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Delineating boundaries of social-ecological systems for landscape planning: A comprehensive spatial approach

Berta Martín-López[a,*], Ignacio Palomo[b,c], Marina García-Llorente[c,d], Irene Iniesta-Arandia[c], Antonio J. Castro[e,f], David García Del Amo[c], Erik Gómez-Baggethun[g,h], Carlos Montes[c]

[a] Leuphana University of Lüneburg, Faculty of Sustainability, Institute of Ethics and Transdisciplinary Sustainability Research, Scharnhorststraβe 1, 21355, Lüneburg, Germany
[b] Basque Centre for Climate Change (BC3), Alameda de Urquijo 4, 48008, Bilbao, Spain
[c] Social-Ecological Systems Laboratory, Department of Ecology, c. Darwin, 2, Edificio de Biología, Universidad Autónoma de Madrid, 28049 Madrid, Spain
[d] Department of Applied Research and Agricultural Extension, Madrid Institute for Rural, Agricultural and Food Research and Development (IMIDRA), Ctra. Madrid-Barcelona (N-II), KM. 38.200, 28802 Alcalá de Henares, Madrid, Spain
[e] Department of Biological Sciences,Idaho State University 921 S. 8th Avenue Mail Stop 8007 Pocatello, ID 83209, USA
[f] Andalusian Center for the Assessment and Monitoring of Global Change (CAESCG), Department of Plant Biology and Ecology, Ctra. Sacramento s/n, La Cañada de San Urbano, Universidad de Almería, 04120 Almería, Spain
[g] Department of International Environment and Development Studies (Noragric), Norwegian University of Life Sciences (NMBU), P.O. Box 5003, N-1432 As, Norway
[h] Norwegian Institute for Nature Research (NINA), Gaustadalleen 21, 0349 Oslo, Norway

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A B S T R A C T

An increasing number of studies demonstrate the need of applying a social-ecological system approach for landscape planning. However, there is a lack of empirical research that operationalizes the concept of social-ecological system for landscape planning through the characterization of social-ecological interactions. In this study, we develop a methodological framework to delineate the boundaries of social-ecological systems and to characterize their main social-ecological units in a spatially explicit way. Social-ecological units represent the interactions between the biophysical and socio-economic sub-systems at local scale. The methodology is structured in four phases: (1) ecological regionalization, i.e. identification and mapping of consistent ecological units based on biophysical variables; (2) socio-economic regionalization, i.e. identification and mapping of homogeneous groups of municipalities based on socio-economic variables; (3) identification of social-ecological systems boundaries and characterization of social-ecological units; and (4) validation of the social-ecological systems boundaries with key informants through participatory mapping. By applying the proposed methodological framework to three different Mediterranean cultural landscapes, we define the boundaries of social-ecological systems and illustrate how social and ecological sub-systems interact at local scale. We conclude that the proposed methodological framework is useful to operationalize the concept of social-ecological systems in landscape planning.

1. Introduction

Many recent studies have recognized that human systems and ecosystems are inextricably linked, forming social-ecological systems (SES) or coupled natural and human systems (e.g. Berkes and Folke, 1998; Liu et al., 2007; Ostrom, 2009). SES are complex adaptive systems in which social and biophysical components are interacting at multiple temporal and spatial scales (Liu et al., 2007). On one hand, biophysical components influence ecosystem properties across temporal and spatial scales in a hierarchical way (Bailey, 1987, 2009; Klijn and Udo de Haes, 1994). Factors, such as geomorphology or climate, operate at large scales determining ecosystem properties from regional to global spatial scales. These factors influence slow-changing variables that remain relatively constant over decades to centuries, such as hydrology (Carpenter and Turner, 2000; Chapin et al., 2006), that ultimately determine ecosystem properties at local spatial scales, such as the soil capacity to recharge water (Fig. 1). The spatial scale at which each of these factors control ecological properties hierarchically

* Corresponding author.
E-mail addresses: martinlo@leuphana.de (B. Martín-López), ignacio.palomo@bc3research.org (I. Palomo), marina.garcia.llorente@madrid.org (M. García-Llorente), irene.iniesta@uam.es (I. Iniesta-Arandia), castanto@isu.edu (A.J. Castro), dvd.gdelamo@gmail.com (D. García Del Amo), erik.gomez@nina.no (E. Gómez-Baggethun), carlos.montes@uam.es (C. Montes).

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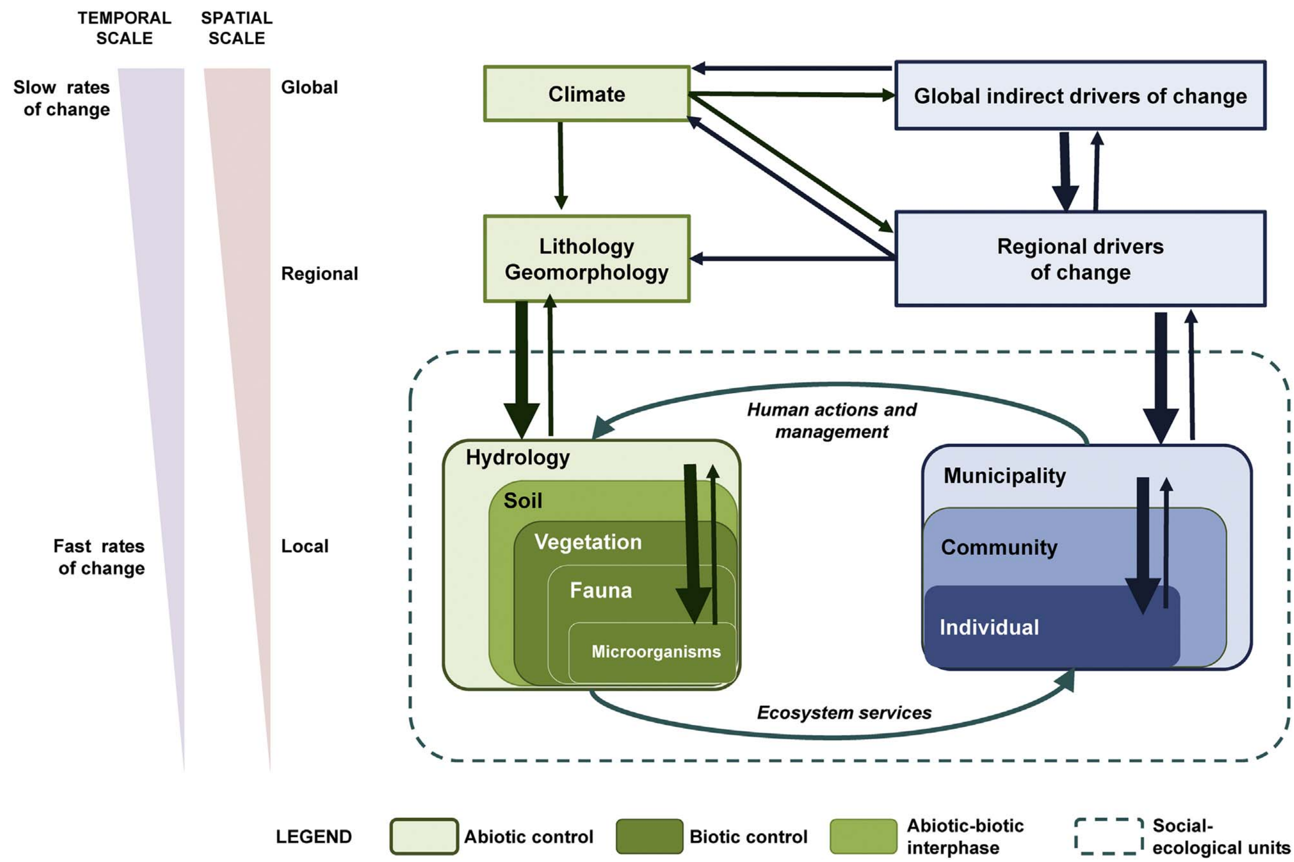

Fig. 1. Conceptual model of ecological and social components that define social-ecological units used to operationalize the delineation of social-ecological systems (SES) at local scale. The ecological subsystem is represented in the left side and the social subsystem is represented in the right side. The interactions between components and across temporal and spatial scales are represented through arrows.

Table 1
The relationship between ecological classification and the relevant biophysical factors operating at various spatial scales. Based on Bailey (1985, 1987) and Klijn and Udo de Haes (1994).

Ecological classification	Mapping scale	Surface of mapping unit	Relevant biophysical factors	Spatial scale
Ecozone	1: > 50 000 000	> 62 500 km^2	Clime	Global
Ecoprovince	1: 10 000 000–50 000 000	2500–62 500 km^2	Clime and geomorphology	Global-Regional
Ecoregion	1: 2 000 000–10 000 000	100–2500 km^2	Lithology and geomorphology	Regional
Ecodistrict	1: 500 000–2 000 000	625–10 000 ha	Hydrology (groundwater and surface water) and topology	Regional-Subregional
Ecosection	1: 100 000–500 000	25–625 ha	Soil, topology, and hydrology (groundwater and surface water)	Subregional
Ecoseries	1: 25 000–100 000	1.5–25 ha	Soil and hydrology (variables that directly affect vegetation growth)	Local
Ecotope	1: 5000–25 000	0.25-1–5 ha	Vegetation	Local
Eco-element	1: < 5000	< 0.25 ha	Fauna	Local

determine the size of ecosystems at different scales (Table 1). Thus, although the boundaries of ecosystems are open to transfer energy and material to or from their surrounding ecosystems (Bailey, 1987, 2009), they are nested, i.e., the boundaries of an ecosystem are entirely enclosed by the boundaries of another ecosystem (Fig. 1) (Allen and Starr, 1982). On the other hand, social systems can be viewed as a hierarchy of systems interconnected by cross-scale interactions from global to local (Chapin et al., 2006). At broader spatial scales, the globalized economy and predominant governance system determine the functioning of social systems at regional scales, which in turn influences the way people, at a local scale, interact to create a shared set of understandings, practices or behaviors that shape interactions among humans and between humans and nature (Ostrom, 2009; Díaz et al., 2015). Analogous to ecological systems, social systems operate hierarchically, where the social system at one scale is nested within another at larger scale (Fig. 1) (Janssen and Ostrom, 2007).

Biophysical and socio-economic variables interact across spatial scales. These linkages include the ecosystem services provided by ecosystems to society and the human actions, mediated by institutions, which affect ecological and social sub-systems (Fig. 1) (Berkes and Folke, 1998; Díaz et al., 2015). Therefore, the identification and characterization of SES cannot be developed by analyzing a narrow set of biophysical or socio-economic variables in isolation, but needs to take into account its whole complexity (Ostrom, 2009). Although the analysis of SES is an emerging field that has received increasing attention in scientific forums from a diversity of methodological frameworks (Binder et al., 2013; Cumming, 2011; Glaser et al., 2012); spatially explicit exercises for mapping SES boundaries are still scarce (Castellarini et al., 2014; Hamann et al., 2015). Whereas some methodological approaches have been suggested for mapping interactions between ecological and social sub-systems at global and regional scales, through the identification, for example, of 'anthropogenic biomes' (or 'anthromes') (Ellis and Ramankutty, 2008), land system archetypes (Václavík et al., 2013), identification of ecoregions (Castellarini et al., 2014) or bundles of ecosystem services use (Hamann et al., 2015); at local scale, few studies have simultaneously