Elsevier Editorial System(tm) for Journal of Environmental Management

Manuscript Draft

Manuscript Number: JEMA-D-18-03609R2

Title: A novel telecoupling framework to assess social relations across spatial scales for ecosystem services research

Article Type: Research Article

Keywords: cross-scale analysis; inequity; scale mismatch; power relations; stakeholders; telecoupling

Corresponding Author: Professor Berta Martin-Lopez, PhD

Corresponding Author's Institution: University of Leuphana

First Author: Berta Martin-Lopez, PhD

Order of Authors: Berta Martin-Lopez, PhD; Maria R Felipe-Lucia, PhD; Elena M Bennett, PhD; Albert Norström, PhD; Garry Peterson, PhD; Tobias Plieninger, PhD; Christina C Hicks, PhD; Francis Turkelboom, PhD; Marina García-Llorente, PhD; Sander Jacobs, PhD; Sandra Lavorel, PhD; Bruno Locatelli, PhD

Abstract: Access to ecosystem services and influence on their management are structured by social relations among actors, which often occur across spatial scales. Such cross-scale social relations can be analyzed through a telecoupling framework as decisions taken at local scales are often shaped by actors at larger scales. Analyzing these cross-scale relations is critical to create effective and equitable strategies to manage ecosystem services. Here, we develop an analytical framework -i.e. the 'cross-scale influence-dependence framework'- to facilitate the analysis of power asymmetries and the distribution of ecosystem services among the beneficiaries. We illustrate the suitability of this framework through its retrospective application across four case studies, in which we characterize the level of dependence of multiple actors on a particular set of ecosystem services, and their influence on decision-making regarding these services across three spatial scales. The 'cross-scale influence-dependence framework' can improve our understanding of distributional and procedural equity and thus support the development of policies for sustainable management of ecosystem services.

Title page

A novel telecoupling framework to assess social relations across spatial scales for ecosystem services research

Berta Martín-López[1*], María R. Felipe-Lucia[2,3,4*], Elena M. Bennett[5], Albert Norström[6], Garry Peterson[6], Tobias Plieninger[7], Christina C. Hicks[8], Francis Turkelboom[9], Marina García-Llorente[10], Sander Jacobs[9], Sandra Lavorel[11], Bruno Locatelli[12,13]

*These authors contributed equally to the development of this manuscript.

1. Faculty of Sustainability, Institute for Ethics and Transdisciplinary Sustainability Research, Leuphana University, Lüneburg, Germany. martinlo@leuphana.de

2. Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany

3. German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Germany

4. Instituto Pirenaico de Ecología, Consejo Superior de Investigaciones Científicas (CSIC), Zaragoza, Spain.

5. Department of Natural Resource Sciences and McGill School of Environment, McGill University, Ste-Anne-de-Bellevue, QC, Canada.

6. Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden.

7. Social-Ecological Interactions in Agricultural Systems, University of Kassel and University of Göttingen, Germany

8. Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YW, UK.

9. Research Group Nature and Society, Research Institute of Nature and Forest Research (INBO), Brussels, Belgium.

10. Department of Applied Research and Agricultural Extension, Madrid Institute for Rural, Agricultural and Food Research and Development (IMIDRA), Alcalá de Henares, Spain.

11. Laboratoire d'Ecologie Alpine, Centre National de la Recherche Scientifique (CNRS) and Université Grenoble-Alpes, Grenoble, France.

12. Agricultural Research for Development (CIRAD), University of Montpellier, Montpellier, France.

13. Centre for International Forestry Research (CIFOR), Lima, Peru.

Corresponding author: Berta Martín-López, Faculty of Sustainability, Institute for Ethics and Transdisciplinary Sustainability Research, Leuphana University, Universitätsallee 1, C11.210e, 21335 Lüneburg, Germany. Telephone: +49 04131 6771725; E-mail: martinlo@leuphana.de

Highlights:

- We propose a framework to disentangle cross-scale relations among actors regarding ecosystem services
- Cross-scale relations among actors shape access and supply of ecosystem services
- Analyzing cross-scale relations among actors reveals inequalities and power asymmetries

Abstract

Access to ecosystem services and influence on their management are structured by social relations among actors, which often occur across spatial scales. Such cross-scale social relations can be analyzed through a telecoupling framework as decisions taken at local scales are often shaped by actors at larger scales. Analyzing these cross-scale relations is critical to create effective and equitable strategies to manage ecosystem services. Here, we develop an analytical framework –i.e. the 'cross-scale influence-dependence framework'- to facilitate the analysis of power asymmetries and the distribution of ecosystem services among the beneficiaries. We illustrate the suitability of this framework through its retrospective application across four case studies, in which we characterize the level of dependence of multiple actors on a particular set of ecosystem services, and their influence on decision-making regarding these services across three spatial scales. The 'cross-scale influence-dependence framework' can improve our understanding of distributional and procedural equity and thus support the development of policies for sustainable management of ecosystem services.

Keywords: cross-scale analysis; inequity; scale mismatch; power relations; stakeholders; telecoupling

1. Introduction

Ecosystem services – i.e. the benefits people obtain from ecosystems (MA, 2005) - are produced by the dynamic interactions of people and nature (Díaz et al., 2015). These interactions can operate at multiple spatial scales and can lead to a variety of scale mismatches (Cumming et al., 2006; Scholes et al., 2013). Scale mismatches complicate the management of ecosystem services by producing complex ecosystem service trade-offs and conflicts among actors (Bennett et al., 2009; Raudsepp-Hearne and Peterson, 2016). For instance, a mismatch between governance scales and the scales at which people benefit from services such as fodder and soil fertility was found in Doñana (Spain): whilst these services are used by local people, their management depends on institutions operating at national and regional scales (Gómez-Baggethun et al., 2013). This mismatch jeopardizes ecosystem services provision and produces conflicts among actors (Gómez-Baggethun et al., 2013). In addition, social relations, particularly power relations, mediate actors' ability to manage and access ecosystem services (Berbés-Blázquez et al., 2017, 2016). However, disentangling how cross-scale social relations impact the distribution of ecosystem services among actors remains a central challenge in ecosystem service research.

To address this challenge, telecoupling has proved to be a crucial framework to examine the social-ecological interactions across regions and scales (Liu et al., 2013). Telecoupling differs from the teleconnection framework as the former refers to coupled social-ecological dynamics across spatially distant regions, while the later only includes biophysical phenomena (Lenschow et al., 2015; Liu et al., 2013). Whilst previous work has considered the role of teleconnections in the supply of ecosystem services (for example, the effect of global transport of dust from Sahara on soil formation in distant places (Muhs et al., 2007)), the consideration of social aspects across scales remains understudied. In fact, despite an increasing focus on telecoupling in sustainability and

social-ecological research (e.g. Fischer et al., 2015; Liu et al., 2013; Reid et al., 2010; Seto et al., 2012), to disentangle cross-scale social relations that underpin the management of ecosystem services and their distribution across actors remains a challenge.

Here, we propose the 'cross-scale influence-dependence' framework that applies a telecoupling lens to assess how social relations across scales influence the supply and distribution of ecosystem services among actors. The 'cross-scale influence-dependence' framework identifies i) how actors at different scales depend on ecosystem services in a particular landscape, ii) how those actors influence the decision-making regarding ecosystem services management at different scales, and iii) how social relations are formed among actors across scales. We retrospectively applied the 'cross-scale influence-dependence' framework to four case studies in order to test its suitability for understanding distributional and procedural equity in ecosystem service research. Distributional equity refers to how costs and benefits, associated with ecosystem services, are allocated among actors, while procedural equity refers to how decisions are made and by whom (McDermott et al., 2013). The case studies are not meant to be seen as vehicles for obtaining results, but rather as vehicles for testing the framework and generate new hypothesis for future research.

The application of the 'cross-scale influence-dependence' framework to the four case studies can illustrate how social relations across scales influence the supply and distribution of ecosystem services and, thus, actors' level of vulnerability. Vulnerable actors are those highly dependent on ecosystem services to fulfill their wellbeing, but with little influence in decisions regarding the management or access to ecosystem services. As the lack of access, which is defined as the ability to benefit from resources (Ribot and Peluso, 2003), has consequences on distributional equity, we then discuss how the framework can serve as a platform for future research regarding distributional

and procedural equity. Finally, we reflect on the implications of using this framework to design policies relevant for sustainability and we identify scientific hypotheses to test in future research.

2. The 'cross-scale influence-dependence' analytical framework

The starting point of the framework is a 'set of ecosystem services' provided by a certain area or landscape. The 'cross-scale influence-dependence' framework is composed of four steps (**Fig. 1**): (1) identification of the relevant actors at each spatial scale associated with a set of ecosystem services, (2) assessment of the actors' dependence on the services at each scale, (3) analysis of actors' influence on ecosystem services management at each scale, and (4) assessment of within- and cross-scale relations among actors in the management of ecosystem services. In the first step, the 'cross-scale influence-dependence' framework identifies the actors who depend on a set of ecosystem services provided in a particular landscape, and those who influence the decision-making regarding their management at the local, regional and global scale. Here, we use 'scale' in terms of the level of jurisdictions or institutions involved, and we use it interchangeably with the term 'level' (Scholes et al., 2013). The local scale includes individuals, households, communities and municipalities. The regional scale is defined by provinces or other supra-local to national level entities. The global scale refers to all jurisdictions beyond national levels.

Building on the 'interest-influence matrix' that seeks to identify and characterize actors in natural resource management (Reed et al., 2009), the 'cross-scale influence-dependence' framework focusses on actors' dependence and influence on ecosystem services at multiple spatial scales (see steps 2 and 3, respectively). In addition, the framework contributes three novel elements to the 'interest-influence matrix'. First, it

considers the actors' level of dependence on ecosystem services, rather than interest. This variation aligns with other modifications of the matrix in ecosystem service research, such as influence vs. dependence (Iniesta-Arandia et al., 2014) or use vs. ability to manage (Felipe-Lucia et al., 2015a). Second, it takes into account the multiple spatial scales at which actors depend on ecosystem services and exert influence in decision-making. By assessing the actors' level of dependence on ecosystem services, we explore their vulnerability to changes in ecosystem services provision. By considering multiple spatial scales, we appraise potential scale mismatches between dependence on and influence in decision-making of ecosystem services. These components facilitate the analysis of distributional and procedural equity in ecosystem services research. Third, it takes into account the social relations across scales that create the conditions by which different actors exert differential influence in decision-making and the management of ecosystem services. In this way, the 'cross-scale influence-dependence' framework aligns with recent approaches that highlight the importance of social interdependencies to foster collective action in ecosystem services management (Barnaud et al., 2018) and the relevance of interactions between influential and non-influential actors to understand ecosystem service trade-offs (Turkelboom et al., 2018). Yet, the 'cross-scale influence-dependence' framework moves one step further by analyzing these social relations across multiple spatial scales and, in doing so, the framework analyzes power relations. In this paper, we understand power as the ability to influence or control the behavior of other people with respect to ecosystem service governance (in the sense of 'power over', see Berbés-Blázquez et al., 2016). Thus, power relations among actors regarding ecosystem services can take many forms, such as controlling the access of other actors to ecosystem services, controlling what type of decisions other actors can make on ecosystem services use or management, and influencing other actors' knowledge.

<Insert Figure 1 around here>

The 'cross-scale influence-dependence' framework allows researchers to bridge the gap between knowledge and methods developed in natural resource management, ecosystem service research, and political ecology studies. For example, it combines knowledge and tools from natural resource management (e.g. dependence-influence matrix) and political ecology (e.g. distributional and procedural equity, access and power relations) with ecosystem services research. By bridging this gap we facilitate the operationalization of an interdisciplinary framework able to integrate social dimensions in ecosystem service research. The 'cross-scale influence-dependence' framework can be applied by using multiple methods, including both qualitative and quantitative methods. For example, cross-scale social relations can be qualitatively assessed by applying actor-linkages matrices in an expert workshop or quantitatively by conducting social network analysis. The use of multiple methods has been recommended in both political ecology and ecosystem services research to achieve the inclusion of different actors and to uncover power asymmetries (Jacobs et al., 2018; Rocheleau, 2008). **Table 1** presents some useful methodological tools to implement this framework, organized according to its four steps. Several tools might be combined within each step to triangulate results and to gain deeper knowledge.

<Insert Table 1 around here>

Step 1. Identification of social actors at multiple spatial scales associated with a particular set of ecosystem services.

The first step identifies the actors associated with a particular set of ecosystem services related in a given area. Social actors are the groups of people, individuals, organizations or corporations who depend on the ecosystem services provided by a a given area and are likely to be affected by, or have an effect on, a planning or management intervention (adapted from Reed *et al.* (2009)). Actors can be the same or different across scales. For example, although decision-makers might be different individuals across scales, decision-makers as a type of actors may appear at local, regional and global scales. In contrast, actors such as multi-national companies or scientists might be present only at a supra-local scale (**Fig. 1**).

Methodological tools to identify actors at different scales include qualitative and quantitative methods, such as participant observation, semi-structured interviews, questionnaires, focus groups and expert panels (Reed et al., 2009) (**Table 1**).

Steps 2 and 3. Determination of the level of dependence and influence of actors

The second and third steps are independent from each other and can be performed in parallel. In step 2, actors at each scale are assigned a relative score according to their dependence on ecosystem services and, in step 3, according to their capacity to influence decision-making regarding these services. We define dependence as the level by which actors' well-being relies on the defined ecosystem services. Influence is defined as the capacity of actors to determine and control management decisions related to these particular ecosystem services and thus it is related with procedural equity. Influence over management decisions can also determine access to ecosystem services by actors and, therefore, is related to distributional equity.

Methodological tools that contribute to assess the actors' level of dependence on services and influence on decision-making at different scales are participant observation (Berbés-Blázquez et al., 2017), cognitive mapping and mental models (Biggs et al., 2011), rainbow diagrams and interest-influence matrices (Reed et al., 2009), participatory and deliberative mapping (Brown and Fagerholm, 2015), and scenario planning (Peterson et al., 2003) (**Table 1**).

Step 4. Identification of within and cross-scale social relations among actors

Social relations occur both within a particular spatial scale and across scales. For instance, while some farmers may exchange seeds with their neighbors (within scale), other farmers may rely on seeds produced by a multi-national company (across scales). Social relations across scales involve the contest between local, national, and global arenas that act as locations of power (Gaventa, 2006). For example, whilst empowering local communities to construct their own voice and decisions can lead to community-based management, power shifts to globalized actors can undermine the influence of local actors in the management of ecosystem services. Nevertheless, power is continuously interrelated between local, national and global scales. Influence in decision-making at local scales is shaped by global actors and, at the same time, local actions are shaping global actors and their power (Gaventa, 2006).

Analysis of power relations include three dimensions (Lukes, 1973): overt (direct control of people's decision through e.g. incentives and force), covert (controlling how people decide) and latent (control of social narratives and discourses to the point that vulnerable actors see their situation as normal or unchangeable) (Peterson, 2000). In addition, power relations might take other forms, such as controlling the means of

197 production (e.g. Bernstein, 2010) or the accumulation of benefits derived from
198 ecosystem services supply (e.g. Ribot 1998).

199 Social and power relations can be mediated by formal institutions (i.e., laws, policies or
200 property rights), as when the farmer has a contract with the company to buy seeds, or
201 by informal institutions (i.e., customs or traditions), as when local varieties of seeds are
202 exchanged within the community. Furthermore, these power and social relations have
203 been sculpted and shaped through historical dynamics embedded in political and
204 cultural structures and processes, such as colonialism (Haraway, 1988; Harding,
205 1986).

206 Methodological tools to identify social relations among actors include network analysis
207 tools, such as social network analysis for quantitative research (Prell et al., 2009) and
208 actor-linkages matrices for qualitative research (Biggs and Matsaert, 1999), as well as
209 institutional ethnography (e.g. Grahame, 1998; Townsend, 1996) (**Table 1**).

210

211 **3. Application of the 'cross-scale influence-dependence' analytical framework to**
212 **four case studies**

213 We explored the value of our framework in four exemplary case studies that represent
214 different and contrasting social-ecological systems (**Table 2**). Two contrasting case
215 studies are presented in the main text: small scale coral reef fishing and tourism along
216 the Southern Kenyan coastline (**Section 3.1**) and traditional farming in the Nacimiento
217 watershed (Southern Spain) (**Section 3.2**). The other two case studies are presented
218 in Appendices: nature-based tourism in the Piedra river valley (Central Spain)
219 (**Appendix A**) and grass-based dairy system in Voeren (Eastern Belgium) (**Appendix**
220 **B**). In each of the case studies, we applied different methodological tools in the
221 different steps of the methodological framework, including interviews, focus groups,

63
64
65

participant observation, face-to-face questionnaires, interest-influence matrix, deliberative mapping, actor-linkages matrix and social network analysis (**Table 2**).

<Insert Table 2 around here>

3.1. Ecosystem services associated with small-scale coral reef fisheries: Southern Kenya.

The southern Kenyan coastline is situated on the east coast of Africa and covers a stretch of approximately 75 km. Dotted along this coastline are a number of small fishing communities where the fishery is characterized as a multispecies artisanal (small scale) coral reef fishery (McClanahan et al., 2008). Fishing, farming, and the informal sector engage the largest, and approximately equal, number of people in rural coastal Kenya (Cinner et al., 2010). The southern Kenyan coastline attracts a significant number of tourists every year (Hicks et al., 2009); yet, few households from this coastline are involved in the tourism industry (Cinner et al., 2010). A series of marine protected areas were instituted along the Kenyan coastline in the post-colonial era. Although this was in response to a growing tourism industry, it also had the effect of conserving the marine environment and stimulating a vibrant research environment.

Step 1. Identification of social actors associated with a particular set of ecosystem services.

By conducting nine focus groups in different coastal communities (with 4-9 participants in each group, **Table 2**), we identified the most relevant actors across scales. At a local scale, the main actors were associated with small-scale coral reef fisheries and

246 included fish workers and coastal residents. National and international actors include
247 fisheries and marine park managers and decision-makers, Kenyan and international
248 owners and employees involved in the tourism industry, and marine, fisheries, and
249 conservation scientists (**Fig. 2**) (Hicks et al., 2013). Five of these focus group
250 discussions with coastal managers, residents, and fishers were also used to identify
251 nine coral reef ecosystem services: materials, fishery, research & education, bequest,
252 culture, recreation, habitat, coastal protection, and sanitation (Hicks et al., 2015, 2013).

253

254 <Insert Figure 2 around here>

255

256 *Step 2. Assessment of the dependence level of social actors*

257 To assess the dependence on ecosystem services of the different actors, we combined
258 information from the nine focus groups with a series of individual semi-structured
259 questionnaires (*N*=180) with local fishers, national and international managers, and
260 scientists (Hicks et al., 2013, 2015; **Table 2**). The majority of fishers are local to the
261 coastline and have a very high dependence on ecosystem services (**Fig. 2a, c**).
262 Fishing, education, and habitat are by far the most important services perceived by
263 fishers (Hicks et al., 2015; Hicks and Cinner, 2014). Furthermore, 80% of rural fishing
264 households identify fishing as their primary source of income. In addition to the direct
265 benefits, fishers' identities are strongly associated with the marine environment and
266 their occupations. The majority of local residents are fishing households with a smaller
267 number engaged in the tourism sector, and few alternative livelihoods available. There
268 are clear signs of erosion along the southern Kenyan coastline and most houses are
269 constructed from material (such as wood and mud) unlikely to survive storm surge
270 events; suggesting a high dependence on regulating services for many low lying

63
64
65

coastal communities. Most of the benefits from tourism do not flow to the local communities who tend to engage in the tourism sector in an informal manner (Cinner et al., 2009). Those formally employed in the tourism industry or in positions of ownership tend to be international or elite Kenyans from up-country (**Fig. 2a, c**).

Step 3. Assessment of the influence on decision-making

The nine focus groups, and 180 individual semi-structured interviews with relevant managers, scientists and fishers were also used to assess the influence of different actors on decision-making regarding ecosystem services (**Table 2**). We established influence (as an indication of power over) through a series of questions around leadership, involvement in formal and informal resource governance organizations, engagement and influence in decision-making, and trust in other actors (Hicks and Cinner, 2014). We used these responses to qualitatively assign influence as no, limited, or large. Fish workers have no influence over this set of ecosystem services at a national or international level. At a local scale, fish workers have limited influence over decisions involving the fishery, but none over decisions involving benefits associated with tourism. The local tourism industry, which mainly involves paid workers, has limited influence over benefits associated with tourism, whereas, the national and international tourism industry have a large influence. Although conflicts sometimes occur with fish workers, limiting where local fishers can operate, the influence of the tourism industry is generally contained within the industry. Local fisheries managers have a large day-to-day influence and control over fishery and research. International policies (e.g. FAO Fisheries guidelines) which determine the frames within which national policy and plans (e.g. Fisheries Act) can be made and local management is enacted, have limited influence over fishery. At a national level, fisheries and park managers also have a large influence over research, as scientists

297 are required to apply for and abide by the relevant research regulations and permits
298 (**Fig. 2b, c**).
299
300 *Step 4. Identification of within and cross-scale social relations among actors*
301 In addition to focus groups and semi-structured questionnaires that evaluated the
302 participation of social actors in resource governance organizations and decision-
303 making processes, participant observation was applied to identify the social relations
304 among actors (**Table 2**). Scientists, managers, and the tourism industry actively
305 engaged across scales both within and across actor groups. This is principally because
306 they have formal and informal modes of communication available, and represent
307 institutions that exist at multiple scales. This cross-scale communication increases the
308 influence that these actors (managers, scientists, tourism industry) have on the local
309 level, and decreases the influence of actors with the greatest dependence on
310 ecosystem services at the local scale (fish workers, residents). Although fish workers
311 and residents do have formal channels to communicate with local managers, they do
312 not actively engage across scales, leaving them disconnected from broader decision-
313 making processes. This is particularly worrying as these are the social groups most
314 dependent on the studied set of ecosystem services. Effective channels of
315 communication are key to reducing the vulnerability of these groups. At a local level,
316 scientists pursue formal and informal communication channels with local fish workers,
317 local managers and national scientists (McClanahan et al., 2016). National scientists
318 regularly communicate with, influence, and are influenced by national managers and
319 international scientists (McClanahan et al., 2016) (**Fig. 2b**).
320
321 ***3.2. Ecosystem services associated to traditional farming in the Nacimiento***
322 ***watershed in Southeastern Spain***

63
64
65

The Nacimiento watershed in Andalusia (Southeastern Spain) is a multifunctional landscape that has been shaped by historical farming practices, such as terraces and irrigation ditches. In the last decades, much of the rural population has migrated to cities as traditional agriculture is no longer profitable. This, in turn, has led to the disappearance of distinct farming landscapes and the associated local ecological knowledge (Iniesta-Arandia et al., 2015). Today, this traditional farming landscape provides provisioning (agricultural food), regulating (erosion control and hydrological regulation), and cultural services (aesthetic landscape values and local identity) to different actors (García-Llorente et al., 2015; Iniesta-Arandia et al., 2014).

Step 1. Identification of social actors associated with a particular set of ecosystem services

By conducting interviews (*N* = 18), participant observation and face-to-face questionnaires (*N* = 181) (**Table 2**), we identified local farmers, other rural and urban people, environmental non-governmental organizations (NGOs) and nature tourists as the actors benefiting from these services (Iniesta-Arandia et al., 2014) (**Fig. 3a**). Besides these beneficiaries, decision-makers were also defined as relevant actors because they influence the management of ecosystem services by either promoting the restoration of irrigation ditches and preservation of local ecological knowledge (e.g. the managers in the Sierra Nevada protected area) or by controlling the access over and use of water resources (e.g. the National Ministry of the Environment).

<Insert Figure 3 around here>

Step 2. Assessment of the dependence level of social actors

Using the information collected through social surveys (*N* = 181, see Step 1) as well as through deliberative mapping (two workshops: *N* = 16 participants) (García-Nieto et al., 2015) (**Table 2**), we assessed the actors' level of dependence on ecosystem services. In the social survey, we provided the respondents with a list of 25 ecosystem services and asked them to select the four most important services for contributing to their wellbeing (García-Llorente et al., 2015; Iniesta-Arandia et al., 2014). To determine the level of dependence of each actor to different ecosystem services, we calculated the mean score of importance of each ecosystem service for the wellbeing of each social actor. By calculating these mean scores, we unraveled the level of reported dependence on ecosystem services by each social actor. The information collected through this survey was also used to depict an adaptation of the interest-influence matrix (Iniesta-Arandia et al., 2014) (**Table 2**). In the deliberative mapping workshops, participants first agreed on the list of the most important ecosystem services for their wellbeing identified through the surveys and then they mapped the places where different actors benefit from them (García-Nieto et al., 2015).

At the local scale, local traditional farmers were highly dependent on erosion control and hydrological regulation as these services are essential for farming, on agricultural food as subsistence agriculture was the basis of their livelihoods and on local identity as traditional farming is a key aspect of their local identity. Therefore, the disappearance of traditional farming practices strongly affected local farmers, but also affected local urban and rural inhabitants who must now import food, as well as regional rural inhabitants (**Fig. 3a**). The loss of traditional farming decreased the landscapes' aesthetic value because farming practices such as almond orchards, holm oak *dehesas* and stone terraces were perceived among the most beautiful landscapes by local farmers, other local and regional rural inhabitants and nature tourists coming from Andalusia and Spain (García-Llorente et al., 2012) (**Fig. 3a**). Although nature

374 tourists living outside the Nacimiento watershed are less dependent on ecosystem
375 services than local actors because their livelihoods do not depend on the benefits
376 derived from these ecosystems, they reported that the aesthetic value of these iconic
377 landscapes is highly important for their wellbeing as it is a source of tranquility and
378 relaxation.

379 The decline of traditional farming was also a concern for environmental NGOs and
380 decision-makers at the local scale because the preservation of the ancient irrigation
381 systems allows water infiltration and conservation of broad-leaf vegetation habitats,
382 which contribute to regulate micro-climatic conditions and create habitats for
383 endangered species (García-Llorente et al., 2016, 2015).

384

385 *Step 3. Assessment of the influence on decision-making*

386 By asking different questions (e.g. '*the village managers and politicians take into*
387 *account my opinion'*, '*I have the opportunity to participate and express my opinion in*
388 *decision-making*') in the face-to-face questionnaires (*N* = 181, see also Steps 1 and 2)
389 (Iniesta-Arandia *et al.* (2014)), we assessed the actors' level of influence on decision-
390 making regarding ecosystem services (**Table 2**). At local scale, environmental
391 managers of the Sierra Nevada protected area, environmental NGOs and the irrigation
392 communities (farmers) had the strongest influence fostering the restoration of irrigation
393 systems. In 2008, together with the Andalusian Environmental Ministry, they
394 implemented the Conservation Program of Ancient Irrigation Channels in Sierra
395 Nevada, having positive implications on the local identity of farmers, aesthetic beauty
396 of landscapes and hydrological regulation. However, the influence of traditional farmers
397 and environmental managers of Sierra Nevada at regional and national scales is more
398 limited. As illustration of their limitation to influence decision-making at national scale, it
399 is the fact that decision-makers have promoted the technological upgrading of ancient

63
64
65

irrigation infrastructure for saving water resources by implementing the National Irrigation Plan Horizon 2008 and the Andalusian Water Act (9/2010) (López-Gunn et al., 2013). The National Irrigation Plan Horizon 2008 and the Andalusian Water Act (9/2010) seek to ensure the efficiency of water use by promoting the modernization of irrigation systems – lining traditional ditches and substituting them with tubes (López-Gunn et al., 2013). These measures have directly affected the hydrological regulation and local identity of farmers, which in turn resulted in the abandonment of traditional farming practices. This leads to negative effects on erosion control, aesthetic values of landscapes and agricultural food (García-Llorente et al., 2015). By contrast, these policies have benefited those farmers who intensively manage their land through greenhouses in the lower part of the watershed (García-Llorente et al., 2015; Quintas-Soriano et al., 2016).

Step 4. Identification of within and cross-scale social relations among actors

We performed face-to-face semi-structured interviews to irrigation communities and local councils (N = 42) to map the interactions among the organizations and actor groups who had co-participated in the development of projects with regards to ecosystem services associated with water management (Iniesta-Arandia 2015). Then, we performed social network analysis of the current collaboration concerning water management (Iniesta-Arandia 2015) (**Table 2**). Results showed that environmental managers in the Sierra Nevada Protected Area recently started collaborating with farmers and NGOs to restore the ancient irrigation systems (**Fig. 3b**). However, the power to decide upon main water management goals is held by institutions operating at supra-local scales (**Fig. 3b**). Here, power is exerted through a top-down model by controlling the irrigation systems through legislation (e.g. National Irrigation Plan Horizon 2008 and the Andalusian Water Act (9/2010)) and by deciding which are the

goals in the water management agenda (i.e. water use efficiency) (López-Gunn et al., 2013).

Consequently, those actors with more power in decision-making at regional and European scales influenced landscape physiognomy by promoting technological investments of irrigation systems. These investments jeopardized the provision of hydrological regulation, erosion control, maintenance of habitats or aesthetic value (García-Llorente et al., 2015), which, in turn, affected local farmers who mostly depend on these services and have restricted access to water. Nevertheless, the Conservation Program of Ancient Irrigation Channels is now counteracting the modernization of irrigation systems in the protected area, becoming a cornerstone for the future sustainability of Sierra Nevada.

4. Discussion

4.1. Lessons from the application of the 'cross-scale influence-dependence' framework

The application of the 'cross-scale influence-dependence' framework in the four case studies surfaces a set of similar patterns regarding dependence on ecosystem services and influence on decision-making (**Fig. 2-3, Fig. S1-S2** in **Appendices A** and **B**). Local actors (e.g. farmers and fishermen) were strongly dependent on ecosystem services, whereas the dependence of the tourism industry and the business sector peaked at the regional scale. In contrast, the ability of actors to influence decision-making regarding ecosystem services shifted from a shared (though unbalanced) influence by most actors at the local scale, to be concentrated in a few actors at larger scales than local (**Fig. 2-3, Fig. S1-S2** in **Appendices A** and **B**). In particular, decision-makers held strong influence at all scales, whereas other actors shifted positions depending on the

scale: e.g. the business sector showed increasing influence at larger scales, while farmers were only influential at local scale (**Fig. 2-3, Fig. S1-S2** in **Appendices A** and **B**).

This uneven distribution of dependence on services and influence in decision-making across actors has implications for distributional and procedural equity. The low representation in decision-making of those actors most reliant on ecosystem services (i.e. local farmers and fishermen) may make these actors to be considered vulnerable actors (**Table 2**). These actors have no control over the access and management of essential ecosystem services, which affects both procedural and distributional equity. By contrast, those actors represented in decision-making, yet being dependent on particular services, are likely to be considered the 'winners' (e.g. tourism industry or farmers practicing intensive farming) (**Table 2**). These findings are consistent with political ecology research on natural resources (Berry, 1989; Ribot and Peluso, 2003; Robbins, 2012), biodiversity conservation (Robbins, 2012) or climate change adaptation (Thomas and Twyman, 2005).

By identifying actor's dependence on ecosystem services and influence on their management, we can detect those actors placed in vulnerable situations, such as fishermen and traditional farmers (**Fig. 2** and **3**, respectively). The application of the framework shows that while the most powerful actors exert their influence on the management of ecosystem services at supra-local scales, the most vulnerable actors appear at the local scale. This demonstrates a scale mismatch between actors' dependence and influence on ecosystem services and a mismatch in ecosystem services governance that should be tackled in order to reduce potential inequalities and conflicts between actors.

Our framework also demonstrates that the distribution of ecosystem services among actors is shaped by social relations occurring across scales rather than by relations

occurring at one single scale. In line with Fedele et al. (2018), we found that the power exerted by actors at the regional and global scales over local actors can define who is engaged in management and, thus, in decisions regarding ecosystem services use and access. Cross-scale power relations among actors can determine the implementation of management actions at the local scale. For example, the prevailing communication channels of managers, scientists and tourism industry across scales in Southern Kenya undermine the influence in decision-making of fishermen, who primarily appear at the local scale (**Fig. 2**). Likewise, the power exerted through legislation by decision-makers at the regional and European levels has fostered the technological upgrading of ancient irrigation channels in the Nacimiento watershed (**Fig. 3**), which affected traditional farmers. Nevertheless, we also found cases where vulnerable actors, such as traditional farmers, establish relations with more powerful actors operating at local and regional scales, such as NGOs and environmental managers in the Nacimiento and Piedra watersheds (**Fig. 3** and **Fig. S1** in **Appendix A**, respectively) or with the municipality and representatives of different regional policy sectors in the grass-based dairy system of Voeren (**Appendix B**).

These cases are examples of how procedural equity can be enhanced via engaging local actors, such as fishers and farmers, in environmental management discussions. Analogous to the results found by Thomas & Twyman (2005), our study suggests that enabling the engagement of marginalized local actors by powerful actors at the regional and global scales could facilitate the implementation of management actions towards sustainability. This aligns with the decentralized and polycentric theories of community-based management, which acknowledge that local actors may have greater interest in the sustainable management of ecosystem services than decision-makers and private actors at larger scales (Andersson and Ostrom, 2008; Brosius et al., 1998; Nagendra and Ostrom, 2012). Local actors are often able and willing to sustainably

503 manage ecosystem services; however, these actors are influenced by other actors and
504 by institutional arrangements operating at larger scales (**Fig. 2-3, Fig. S1-S2** in
505 **Appendices A** and **B)**. Thus, our study suggests that ecosystem services
506 management requires governance mechanisms that are neither local nor global, but
507 multilevel and interconnected, i.e. polycentric (Oberlack et al., 2018).

508 We also found that relations occurring at the local scale between vulnerable and more
509 powerful actors are often mediated by informal institutions, such as traditions and
510 customs (**Fig. 2c-3c, Fig. S1c-S2c** in **Appendices A** and **B**). In these situations,
511 engaging vulnerable actors in environmental decision-making does not necessarily
512 lead to procedural equity because local elites might determine the goals of
513 environmental management (Sikor et al., 2014). To counteract these differences of
514 power, it is necessary to ensure well-structured dialogues, transparent communication,
515 and recognition of possible conflicts regarding conservation interests and ecosystem
516 services use, access and management (Dietz et al., 2003).

517

518 ***4.2. Hypotheses for future research***

519 By illustrating the suitability of the framework across a set of distinct case studies, we
520 identified several hypotheses that could be tested in future research. First, at the
521 regional and international level, power might be more strongly concentrated in a small
522 and privileged set of actors who influence ecosystem services management, while at
523 the local scale dependence on services is higher. Powerful actors can influence
524 management over distant areas to benefit from the provision of a particular ecosystem
525 service, which may cause burdens on other ecosystem services and thus, affect the
526 wellbeing of local actors in these areas (Pascual et al., 2017; Schröter et al., 2018).
527 This is particularly relevant in the case of ecosystem service trade-offs between

63
64
65

regulating and provisioning services (e.g. Bennett et al., 2009; García-Llorente et al., 2015). For example, former literature suggests that benefits and burdens of trade-offs between regulating and provisioning services are unevenly distributed among actors (e.g. Felipe-Lucia et al, 2015a; Iniesta-Arandia et al., 2014).

Second, taking into account that ecosystem services interact, leading to trade-offs and synergies (Bennett et al., 2009), social actors might become vulnerable when they have no power to manage the intermediate services (often regulating), on which the final service relies on (often provisioning) (Felipe-Lucia et al., 2015a; Berbés-Blazquéz et al., 2016).

Third, the application of the framework leads to the hypothesis that social relations between local and external actors shape actual supply and distribution of ecosystem services. For example, the power exerted by policy-makers at national and regional level over local farmers regarding the management of irrigation systems in the Nacimiento watershed had a direct impact on the provision of essential ecosystem services for local farmers, such as hydrological regulation and erosion control. This result is consistent with the findings from Fedele et al. (2018), which shows that systems with few local actors influencing decision-making (although highly dependent on ecosystem services) and with influential actors operating remotely from the site might generate intense trade-offs among ecosystem services. By contrast, systems with less influential external actors where multiple local actors influence decision-making regarding ecosystem services may weaken ecosystem services trade-offs.

The fourth hypothesis is that the increasing interest of few powerful actors (mostly at larger scales) to intensify farming systems for single ecosystem services, such as crop or freshwater, will reduce the capacity of landscapes to provide ecosystem services to multiple people, whereas multifunctional landscapes should be able to provide services to a more diverse number of actors (Fischer et al., 2017).

554 Finally, dependence on ecosystem service and influence in their management might be
555 allocated in different stages of the so-called 'ecosystem services cascade' (Haines-
556 Young and Potschin, 2010). Dependency is often located 'downstream' in the cascade,
557 where ecosystem services benefit actors. However, influence might often be exerted
558 'upstream', where ecosystem processes lead to the flow of ecosystem services
559 towards beneficiaries. For example, Felipe-Lucia et al. (2015a) found that decision-
560 makers have higher ability to manage habitat quality and the ecological processes
561 underpinning the provision of water quality, whilst farmers and recreation sector
562 depend on those ecosystem services that directly benefit people, such as freshwater
563 and recreation experiences.

564

565 **5. Conclusions**

566 By disentangling how cross-scale social relations shape the distribution of ecosystem
567 services and decision-making about their management, our framework enables the
568 integration of procedural and distributional equity in ecosystem services assessments,
569 policies and management for the first time. First, the application of the framework can
570 contribute to the identification of mismatches between actors' dependence on
571 ecosystem services and influence over decision-making regarding ecosystem services.
572 Second, it can be used to identify scales at which changes in governance could
573 influence and reduce these mismatches. Third, knowledge that emerges from the
574 application of the framework can be used as a tool to assess how existing policies
575 shape procedural and distributional equity and to anticipate how future policies may
576 affect both forms of equity. Consequently, the 'cross-scale influence-dependence
577 framework' that we present in this study can help to address the challenge of
578 integrating knowledge from political ecology in ecosystem service research, by
579 assembling information on power relations and distributional and procedural equity

63
64
65

regarding ecosystem services. This framework also contributes to advance the research on telecoupling by considering cross-scale social relations as a type of inter-regional flows relevant for ecosystem services assessment, something which is not yet acknowledged in the telecoupling framework (Liu et al., 2013; Schröter et al., 2018). Finally, the framework can be used to practically identify ecosystem services management strategies that move towards sustainability by enhancing procedural and distributional equity.

6. Acknowledgements

The intellectual basis for this article stems from the workshop “Ecosystem service trade-offs and synergies" organized by PECS (http://www.pecs-science.org/), and funded by FORMAS project 2012-1058. We thank J. Fischer, I. Palomo, I. Iniesta-Arandia and J. Qiu for valuable discussions. The Voeren research was sponsored by the Flemish Land Agency. MFL was granted by the Spanish National Research Council (JAE-Pre-2010-044). EMB was supported by NSERC EWR Steacie Fellowship. AN and GP were supported by the Swedish Research Council Formas (project 2012-1058). MGL was supported by the Spanish National Institute for Agriculture and Food Research and Technology (INIA). SL and BL were funded by OPERAs FP7-ENV-2012-two-stage-308393. We thank two anonymous reviewers for their constructive comments.

7. References

Andersson, K.P., Ostrom, E., 2008. Analyzing decentralized resource regimes from a polycentric perspective. Policy Sci. 41, 71–93. https://doi.org/10.1007/s11077-007-9055-6

Annys S., Verhoeve A., en Wauters, E., 2017. Analyse van de relatie tussen landbouw en landschap in Voeren - Trends en drivers. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2017 (24). Instituut voor Natuur- en Bosonderzoek,

608 Brussel. DOI: doi.org/10.21436/inbor.13114647

609 Barnaud, C., Corbera, E., Muradian, R., Salliou, N., Sirami, C., Vialatte, A., Choisis, J.-
610 P., Dendoncker, N., Mathevet, R., Moreau, C., Reyes-García, V., Boada, M.,
611 Deconchat, M., Cibien, C., Garnier, S., Maneja, R., Antona, M., 2018. Ecosystem
612 services, social interdependencies, and collective action: a conceptual
613 framework. Ecol. Soc. 23,15. https://doi.org/10.5751/ES-09848-230115

614 Bennett, E.M., Peterson, G.D., Gordon, L.J., 2009. Understanding relationships among
615 multiple ecosystem services. Ecol. Lett. 12, 1394–1404.
616 https://doi.org/10.1111/j.1461-0248.2009.01387.x

617 Berbés-Blázquez, M., Bunch, M.J., Mulvihill, P.R., Peterson, G.D., van Wendel de
618 Joode, B., 2017. Understanding how access shapes the transformation of
619 ecosystem services to human well-being with an example from Costa Rica.
620 Ecosyst. Serv. 28, 320–327. https://doi.org/10.1016/j.ecoser.2017.09.010

621 Berbés-Blázquez, M., González, J.A., Pascual, U., 2016. Towards an ecosystem
622 services approach that addresses social power relations. Curr. Opin. Environ.
623 Sustain. 19, 134–143. https://doi.org/10.1016/j.cosust.2016.02.003

624 Bernstein, H., 2010. Class dynamics of agrarian change. Halifax: Fernwood Publishing.

625 Berry, S., 1989. Social institutions and access to resources. Africa J. Int. African Inst.
626 59, 41–55. https://www.jstor.org/stable/1160762

627 Biggs, D., Abel, N., Knight, A.T., Leitch, A., Langston, A., Ban, N.C., 2011. The
628 implementation crisis in conservation planning: Could "mental models" help?
629 Conserv. Lett. 4, 169–183. https://doi.org/10.1111/j.1755-263X.2011.00170.x

630 Biggs, S., Matsaert, H., 1999. An actor-oriented approach for strengthening research
631 and development capabilities in natural resource systems. Public Adm. Dev. 19,
632 231–262. https://doi.org/10.1002/(SICI)1099-162X(199908)19:3%3C231::AID-
633 PAD71%3E3.0.CO;2-E

634 Bohensky, E.L., Reyers, B. & Van Jaarsveld, A.S., 2006. Conservation in practice:
635 Future ecosystem services in a Southern African river basin: a scenario planning
636 approach to uncertainty. Conserv. Biol., 20, 1051–1061.
637 https://doi.org/10.1111/j.1523-1739.2006.00475.x

638 Brosius, J.P., Tsing, A.L., Zerner, C., 1998. Representing communities: Histories and
639 politics of community-based natural resource management. Soc. Nat. Resour. 11,
640 157–168. https://doi.org/10.1080/08941929809381069

641 Brown, G., Fagerholm, N., 2015. Empirical PPGIS/PGIS mapping of ecosystem
642 services: A review and evaluation. Ecosyst. Serv., 13, 119–133.
643 https://doi.org/10.1016/j.ecoser.2014.10.007

644 Calvet-Mir, L., Gómez-Baggethun, E., Reyes-García, V., 2012. Beyond food
645 production: Ecosystem services provided by home gardens. A case study in Vall
646 Fosca, Catalan Pyrenees, Northeastern Spain. Ecol. Econ., 74, 153–160.
647 https://doi.org/10.1016/j.ecolecon.2011.12.011

648 Chevalier, J.M., Buckles, D.J., 2008. SAS 2 A Guide to Collaborative Inquiry and Social
649 Engagement. Sage Publications. http://dx.doi.org/10.4135/9789351507734

650 Cinner, J.E., Bodin, Ö., Randriamahazo, H., Dasgupta, P., Holling, C., 2010. Livelihood
651 diversification in tropical coastal communities: A network-based approach to

63
64
65

analyzing 'livelihood landscapes.' PLoS One 5, e11999. https://doi.org/10.1371/journal.pone.0011999

Cinner, J.E., McClanahan, T.R., Abunge, C., Wamukota, A.W., 2009. Human dimensions of conserving Kenya's coral reefs, in: Hoorweg, J., Muthiga, N. (Eds.), Advances in Coastal Ecology. African Studies Center, Leiden, pp. 60–78.

Crouzat, E., Martín-López, B., Turkelboom, F., Lavorel, S., 2016. Disentangling trade-offs and synergies around ecosystem services with the Influence Network Framework - Illustration from a consultative process over the French Alps. Ecol. Soc., 21, 32. http://dx.doi.org/10.5751/ES-08494-210232

Cumming, G.S., Cumming, D.H.M., Redman, C.L., 2006. Scale mismatches in social-ecological systems: causes, consequences, and solutions. Ecol. Soc. 11, 14. http://www.ecologyandsociety.org/vol11/iss1/art14/

Cundy, A.B., Bardos, R.P., Church, A., Puschenreiter, M., Friesl-Hanl, W., Müller, I., Neu, S., Mench, M., Witters, N., Vangronsveld, J., 2013. Developing principles of sustainability and stakeholder engagement for "gentle" remediation approaches: The European context. J. Environ. Manage., 129, 283–291. https://doi.org/10.1016/j.jenvman.2013.07.032

Demeyer, R., De Smet, L., Turkelboom, F., 2017. Stakeholderidentificatie en -analyse van Voeren. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2017 (23). Instituut voor Natuur- en Bosonderzoek, Brussel, DOI: doi.org/10.21436/inbor.12669854

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Ram Adhikari, J., Arico, S., Bá ldi, A., Bartuska, A., Andreas Baste, I., Bilgin, A., Brondizio, E., Chan, K.M., Elsa Figueroa, V., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martín-López, B., Okumura, M., Pacheco, D., Pascual, U., Selvin Pé rez, E., Reyers, B., Roth, E., Saito, O., John Scholes, R., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Abdul Hamid, Z., Failler, P., Moustafa Mokhtar Fouda, A., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Armand Mala, W., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Paul Metzger, J., Bruno Mikissa, J., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Apau Oteng-Yeboah, A., rgy Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y., Zlatanova, D., 2015. The IPBES Conceptual Framework — connecting nature and people. Curr. Opin. Environ. Sustain. 14, 1–16. https://doi.org/10.1016/j.cosust.2014.11.002

Dietz, T., Ostrom, E., Stern, P.C., 2003. The struggle to govern the commons. Science. 302, 1907–1912. DOI: 10.1126/science.1091015

Ernstson, H., Sörlin, S., Elmqvist, T., 2008. Social movements and ecosystem services: the role of social network structure in protecting and managing urban green areas in Stockholm. Ecol. Soc., 13, 39. http://www.ecologyandsociety.org/vol13/iss2/art39/

Fazey, I., Kesby, M., Evely, A., Latham, I., Wagatora, D., Hagasua, J.-E., Reed, M.S., Christie, M., 2010. A three-tiered approach to participatory vulnerability assessment in the Solomon Islands. Glob. Environ. Chang., 20, 713–728. https://doi.org/10.1016/j.gloenvcha.2010.04.011

Fedele, G., Locatelli, B., Djoudi, H., Colloff, M.J., 2018. Reducing risks by transforming landscapes: Cross-scale effects of land-use changes on ecosystem services. PLoS One 13, e0195895. https://doi.org/10.1371/journal.pone.0195895

Felipe-Lucia, M.R., Martín-López, B., Lavorel, S., Berraquero-Díaz, L., Escalera-Reyes, J., Comín, F.A., Margalida, A., 2015a. Ecosystem services flows: Why stakeholders' power relationships matter. PLoS One 10, e0132232. https://doi.org/10.1371/journal.pone.0132232

Felipe-Lucia, M.R., Comín, F.A., Escalera-Reyes, J., 2015b. A framework for the social valuation of ecosystem services. Ambio 44, 308–318. doi: 10.1007/s13280-014-0555-2

Fischer, J., Gardner, T. A., Bennett, E.M., Balvanera, P., Biggs, R., Carpenter, S., Daw, T., Folke, C., Hill, R., Hughes, T.P., Luthe, T., Maass, M., Meacham, M., Norström, A. V., Peterson, G., Queiroz, C., Seppelt, R., Spierenburg, M., Tenhunen, J., 2015. Advancing sustainability through mainstreaming a social–ecological systems perspective. Curr Opin Environ Sustain 14:144–149. https://doi.org/10.1016/j.cosust.2015.06.002

Fischer, J., Meacham, M., Queiroz, C., 2017. A plea for multifunctional landscapes. Front. Ecol. Environ. 15, 59–59. https://doi.org/10.1002/fee.1464

Fliervoet, J.M., Geerling, G.W., Mostert, E., Smits, A.J.M., 2016. Analyzing collaborative governance through social network analysis: A case study of river management along the Waal River in The Netherlands. Environ. Manage., 57, 355–367. doi: 10.1007/s00267-015-0606-x

Friis, C. & Nielsen, J.Ø. (2014). *Exploring the potential of the telecoupling framework for understanding land change*. Berlin. THESys Discussion Paper No. 2014-1

García-Llorente, M., Harrison, P.A., Berry, P., Palomo, I., Gómez-Baggethun, E., Iniesta-Arandia, I., Montes, C., García Del Amo, D., Martín-López, B., 2016. What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. Biodivers. Conserv. 1–23. https://doi.org/10.1007/s10531-016-1152-4

García-Llorente, M., Iniesta-Arandia, I., Willaarts, B.A., Harrison, P.A., Berry, P., Bayo, M. del M., Castro, A.J., Montes, C., Martín-López, B., 2015. Biophysical and sociocultural factors underlying spatial trade-offs of ecosystem services in semiarid watersheds. Ecol. Soc. 20, 39. https://doi.org/10.5751/ES-07785-200339

García-Llorente, M., Martín-López, B., Iniesta-Arandia, I., López-Santiago, C.A., Aguilera, P.A., Montes, C., 2012. The role of multi-functionality in social preferences toward semi-arid rural landscapes: An ecosystem service approach. Environ. Sci. Policy 19–20, 136–146. https://doi.org/10.1016/j.envsci.2012.01.006

García-Nieto, A.P., Quintas-Soriano, C., García-Llorente, M., Montes, C., Martín-López, B., 2015. Collaborative mapping of ecosystem services: The role of stakeholders' profiles. Ecosyst. Serv., 13, 141–152. https://doi.org/10.1016/j.ecoser.2014.11.006

Gaventa, J., 2006. Finding the spaces for change: a power analysis. IDS Bulletin 37(6), 23-33. https://doi.org/10.1111/j.1759-5436.2006.tb00320.x

Geneletti, D., 2007. Expert panel-based assessment of forest landscapes for land use planning. Mt. Res. Dev., 27, 220–223. https://doi.org/10.1659/0276-

4741(2007)27[220:EPAOFL]2.0.CO;2

Gómez-Baggethun, E., Kelemen, E., Martín-López, B., Palomo, I., Montes, C., 2013. Scale misfit in ecosystem service governance as a source of environmental conflict. Soc. Nat. Resour. 26, 37–41. https://doi.org/10.1080/08941920.2013.820817

Gould, R.K., Klain, S.C., Ardoin, N.M., Satterfield, T., Woodside, U., Hannahs, N., Daily, G.C., Chan, K.M., 2015. A protocol for eliciting nonmaterial values through a cultural ecosystem services frame. Conserv. Biol., 29, 575–586. https://doi.org/10.1111/cobi.12407

Grahame, P., 1998. Ethnography, institutions, and the problematic of the everyday world. Human Stud. 21, 347-360. https://doi.org/10.1023/A:1005469127008

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being. Ecosyst. Ecol. A new Synth. 110–139. https://doi.org/10.1017/CBO9780511750458.007

Hanspach, J., Hartel, T., Milcu, A.I., Mikulcak, F., Dorresteijn, I., Loos, J., von Wehrden, H., Kuemmerle, T., Abson, D., Kovács-Hostyánszki, A., Báldi, A., Fischer, J., 2014. A holistic approach to studying social-ecological systems and its application to southern Transylvania. Ecol. Soc., 19, art32. http://dx.doi.org/10.5751/ES-06915-190432

Haraway, D., 1988. Situated knowledges: The science question in feminism and the privilege of partial perspective. Fem. Stud. 14, 575-599. https://www.jstor.org/stable/3178066

Harding S (1986) The science question in feminism. Ithaca: Cornell University Press.

Hicks, C.C., Cinner, J.E., 2014. Social, institutional, and knowledge mechanisms mediate diverse ecosystem service benefits from coral reefs. Proc. Natl. Acad. Sci. U. S. A. 111, 17791–6. https://doi.org/10.1073/pnas.1413473111

Hicks, C.C., Cinner, J.E., Stoeckl, N., McClanahan, T.R., 2015. Linking ecosystem services and human-values theory. Conserv. Biol. 29, 1471–1480. https://doi.org/10.1111/cobi.12550

Hicks, C.C., Graham, N.A.J., Cinner, J.E., 2013. Synergies and tradeoffs in how managers, scientists, and fishers value coral reef ecosystem services. Glob. Environ. Chang. 23, 1444–1453. https://doi.org/10.1016/j.gloenvcha.2013.07.028

Hicks, C.C., Mcclanahan, T.R., Cinner, J.E., Hills, J.M., 2009. Trade-offs in values assigned to ecological goods and services associated with different coral reef management strategies. Ecol. Soc. 14, 10. http://www.ecologyandsociety.org/vol14/iss1/art10/

Iniesta-Arandia, I., García-Llorente, M., Aguilera, P.A., Montes, C., Martín-López, B., 2014. Socio-cultural valuation of ecosystem services: uncovering the links between values, drivers of change, and human well-being. Ecol. Econ. 108, 36–48. https://doi.org/10.1016/j.ecolecon.2014.09.028

Iniesta-Arandia, I., García del Amo, D., García-Nieto, A.P., Piñeiro, C., Montes, C., Martín-López, B., 2015. Factors influencing local ecological knowledge maintenance in Mediterranean watersheds: insights for conservation policies. AMBIO. 44, 285–296. DOI: 10.1007/s13280-014-0556-1

Iniesta-Arandia I., 2015. Water never sleeps: a social-ecological approach to rural irrigation systems in two semi-arid watersheds in SE Spain. PhD dissertation. Autonomous University of Madrid, Spain.

IPBES. (2016). The methodological assessment report on scenarios and models on biodiversity and ecosystem services. Ferrier, S., Ninan, K. N., Leadley, P., Alkemade, R., Acosta, L.A., Akçakaya, H. R., Brotons, L., Cheung, W. W. L., Christensen, V., Harhash, K. A., Kabubo-Mariara, J., Lundquist, C., Obersteiner, M., Pereira, H. M., Peterson, G., Pichs-Madruga, R., Ravindranath, N., Rondinini, C., Wintle, B.A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 348 pages.

Jacobs, S., Martín-López, B., Barton, D.N., Dunford, R., Harrison, P.A., Kelemen, E., Saarikoski, H., Termansen, M., García-Llorente, M., Gómez-Baggethun, E., Kopperoinen, L., Luque, S., Palomo, I., Priess, J.A., Rusch, G.M., Tenerelli, P., Turkelboom, F., Demeyer, R., Hauck, J., Keune, H., Smith, R., 2018. The means determine the end – Pursuing integrated valuation in practice. Ecosyst. Serv. 29, 515–528. https://doi.org/10.1016/j.ecoser.2017.07.011

Klain, S.C., Satterfield, T.A., Chan, K.M.A., 2014. What matters and why? Ecosystem services and their bundled qualities. Ecol. Econ., 107, 310–320. https://doi.org/10.1016/j.ecolecon.2014.09.003

Lenschow, A., Newig, J., Challies, E., 2016. Globalization's limits to the environmental state? Integrating telecoupling into global environmental governance. Environm. Politics, 25,136-159. https://doi.org/10.1080/09644016.2015.1074384

Liu, J., Hull, V., Batistella, M., DeFries, R., Dietz, T., Fu, F., Hertel, T.W., Izaurralde, R.C., Lambin, E.F., Li, S., Martinelli, L. a., McConnell, W.J., Moran, E.F., Naylor, R., Ouyang, Z., Polenske, K.R., Reenberg, A., de Miranda Rocha, G., Simmons, C.S., Verburg, P.H., Vitousek, P.M., Zhang, F., Zhu, C., 2013. Framing sustainability in a telecoupled world. Ecol. Soc. 18, 26. https://doi.org/10.5751/ES-05873-180226

López-Gunn, E., Willaarts, B., Rica, M., Corominas, J., Llamas, R., 2013. The Spanish water "pressure cooker": Threading the interplay between resource resilient water governance outcomes by strengthening the robustness of water governance processes. Int. J. Water Gov. 1, 13–40. doi:10.7564/12-IJWG8

Lukes, S., 1973. Power: A Radical View. Macmillan Press, London.

(MA) Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis. Washington, DC.: Island Press.

Maguire, B., Potts, J., Fletcher, S., 2012. The role of stakeholders in the marine planning process—Stakeholder analysis within the Solent, United Kingdom. Mar. Policy, 36, 246–257. https://doi.org/10.1016/j.marpol.2011.05.012

Malinga, R., Gordon, L.J., Lindborg, R., Jewitt, G., 2013. Using participatory scenario planning to identify ecosystem services in changing landscapes. Ecol. Soc., 18, 10. http://dx.doi.org/10.5751/ES-05494-180410

Martín-López, B., Montes, C., Benayas, J., 2007. Influence of user characteristics on valuation of ecosystem services in Doñana Natural Protected Area (south-west Spain). Environ. Conserv., 34, 215–224. https://doi.org/10.1017/S0376892907004067

McClanahan, T., Muthiga, N.A., Abunge, C.A., 2016. Establishment of community managed fisheries' closures in Kenya: early evolution of the *Tengefu* movement. Coast Manage., 44, 1-20. https://doi.org/10.1080/08920753.2016.1116667

McClanahan, T.R., Hicks, C.C., Darling, E.S., 2008. Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. Ecol. Appl. 18, 1516–1529. https://doi.org/10.1890/07-0876.1

McDermott, M., Mahanty, S., Schreckenberg, K., 2013. Examining equity: A multidimensional framework for assessing equity in payments for ecosystem services. Environ. Sci. Policy 33, 416–427. https://doi.org/10.1016/j.envsci.2012.10.006

Moreno, J., Palomo, I., Escalera, J., Martín-López, B., Montes, C., 2014. Incorporating ecosystem services into ecosystem-based management to deal with complexity: a participative mental model approach. Landsc. Ecol., 29, 1407–1421. https://doi.org/10.1007/s10980-014-0053-8

Muhs, D. R., Budahn, J. R., Prospero, J. M., Carey, S. N., 2007. Geochemical evidence for African dust inputs to soils of western Atlantic islands: Barbados, the Bahamas and Florida. J. Geophys. Res., 112, F02009, doi:10.1029/2005JF000445

Nagendra, H., Ostrom, E., 2012. Polycentric governance of multifunctional forested landscapes. Int. J. Commons 6, 104. https://doi.org/10.18352/ijc.321

Newing, H., Eagle, C.M., Puri, R.K., Watson, C.W., 2011. Conducting Research in Conservation: A Social Science Perspective. Routledge, New York.

Oberlack, C., Boillat, S., Brönnimann, S., Gerber, J.-D., Heinimann, A., Speranza, C.I., Messerli, P., Rist, S., Wiesmann, U., 2018. Polycentric governance in telecoupled resource systems. Ecol. Soc 23(1):16. https://doi.org/10.5751/ES-09902-230116

Orsi, F., Geneletti, D., Newton, A.C., 2011. Towards a common set of criteria and indicators to identify forest restoration priorities: An expert panel-based approach. Ecol. Indic., 11, 337–347. https://doi.org/10.1016/j.ecolind.2010.06.001

Oteros-Rozas, E., Martín-López, B., Daw, T.M., Bohensky, E.L., Butler, J.R.A., Hill, R., Martin-Ortega, J., Quinlan, A., Ravera, F., Ruiz-Mallón, I., Thyresson, M., Mistry, J., Palomo, I., Peterson, G.D., Plieninger, T., Waylen, K.A., Beach, D.M., Bohnet, I.C., Hamann, M., Hanspach, J., Hubacek, K., Lavorel, S., Vilardy, S.P., 2015. Participatory scenario planning in place-based social-ecological research: Insights and experiences from 23 case studies. Ecol. Soc., 20, 32. http://dx.doi.org/10.5751/ES-07985-200432

Oteros-Rozas, E., Martín-López, B., López, C. A., Palomo, I., González, J. A., 2013. Envisioning the future of transhumant pastoralism through participatory scenario planning: a case study in Spain. Rangel. J., 35, 251–272. https://doi.org/10.1071/RJ12092

Palomo, I., Martín-López, B., Potschin, M., Haines-Young, R., Montes, C., 2013. National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows. Ecosyst. Serv., 4, 104–116. https://doi.org/10.1016/j.ecoser.2012.09.001

Palomo, I., Martín López, B., López-Santiago, C., Montes, C., 2011. Participatory scenario planning for protected areas management under the ecosystem services

framework: the Donana social-ecological system in southwestern Spain. Ecol. Soc., 16, 23. http://www.ecologyandsociety.org/vol16/iss1/art23/

Pascual, U., Palomo, I., Adams, W., Chan, K.M.A., Daw, T., Garmendia, E., Gómez-Baggethun, E., de Groot, R., Mace, G., Martín-López, B., Phelps, J., 2017. Off-stage ecosystem service burdens: a blind spot for global sustainability. Environ. Res. Lett. 12, 075001. http://iopscience.iop.org/article/10.1088/1748-9326/aa7392

Perreault, T., 2003. A people with our own identity: toward a cultural politics of development in Ecuadorian Amazonia. Environ. Plan. D: Soc. Space 21, 583–606. https://doi.org/10.1068%2Fd339

Peterson, G., 2000. Political ecology and ecological resilience: An integration of human and ecological dynamics. Ecol. Econ. 35, 323–336. https://doi.org/10.1016/S0921-8009(00)00217-2

Peterson, G.D., Cumming, G.S., Carpenter, S.R., 2003. Scenario Planning: a tool for conservation in an uncertain world. Conserv. Biol. 17, 358–366. https://doi.org/10.1046/j.1523-1739.2003.01491.x

Plieninger, T., Dijks, S., Oteros-Rozas, E., Bieling, C., 2013. Assessing, mapping, and quantifying cultural ecosystem services at community level. Land use policy, 33, 118–129. https://doi.org/10.1016/j.landusepol.2012.12.013

Prell, C., Hubacek, K., Reed, M., 2009. Stakeholder analysis and social network analysis in natural resource management. Soc. Nat. Resour. 22, 501–518. https://doi.org/10.1080/08941920802199202

Quintas-Soriano, C., Castro, A.J., Castro, H., García-Llorente, M., 2016. Impacts of land use change on ecosystem services and implications for human well-being in Spanish drylands. Land use policy 54, 534–548. https://doi.org/10.1016/j.landusepol.2016.03.011

Rathwell, K.J., Peterson, G.D., 2012. Connecting social networks with ecosystem services for wgatershed Governance: a social-ecological network perspective highlights the critical role of bridging organizations. Ecol. Soc., 17, 24. http://dx.doi.org/10.5751/ES-04810-170224

Raudsepp-Hearne, C., Peterson, G.D., 2016. Scale and ecosystem services: how do observation, management, and analysis shift with scale-lessons from Québec. Ecol. Soc. 21, art16. https://doi.org/10.5751/ES-08605-210316

Reid, W. V., Chen, D., Goldfarb, L., Hackmann, H., Lee, Y.T., Mokhele, K., Ostrom, E., Raivio, K., Rockstrom, J., Schellnhuber, H.J., Whyte, A., 2010. Earth system science for global sustainability: grand challenges. Science 330, 916–917. DOI: 10.1126/science.1196263

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H., Stringer, L.C., 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. J. Environ. Manage. 90, 1933–49. https://doi.org/10.1016/j.jenvman.2009.01.001

Ribot, J. C., 1998. Theorizing access: forest profits along Senegal's charcoal commodity chain. Dev. Change 29, 307-341. https://doi.org/10.1111/1467-7660.00080

Ribot, J.C., Peluso, N.L., 2003. A Theory of Access. Rural Sociol. 68, 153–181.

https://doi.org/10.1111/j.1549-0831.2003.tb00133.x

Robbins, P., 2012. Political ecology : a critical introduction. J. Wiley & Sons.

Rocheleau, D.E., 2008. Political ecology in the key of policy: From chains of explanation to webs of relation. Geoforum 39, 716–727. https://doi.org/10.1016/j.geoforum.2007.02.005

Schiffer, E., Hauck, J., 2010. Net-Map: Collecting social network data and facilitating network learning through participatory influence network mapping. Field methods, 22, 231–249. https://doi.org/10.1177%2F1525822X10374798

Scholes, R., Reyers, B., Biggs, R., Spierenburg, M., Duriappah, A., 2013. Multi-scale and cross-scale assessments of social–ecological systems and their ecosystem services. Curr. Opin. Environ. Sustain. 5, 16–25. https://doi.org/10.1016/j.cosust.2013.01.004

Schröter, M., Koellner, T., Alkemade, R., Arnhold, S., Bagstad, K.J., Erb, K.-H., Frank, K., Kastner, T., Kissinger, M., Liu, J., López-Hoffman, L., Maes, J., Marques, A., Martín-López, B., Meyer, C., Schulp, C.J.E., Thober, J., Wolff, S., Bonn, A., 2018. Interregional flows of ecosystem services: Concepts, typology and four cases. Ecosyst. Serv. 31, 231–241. https://doi.org/10.1016/j.ecoser.2018.02.003

Seto, K. C., Reenberg, A., Boone, C. G., Fragkias, M., Haase, D., Langanke, T., Marcotullio, P., Munroe, D. K., Olah, B., Simon, D., 2012. Urban land teleconnections and sustainability. Proc Natl Acad Sci USA, 109,7687-7692. http://dx.doi.org/10.1073/ pnas.1117622109

Sikor, T., Martin, A., Fisher, J., He, J., 2014. Toward an empirical analysis of justice in ecosystem governance. Conserv. Lett. 7, 524–532. https://doi.org/10.1111/conl.12142

Starick, A., Syrbe, R.-U., Steinhäußer, R., Lupp, G., Matzdorf, B., Zander, P., 2014. Scenarios of bioenergy provision: technological developments in a landscape context and their social effects. Environ. Dev. Sustain., 16, 575–594. https://doi.org/10.1007/s10668-013-9495-4

Thomas, D.S.G., Twyman, C., 2005. Equity and justice in climate change adaptation amongst natural-resource-dependent societies. Glob. Environ. Chang. 15, 115–124. https://doi.org/10.1016/j.gloenvcha.2004.10.001

Thoonen, M., De Smet, L., 2017. Analyse van de relatie tot het landschap in Voeren van de sectoren erfgoed, natuur, recreatie; toerisme en wonen. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2017 (25). Instituut voor Natuur- en Bosonderzoek, Brussel. DOI: doi.org/10.21436/inbor.12669883

Townsend, E., 1996. Institutional ethnography: a method for showing how the context shapes practice. Occup Ther J Res.16, 179-199. https://doi.org/10.1177%2F153944929601600303

Turkelboom, F., Leone, M., Jacobs, S., Kelemen, E., García-Llorente, M., Baró, F., Termansen, M., Barton, D.N., Berry, P., Stange, E., Thoonen, M., Kalóczkai, Á., Vadineanu, A., Castro, A.J., Czúcz, B., Röckmann, C., Wurbs, D., Odee, D., Preda, E., Gómez-Baggethun, E., Rusch, G.M., Pastur, G.M., Palomo, I., Dick, J., Casaer, J., van Dijk, J., Priess, J.A., Langemeyer, J., Mustajoki, J., Kopperoinen, L., Baptist, M.J., Peri, P.L., Mukhopadhyay, R., Aszalós, R., Roy, S.B., Luque, S., Rusch, V., 2018. When we cannot have it all: ecosystem services trade-offs in the

context of spatial planning. Ecosyst. Serv. 29, 566–578. http://dx.doi.org/10.1016/j.ecoser.2017.10. 011.

Vance-Borland, K., Holley, J., 2011. Conservation stakeholder network mapping, analysis, and weaving. Conserv. Lett., 4, 278–288. https://doi.org/10.1111/j.1755-263X.2011.00176.x

Vihervaara, P., Marjokorpi, A., Kumpula, T., Walls, M., Kamppinen, M., 2012. Ecosystem services of fast-growing tree plantations: A case study on integrating social valuations with land-use changes in Uruguay. For. Policy Econ., 14, 58–68. https://doi.org/10.1016/j.forpol.2011.08.008

von Heland, J., Folke, C., 2014. A social contract with the ancestors—Culture and ecosystem services in southern Madagascar. Glob. Environ. Chang., 24, 251–264. https://doi.org/10.1016/j.gloenvcha.2013.11.003

Williams, A., Rankin, J. M., 2015. Interrogating the ruling relations of Thailand's post-tsunami reconstruction: Empirically tracking social relations in the absence of conventional texts. J. Soc. & Soc. Welfare, XLII (2), 79–102. https://scholarworks.wmich.edu/jssw/vol42/iss2/6

983 **Table 1.** Description of methodological tools relevant for cross-scale dependence-
984 influence analysis in ecosystem services research.

Tool	Description	Relevance for analysis of cross-scale social interactions	Examples of relevant applications
Stage 1. Identification of social actors			
Participant observation	Researchers build a close and trustful relation with social groups or communities through an intensive involvement over an extended period of time in their daily practices, activities or routines. This method is usually combined with interviews (Newing et al., 2011).	It allows to engage in the community and to gain deep knowledge about who gain and loose from ecosystem services. Through this method, researchers can also uncover discrepancies between what participants say (e.g. in interviews) and what actually does happen.	(Calvet-Mir et al., 2012; Iniesta-Arandia et al., 2014; von Heland and Folke, 2014)
Semi-structured interviews	Pre-arranged interviews based on a guide or structure (a list of topics or questions to address) but not constrained by it (Newing et al., 2011; Reed et al., 2009)	By allowing open-ended answers, it allows for a deeper understanding of the topic. It also allows to apply snowball sampling that contributes to identify the full suite of social actors.	(Felipe-Lucia et al., 2015a; Gould et al., 2015; Klain et al., 2014; von Heland and Folke, 2014)
Questionnaires	The most structured social research method, consisting of a set of specific questions, often closed-ended questions, with the aim to elicit information on a particular, quantifiable variable (Newing et al., 2011).	By administering the questionnaire to a representative population and through the use of comparable questions (ranking, rating scales or closed checklists), questionnaires allow to characterize communities and relationships between variables, i.e. dependence on ecosystem services or influence on decision-making, on the basis of statistical evidence.	(Felipe-Lucia et al., 2015a; Martín-López et al., 2007)
Focus groups	Pre-arranged group interviews and discussion with a small selection of participants that often follow a guide (Reed et al., 2009). Focus groups allow participants to voice their opinions and knowledge, although they include the risk that the discussion might be dominated by certain individuals.	Focus groups contribute to reach consensus regarding the social actors relevant for the analysed ecosystem services, who gain or loss from it, and who influence decision-making.	(Crouzat et al., 2016; Fazey et al., 2010)
Expert panel-based approaches	Selection of people supposed to have expertise enough to assess a topic. This method is used when specialized knowledge and input is required.	Expert-panel approaches contribute to gain knowledge about existing social actors in a short time-frame. However, as it is limited in terms of social actors involved, it might hide relevant actors.	(Geneletti, 2007; Orsi et al., 2011)
Stages 2 and 3. Assessment of the level of dependence on ecosystem services and influence on decision-making			

63
64
65

Cognitive mapping and mental models	A process by which respondents filter, recall and decode their cognitive frameworks regarding the interpretation and understanding of their environment and their relationships with it (Biggs et al., 2011) .	Eliciting and sharing mental models can strengthen the uptake of multiple sources of knowledge, thereby, building understanding about the multiple social actors operating at different scales regarding the use and management of ecosystem services.	(Moreno et al., 2014; Vihervaara et al., 2012)
Rainbow diagrams	Tool to classify social actors according to the degree they can affect or be affected by a problem or action (Chevalier and Buckles, 2008)	Can be adapted to assess to what degree different social actors influence or are dependent on ecosystem services.	(Cundy et al., 2013; Starick et al., 2014)
Interest-influence matrix	Analytical tool to sort social actors in a two-dimensional plot according to their relative level of interest and influence on a certain environmental issue (Reed et al., 2009).	The purpose of this tool is to prepare a sound classification of social actors that helps understand their dependence on ecosystem services and their influence in management of ecosystem services. It also supports the understanding of stakeholders' viewpoint and motivations related to ecosystem services. It finally contributes to predict possible social conflicts derived from management actions.	(García-Nieto et al., 2015; Iniesta-Arandia et al., 2014; Maguire et al., 2012)
Participatory and deliberative mapping	Method for collecting spatial information about natural resources, ecological properties and components, and their use by people, within a geographical framework (Newing et al., 2011). It is often based on local and experiential knowledge (Brown and Fagerholm, 2015).	Participatory mapping is used to engage different social actors in the identification of relevant ecosystem services, and to spatially identify where they are provided and used or demanded by people (Brown and Fagerholm, 2015). Therefore, it is able to spatially identify those actors who depend on and use a particular set of ecosystem services.	(García-Nieto et al., 2015; Palomo et al., 2013; Plieninger et al., 2013)
Scenario planning	Scenario planning aims at developing multiple alternative futures, which should be coherent, internally consistent and plausible (Peterson et al., 2003). Participatory scenario planning also entails the construction of futures with multiple social actors, fostering the integration of complementary types of knowledge as well as social learning and innovation (Oteros-Rozas et al., 2015).	Scenarios and visioning of the possible and plausible future relations between drivers of change, ecosystem services and the human wellbeing of multiple social actors contributes to improve understanding of important interlinkages and feedbacks between components of social-ecological systems across scales (IPBES, 2016).	(Bohensky et al., 2006; Hanspach et al., 2014; Malinga et al., 2013; Oteros-Rozas et al., 2013; Palomo et al., 2011)
Stage 4. Type and strength of interactions among social actors within and across scales			
Actor-linkages matrices	Mapping and descriptive tool used as starting point for discussing relationships (usually based on flows	It can produce a graphical representation of the information flows between actors influencing the	(Biggs and Matsaert, 1999)

	of information) between key actors. One of the main aims is to explore power relationships in the control of flow of information (Biggs and Matsaert, 1999).	management of ecosystem services.	
NetMap	Mapping tool based on interviews that allows the identification, among others outcomes, of complex formal and informal relations and power relations among social actors (Schiffer and Hauck, 2010).	It increases network understanding by combining structural measures of the network with attributes of actors, such as influence or dependence on ecosystem services.	(Schiffer and Hauck, 2010)
Social network analysis	Social networks are comprised of social actors who are tied to one another through meaningful relations, based on information, resources or material flows. The focus of social network analysis goes beyond attributes of individual actors, and explores how actors are allocated within a network, which subgroups of actors emerge based on their relations and how relations are overall structured in the network (Friis and Nielsen, 2014; Prell et al., 2009)	It can identify influential social actors in ecosystem services management, as well as 'brokers' (i.e. social actors who guarantee the connection between groups of social actors or between systems) and, thereby, allows to identify which actors are decisive in the system and at which scale operate (Friis and Nielsen, 2014)	(Ernstson et al., 2008; Fliervoet et al., 2016; Rathwell and Peterson, 2012; Vance-Borland and Holley, 2011)
Institutional ethnography	This method seeks to make connections among the situations of everyday life experienced by individuals in working within institutions (e.g. Grahame, 1998; Townsend, 1996)	It can contribute to identify power dynamics in the daily life of different actors when working with institutions.	(Perreult, 2003; Williams and Ranking, 2015)

985

63
64
65

986 Table 2. Summary of the four case studies used to illustrate the suitability of the 'cross-scale influence-dependence framework', including the
987 ecosystem services related to the case study, main actors identified at each spatial scale and the method used for their identification, and
988 discussion on distributional and procedural equity. Methods used to collect the data are also presented, indicating (a) methods used to identify
989 ecosystem services and (b-e) methods used in each step of the 'cross-scale influence-dependence framework' (1-4, respectively). Decision-
990 makers include both policy advisers and resource managers.

Case study	**Main ecosystem services**	**Actors**			**Method to identify actors**	**Distributional equity**	**Procedural equity**	**Methods**	**References**
		Local	**Regional**	**Global**					
Small-scale coral reef fisheries in Southern Kenya (~175 km coastline) (**Section 3.1.**)	Provisioning: materials and fishery. Cultural: research, education, cultural heritage and recreation. Regulating: habitat maintenance, coastal protection, sanitation.	Fish workers, coastal residents	Fisheries, park managers, decision-makers, tourism industry, scientists		Focus groups (9 focus groups with 4-9 participants per group).	Winners: Tourism industry and scientists, both at the regional and global scales. Losers: Fishermen and residents, both at the local scale.	Well represented in decision-making: Managers (local scale), Tourism industry (regional and global scales). Less represented: Fish workers (local scale).	Focus groups (a-e); Individual semi-structured interviews (*N*= 180) (c, e); Participant observation (e).	(Hicks et al., 2015, 2013; Hicks and Cinner, 2014)
Traditional farming in the Nacimiento	Provisioning: food. Cultural: aesthetic enjoyment, local	Farmers, rural residents,	Urban residents, nature	NGOs, decision-makers	Interviews (*N* = 18). Participant observation. Face-to-face	Winners: intensive agriculture	Represented in decision-making: environmental	Interviews (a, b, e); Face-to-face questionnaires (b-	(García-Llorente et al., 2015, 2012;

watershed, SE Spain (598 km^2) (**Section 3.2.**)	identity, tourism. Regulating: erosion control, hydrological regulation.	NGOs, decision-makers	tourists, NGOs, decision-makers		questionnaires (*N* = 181): Farmers (9.6%); rural residents (31.2%); nature and rural tourists (33%); NGOs and decision-makers (26.2%).	farmers (includes greenhouses). Losers: traditional farmers and rural residents (local scale), urban residents and nature tourists (regional scale).	managers, NGOs and farmers (local scale), environmental NGOs and decision-makers (regional scale); decision-makers related with water efficiency (regional and European scales)	d); Focus groups and participant observation (b); Interest-influence matrix (c-d); Deliberative mapping workshops (16 participants) (c); Social network analysis (e)	García-Nieto et al., 2015; Iniesta-Arandia et al., 2014; Iniesta-Arandia 2015)
Nature tourism in rural areas in the Piedra River valley, NE Spain (616 km^2) (**Appendix A**)	Cultural: aesthetic enjoyment, recreation and nature tourism, environmental education, and cultural identity. Regulating: habitat maintenance, water depuration, climate regulation, and biological control,	Farmers, rural population, local NGOs	Tourism industry, tourists, decision-makers.	European decision-makers, scientists, tourism industry	Interviews (*N= 71):* Farmers (23%); tourism industry (18%); leisure sector (37%); organizations (23%)	Winners: Workers of the tourism industry; Losers: local residents	Represented in decision-making: Tourism industry, NGOs, farmers (local scale), decision-makers (all scales)	Semi-structured interviews (a-e); Face-to-face questionnaires (a); Participant observation (c-e); Interest-influence matrix (c-d); Actor-linkages matrix (e)	(Felipe-Lucia et al., 2015a, 2015b)
Grass-based dairy system in Voeren Eastern	Provisioning: fodder and milk production. Cultural: aesthetic enjoyment, cultural	Dairy and arable farmers, horse	Tourists, decision-makers, agro-	European decision-makers, agro-	A stakeholder analysis workshop with 7 local experts with a helicopter view. Twelve	Winners: arable farmers and horse owners (local scale).	Represented in decision-making: decision makers (all scales), and	Interviews (a-e); Card-game (a); workshops (b-e); interest-influence	(Annys et al., 2017; Demeyer et al., 2017;

Belgium (51 km^2) (**Appendix B**)	identity, recreation, nature tourism. Regulating: water flow regulation and carbon sequestration.	owners, local community	business sector	business sector	semi-structured interviews of local experts with different backgrounds: Farmers, tourism, public organizations.	Losers: dairy farmers and local community, both at the local scale.	agro-business sector (regional and European scales)	matrix (b-d)	Thoonen and De Smet, 2017)

991

992 **Figure legends**

993 Figure 1. Visual representation of the cross-scale influence-dependence framework.
994 We illustrate the framework by including five different social actors, but other actors can
995 be relevant as well, such as rural communities, researchers or environmental
996 managers. In step 4, arrows are simplified to represent relations between different
997 social actors within a particular spatial scale and across scales. Arrow thickness
998 denotes the strength of the relations among social actors mediated by formal (solid
999 line) and informal (dashed line) institutions. Note that this figure is a schematic
1000 representation of our framework, not a summary of the results. See main text for
1001 details.

1002

1003 Figure 2. Application of the cross-scale influence-dependence framework in the
1004 southern Kenyan coastline: (a) Dependence on ecosystem services associated with
1005 coral reef fisheries: materials, fishery, research & education, bequest, culture,
1006 recreation, habitat, coastal protection, and sanitation (Hicks et al., 2015, 2013). (b)
1007 Cross-scale patterns of influence on the management of ecosystem services by
1008 different social actors. Arrows denote the most important relations mediated by formal
1009 (solid lines) and informal institutions (dashed lines) among actors regarding the
1010 decision-making on ecosystem services. The length of petals, scoring from 0 (without
1011 influence) to 5 (large influence), is based on expert opinion. (c) Dependence-influence
1012 matrices across scales.

1013

1014 Figure 3. Application of the cross-scale influence-dependence framework in the
1015 Nacimiento watershed (SE Spain): (a) Dependence on ecosystem services associated
1016 with traditional farming by different social actors at different scales. Such ecosystem

63
64
65

services include food, erosion control, hydrological regulation and aesthetic values (García-Llorente et al., 2015, 2012). The length of petals, scoring from 0 (not dependence) to 5 (highly dependent) is based on Iniesta-Arandia et al. (2014). (b) Cross-scale patterns of influence on the management of ecosystem services by different social actors. Arrows denote the most important relations mediated by formal (solid lines) and informal institutions (dashed lines) among social actors regarding decision-making on ecosystem services. The length of petals, scoring from 0 (without influence) to 5 (highly influential), is based on Iniesta-Arandia et al. (2014) and expert opinion. (c) Dependence-influence matrices across scales.

Figure 1

Click here to download high resolution image

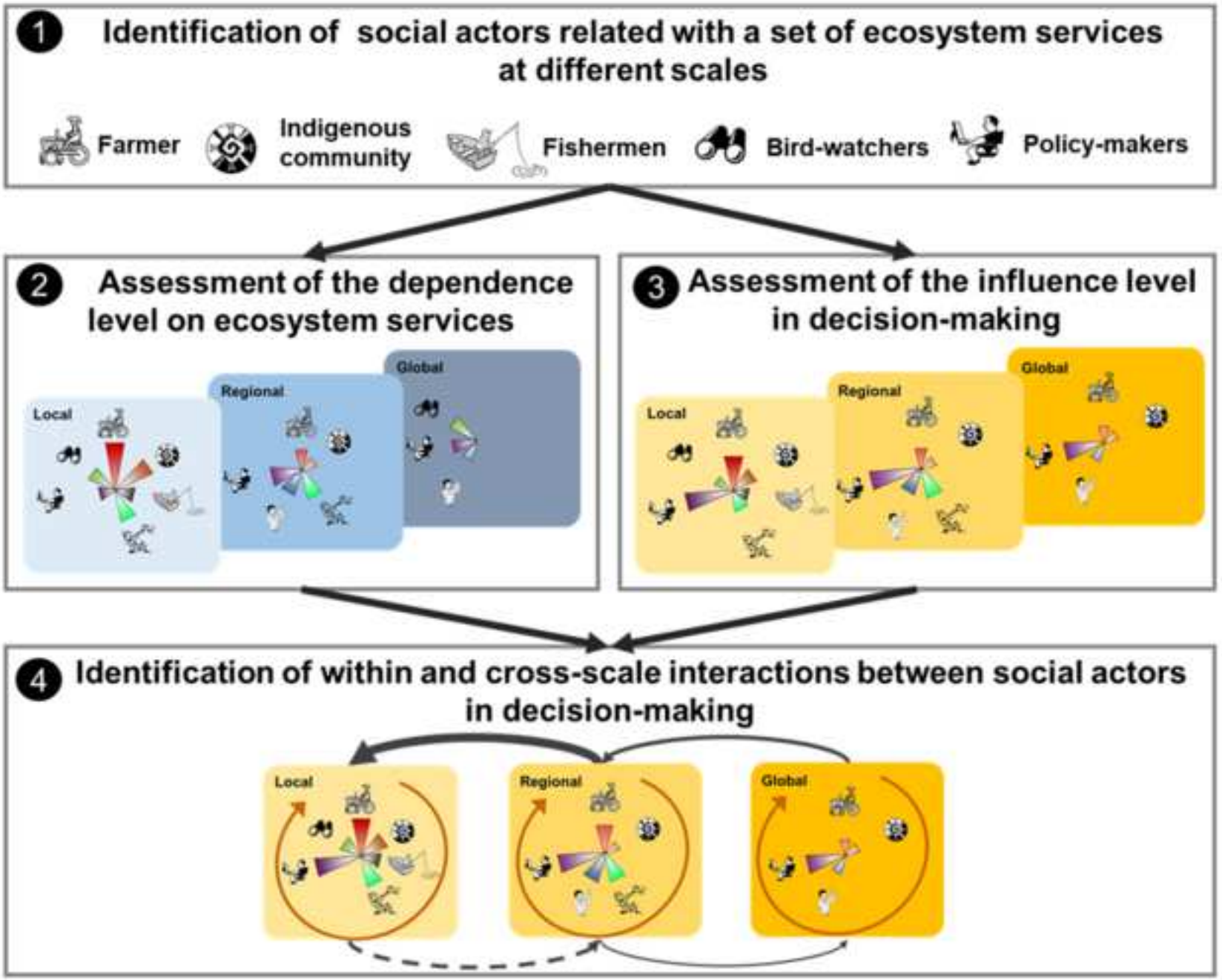


Figure 2

Click here to download high resolution image

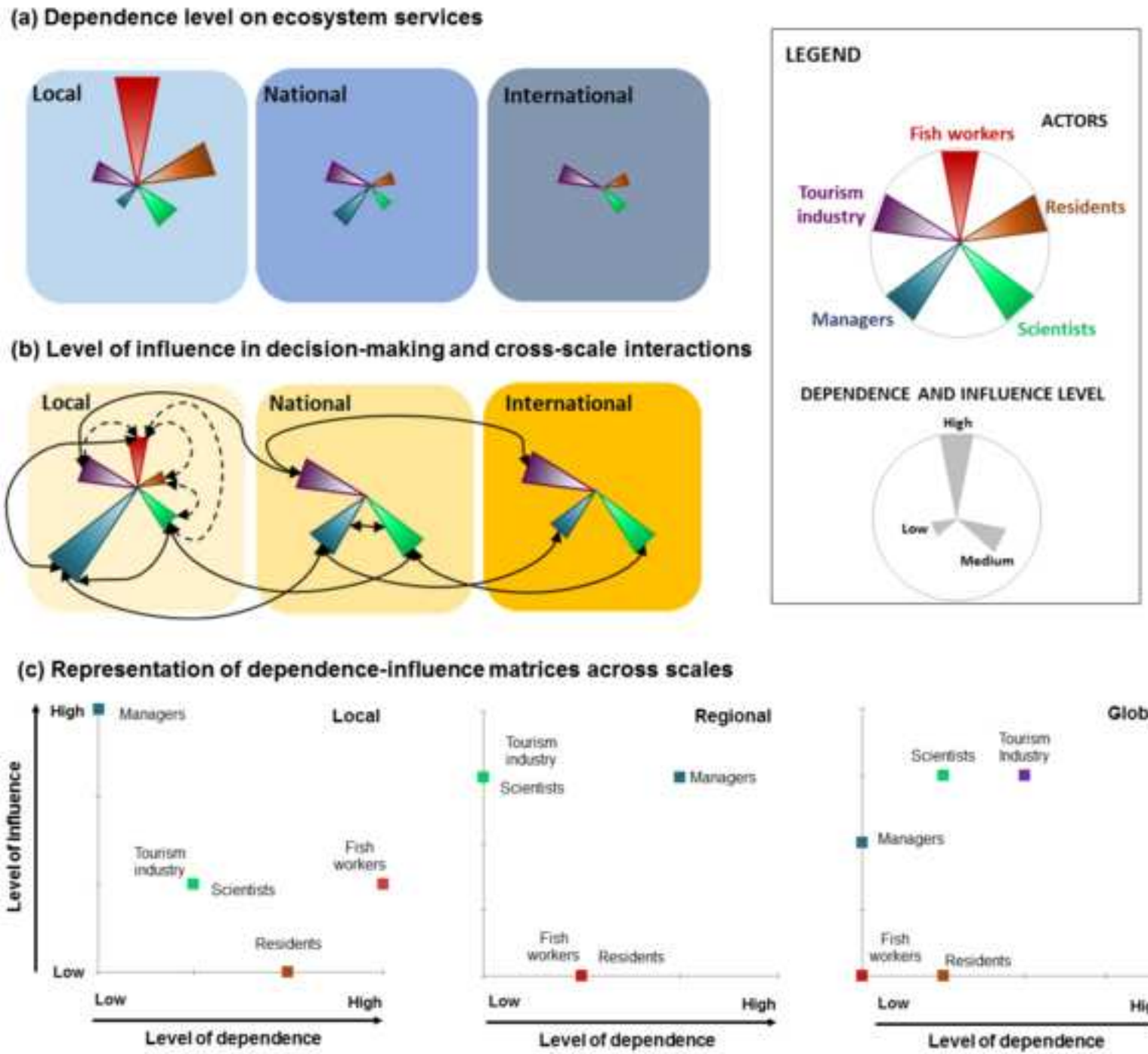
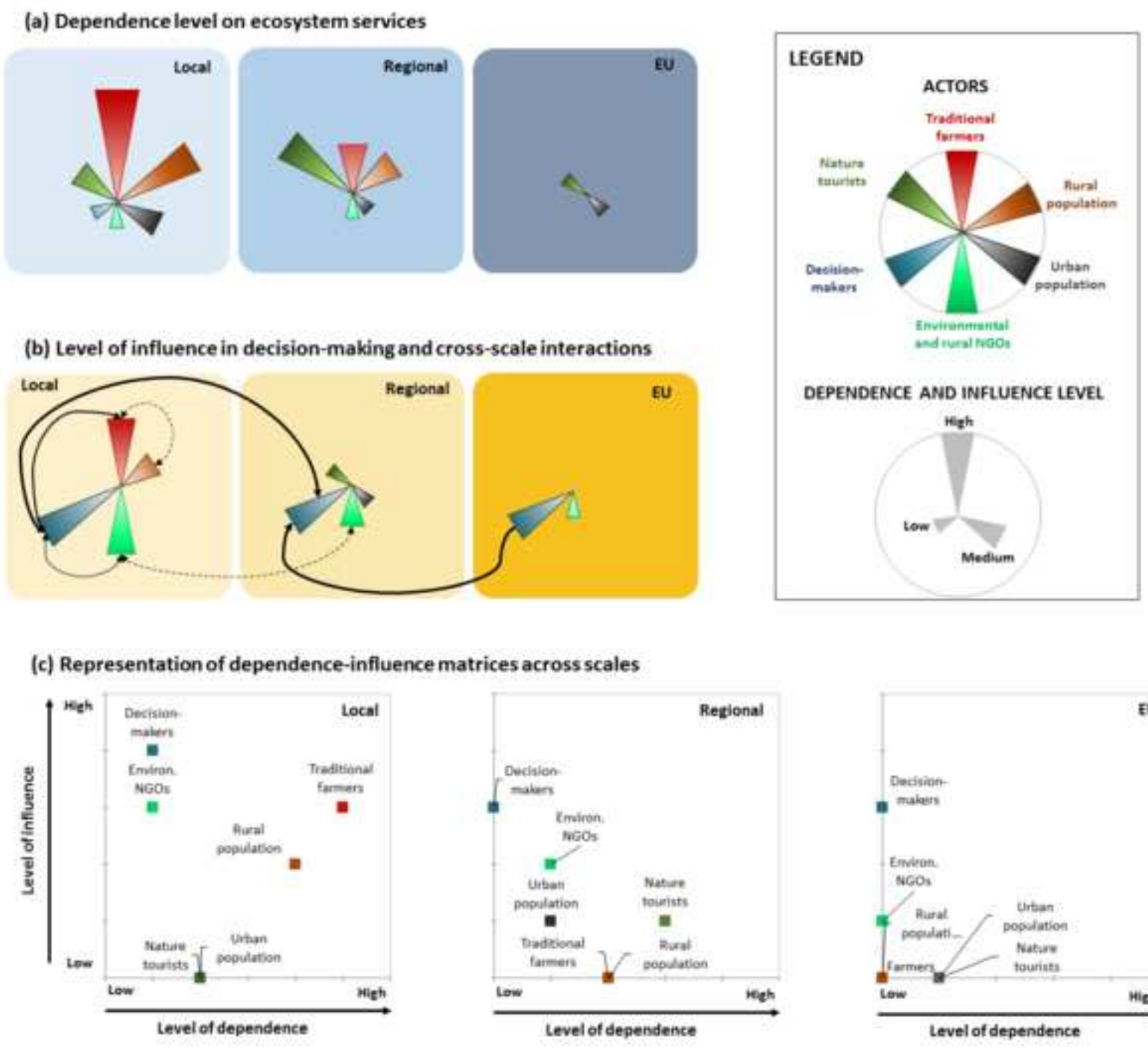


Figure 3

Click here to download high resolution image



Appendix A

Click here to download e-component: Appendix A_05_03.docx

Appendix B

Click here to download e-component: Appendix B_08_03.docx