for similar ecosystems the same bundles can be found;
2. By considering the bundle of ES associated with an ecosystem service provider, potential synergies can be highlighted and potential trade-offs can be identified (but still need to be verified);
3. Potential reduction in management costs as multiple ES can be managed together by strategies focussing on the ecosystem service provider;
4. Potential opportunities for increasing cross-sectoral cooperation between sectors and stakeholders to work together to achieve their respective objectives. However, initial investment for cooperation will be required; and
5. Reduced risk of policy failure: by focusing on inherently synergistic bundles of ES, rather than individual ES, the risk of policies failing due to divergent management or stakeholder responses to multiple drivers is reduced.

Possible **disadvantages** include potential increased risks of policy failure if uncertainty or knowledge gaps are not taken into consideration. For example, bundles of ES are often displayed on maps, which have an air of authority (Hauck et al, 2013), but rarely communicate the underlying assumptions. In addition, ES bundles give an indication of potential delivery of ES, but without local verification of the actual ES delivery, policy decisions could result in undesirable results. Also, ecosystem management strategy based on bundling ES may serve the interests of some stakeholders above others, which may lead to issues in distributive impacts, legitimacy and power asymmetries (Daw et al., 2011; Felipe-Lucia et al., in press). There is a lack of knowledge and some disagreement about how often ES co-occur spatially and the mechanisms behind this coincidence are often not assessed (Bennett et al., 2009). Addressing this is important for analysing synergies and trade-offs (Turkelboom et al., 2015).

Integrating ecosystem multifunctionality and bundles into assessments and tools is proving quite challenging and a number of **different methods** have been used for identifying and analysing ES bundles. Initial identification is most commonly done by the mapping the spatial coincidence of ES (e.g. Nelson et al., 2009). Some studies enhance this basic land use/land cover association approach by using:

- additional biophysical datasets, such as soil and hydrological data (Kienast et al., 2009; van der Biest et al., 2013);
- indicators of biophysical and social properties of the land for specific ES (de Groot et al., 2010);
- information on condition or on level of regulation (e.g. protected areas etc.) or accessibility of areas (Kopperoinen et al., 2015);
- Service Providing Units (the ecosystem structures and processes that provide a specific ES at a particular spatial scale) as the basis for analysis (García-Nieto et al., 2013).

Alternatives to mapping the spatial coincidence of ES bundles include using multivariate techniques, such as cluster analysis (Raudsepp-Hearne et al., 2010) and principal components analysis (Maes et al., 2012). A

[1] http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCoQFjAA&url=http%3A%2F%2Fwww.unep.org%2Fecosystemmanagement%2FPortals%2F7%2FDocuments%2FEcosystems-Management-Introduction.pdf&ei=azuVVdjaLejfywPJnqroCg&usg=AFQjCNFQfiufS6vLchta4Fvwktbr2gxiBw&bvm=bv.96952980,d.bGQ

pairwise comparison of ES in 137 municipalities in Quebec, found spatial coincidence between all regulating services, with negative associations particularly occurring between the two intensive provisioning services, crop and pork production, and all other services (Rausepp-Hearne et al., 2010). The overall findings of Maes et al. (2012), Martín-López et al. (2012) and García-Nieto et al. (2013) were similar, with negative associations primarily occurring between provisioning and other service categories. It is important to recognise that the nature of these associations may depend on the spatial and temporal scale being considered. Bayesian Belief Networks which allow modelling and mapping of multiple services have been used for an 'ES bundle index' (van der Biest et al., 2013). It combined land use and biophysical data to calculate ES provision indicator scores for each ES, which was weighted according to various hypothetical management strategies in order to provide spatially explicit optimisation scenarios for decision-makers. A comprehensive overview of ES bundle methods is provided by Mouchet et al. (2014).

The social dimension of ES increasingly is incorporated into bundling. For example, Reyers et al. (2013) argue for a social–ecological systems (SES) approach, moving beyond ecological considerations of ES bundle provision to include the social factors that produce ES, as well as benefits to humans and their well-being (Jax and Heink, 2015). For example, Martín-López et al. (2012) analysed social preferences using redundancy analysis and hierarchical cluster analysis to identify ES bundles on the demand side, while García-Nieto et al. (2013) mapped both the supply of and the demand for ES. Raudsepp-Hearne et al. (2010) were able to map their ES bundles onto landscape social–ecological subsystems. The SES approach, however, may pose challenges for good governance (see Görg et al., 2015).

Some studies have extended the analysis to consider links between the conservation of ES bundles and biodiversity (e.g. Nelson et al., 2009; Schneiders et al., 2012, Bai et al., 2012; Maes et al., 2012). Maes et al. (2012), for example, explored the relationship between ES and "biodiversity", as represented by mean species abundance (MSA), tree diversity and the percentage of land covered by Natura 2000 sites. They found significant positive correlations between these factors. In addition, Martín-López et al. (2012) and García-Nieto et al. (2013) have explored the effects of different conservation (management) strategies. However, neither land use intensification nor strict conservation strategies (or land abandonment) can promote the provision of a diverse set of ecosystem services (Palomo et al., 2014).

Issues to be discussed during the lifetime of OpenNESS

1. How to fit ES bundles into the cascade (or any other proposed) framework, e.g. how to explicitly capture multiple functions, services and benefits?
2. How to integrate ES bundles into assessments and tools?
3. How power asymmetries among institutions might influence multifunctionality and ES bundles?
4. How does ecosystem management affect ES bundles and the value of the ES they deliver? Can we identify leverage points where a small change in management can impact the delivery of ES bundles, reduce trade-offs and lead to substantial benefits?
5. How to reduce the potential risk for policy failure by the policy use of ES bundles (e.g. equalizing potential ES delivery with actual delivery, equity issues)?
6. How do ES bundles and managing ES as bundles affect the four challenges?

Significance to OpenNESS and specific Work Packages

WP1: The integration of ES bundles into the concepts and frameworks is fundamental, including the spatial and temporal variations in their delivery of ES.
WP2: The examination of existing and forthcoming EU and national regulatory frameworks addressing ES and natural capital should also see if ES bundles are considered, as this has implications for WP6. ES bundles are also relevant to potential synergies and trade-offs between EU regulatory frameworks and the analysis of how individual or a mix of policy interventions might mitigate or manage impacts on ES and NC.
WP3: How to assess ES bundles? What is the role of different biodiversity components in the provision of ES bundles?
WP4: How well do the hybrid and integrated methodologies being developed enable the valuation of multiple uses (ES bundles)? ES bundles are a challenge for non-market valuation methods because the

focus on marginal changes often leads to the valuation of incremental changes in single ES. Discussion is needed with WP1 and WP3 about how the concept of ES bundles will be used to assess and value multifunctionality in the case studies (WP5), and how multi-functionality is related to monetary assessments of policy mixes (WP2).

WP5: The concept of ES bundles can be used to assess multifunctionality in landscapes of the case studies which are also an opportunity to explore and test some of the gaps in our understanding of the ES bundle concept and its operationalization.

WP6: Is additional work needed on policy applications involving ES bundles and feedback processes at different scales? How can the concept and operationalization of ES bundles be translated into policy recommendations and integrated into the Menu of Multi-Scale Solutions and associated datasets?

Relationship to the four challenges

Human well-being: Little is known about how changes in ES bundle delivery will affect human well-being, but it is a component of the CBD Target 14.	**Sustainable Ecosystem Management:** ES bundles may represent opportunities for more sustainable management, by maintaining stocks and enhancing sustainable flows of a range of ES from ecosystems while preserving their ecological value and biological diversity.
Governance: Cross-sectoral policies and governance will be needed to ensure the sustainable delivery of ES bundles	**Competiveness:** Stable ES provision via bundles may enhance stability and resilience of private sector initiatives depending on natural resources and ecosystems (e.g. agriculture, nature-based tourism), and hence strengthen competitiveness.

Recommendations to the OpenNESS consortium

To (i) adopt the definitions of ecosystem supply and demand bundles and multifunctionality as given on page 1 (ii) not just focus on individual ES, but constantly evaluate whether the ecosystem or landscape is providing multiple ES. If we can embed ES bundles in all aspects of the research, we should end up with a more realistic/holistic operationalization of ES.

Suggested three "must read" papers

Bennett E.M., Peterson G.D. and Gordon L.J. (2009): Understanding relationships among multiple ecosystem services. *Ecology Letters* **12**: 1394–404.

Raudsepp-Hearne, C., Peterson, G.D. and Bennett, E.M. (2010): Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proceedings of the National Academy of Sciences* **107(11)**: 5242-5247.

Mouchet, M., et al. (2014): An interdisciplinary methodological guide for quantifying associations between ecosystem services. *Global Environmental Change* **28:** 298-308.

Further cited papers

Bai, Y., *et al.* (2012): Spatial characteristics between biodiversity and ecosystem services in a human-dominated watershed. *Ecological Complexity* **8**: 177–183.

Daw T., et al. (2011): Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. *Environ Conserv*. **38**: 370–379. doi:10.1017/S0376892911000506

de Groot, R.S., *et al.* (2010): Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity* **7(3)**: 260-272.

Felipe-Lucía M., *et al.* (in press): Ecosystem services flows: why stakeholders' power relationships matters. PLoS ONE. DOI: 10.1371/journal.pone.0132232

García-Nieto A.P., *et al.* (2013): Mapping forest ecosystem services: From providing units to beneficiaries. *Ecosystem Services* **4:** 126-138.

Görg, C., *et al.* (2015): Good Governance. In: Potschin, M. and K. Jax (eds): OpenNESS Ecosystem Service Reference Book. EC FP7 Grant Agreement no. 308428. Available via: www.openness-project.eu/library/reference-book

Hauck, J., *et al.* (2013): Maps have an air of authority: potential benefits and challenges of ecosystem service maps at different levels of decision making. Ecosystem Serv. **4**: 25–32. http://dx.doi.org/10.1016/j.ecoser.2012.11.003.

Iniesta-Arandia, I., *et al.* (2014): Socio-cultural valuation of ecosystem services: uncovering the links between values, drivers of change and human well-being. Ecological Economics **108**: 36-48.

Jax, K. and U. Heink (2015): Human Well-Being. In: Potschin, M. and K. Jax (eds): *OpenNESS Ecosystem Service Reference Book*. EC FP7 Grant Agreement no. 308428.

Kienast, F., *et al.* (2009): Assessing landscape functions with broad-scale environmental data: insights gained from a prototype development for Europe. *Environmental Management* **44:** 1099–1120.

Kopperoinen, L., *et al.* (2015): International experiences and mapping approaches in ecosystem service valuation. In *Towards a sustainable and genuinely green economy. The value and social significance of ecosystem services in Finland (TEEB for Finland)*. Synthesis and roadmap: Jäppinen, J.-P. & Heliölä, J. (eds.). The Finnish Environment 1en/2015. The Finnish Ministry of Environment, Helsinki: 46-55.

Lavorel, S., *et al.* (2011): Using plant functional traits to understand the landscape-scale distribution of multiple ecosystem services. Journal of Ecology, **99**, 135–147.

Maes, J., *et al.* (2012): Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. *Biological Conservation* **155**: 1–12.

Martín-López, B., *et al.* (2012): Uncovering ecosystem service bundles through social preferences. *PLoSONE* **7:** 1-11.

Nelson, E. *et al*. (2009): Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. *Frontiers in Ecology and the Environment* 7, 4–11.

Palomo, I., *et al*. (2014): Deliberative mapping of ecosystem services within and around Doñana National Park (SW Spain) in relation to land use change. Regional Environmental Change. **14(1):** 237-251.

Reyers, B., *et al.* (2013): Getting the measure of ecosystem services: a social–ecological approach. *Frontiers in Ecology and the Environment* **11(5)**: 268-273.

Schneiders, A., *et al.* (2012): Biodiversity and ecosystem services: complementary approaches for ecosystem management? *Ecological Indicators* **21**:123–133.

Turkelboom *et al*. (2015): Ecosystem services trade-offs and synergies. In: Potschin, M. and K. Jax (eds): OpenNESS Ecosystem Service Reference Book. EC FP7 Grant Agreement no. 308428. Available via: www.openness-project.eu/library/reference-book

Van der Biest, K., *et al.* (2013): Chapter 20 - EBI—An Index for Delivery of Ecosystem Service Bundles. In *Ecosystem Services*. S. Jacobs, N. Dendoncker and H. Keune (eds.). Boston, Elsevier: 263-272.

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