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RESEARCH ARTICLE

A conceptual framework for the governance of multiple ecosystem services in agricultural landscapes

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Abstract
Context While the concept of ecosystem services (ES) is well established in the scientific and policy arenas, its operationalization faces many challenges. Indeed, ES supply, demand and flow are related to ecological and social processes at multiple space and time scales, leading to complex interactions in the provision of multiple ES.
Objectives To develop a conceptual framework (CF) to facilitate the study and governance of multiple ES in agricultural social-ecological landscapes.
Method We examined the ecological and social literatures to identify how approaches at the landscape level contribute to a better understanding of ES supply, demand and flow in agricultural systems. After detailing our CF, we use a case study to illustrate how methods from different disciplines can be combined to operationalize our CF.
Results The literature suggests that the landscape level is likely to be the level of organization that will make it possible to (i) integrate different components of ES co-production, i.e. ecological processes, agricultural practices and social structures, (ii) understand interactions between stakeholders, including ES co-producers and beneficiaries, (iii) explicit ES trade-offs, i.e. social choices between ES.
Conclusion The production of multiple ES at the landscape level involves different types of interdependencies among ES co-producers and beneficiaries. These need to be addressed in concerted and integrated ways to achieve sustainable and equitable governance of agricultural landscapes.

Keywords Agricultural practices · Biodiversity · Companion modeling · Ecological functions · Mapping · Remote sensing · Social interactions · Stakeholders · Spatio-temporal scales · Trade-offs

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Introduction

The concept of ecosystem services (ES), broadly defined as nature's benefits to people, is now well established in both scientific and policy arenas (e.g. Daily et al. 2009; Burkhard et al. 2013; Braat et al. 2018; Peterson et al. 2018 but see Díaz et al. 2018). ES provision results from three processes: ES supply (the potential of ecosystems to produce ES), ES demand (the level of ES provision desired or required by people) and ES flow (the connection between ES supply and ES demand; Fisher et al. 2009; Villamagna et al. 2013). Because it connects social and ecological dynamics, the concept of ES has been advocated to better understand social-ecological systems and to provide recommendations for their sustainable management. Numerous conceptual frameworks (CF) on ES provision have been developed over the years (e.g. MEA 2005; Larigauderie and Mooney 2010; Collins et al. 2011; Potschin and Haines-Young 2013; Fedele et al. 2017; Dendoncker et al. 2018). These CF have considerably improved the integration of the ecological and social components of ES provision. However, few have developed an integrative approach that simultaneously considers multiple ES, multiple ecosystems and multiple stakeholders.

A truly integrative approach to multiple ES governance needs to take several key challenges into account. First, it needs to consider that ES provision results from the combination of ES supply, demand and flow (Fischer and Eastwood 2016). For instance, ES flow, i.e., the fact that many ES are supplied by one ecosystem but in demand in other ecosystems remains overlooked. Second, it needs to consider that multiple space and time scales and levels are involved in ES supply and demand (Hein et al. 2006; Wu 2013). For instance, there is a need to account for the fact that ES demand may vary among stakeholders who act at different geographical and organizational levels, e.g., provisioning ES is more likely to be important for local stakeholders, while nature conservation may be more important for national and international stakeholders (Hein et al. 2006). Third, it needs to consider interactions between multiple ES (Bennett et al. 2009; Howe et al. 2014). In terms of ES supply, synergies/antagonisms between ES imply that the supply of one or several ES increases/decreases the supply of one or several others. Antagonisms among ES may generate conflicts between stakeholders with diverging ES demands (King et al. 2015; Turkelboom et al. 2018). Although there is a growing literature on these topics, few CF consider ES trade-offs in space, i.e., trade-offs across multiple ecosystems. Fourth, it needs to consider that some ecological processes result in perceived or actual nuisances to people, i.e., in ecosystem disservices (EDS, Shackleton et al. 2016). Beyond EDS trade-offs, trade-offs between ES and EDS may play a significant role in people's behaviors towards a given ecosystem and may reinforce conflicts between stakeholders who are differently affected by EDS (Blanco et al. 2019). Lastly, from a governance perspective, agricultural and environmental policies are often designed and implemented separately, and there is thus a need for coherence between policies (Primmer and Furman, 2012).

Landscape ecology has been proposed as a pivotal discipline to achieve truly integrative ES research (Müller et al. 2010; Wu 2013). First, landscape ecology defines "landscape" as an organizational level where different ecosystems and stakeholders interact. It is therefore an appropriate level to understand how ecological and social processes jointly contribute to ES provision. Second, landscape ecology typically considers the role of multiple space and time scales (scale being the extent or grain considered; Allen and Starr 1982). It considers that "landscape services", i.e., ES provided by multiple ecosystems in combination, are an emergent property of landscapes (Termorshuizen and Opdam 2009; Wu 2013; Bastian et al. 2014). Finally, today landscape ecology is increasingly focused on multifunctionality and the provision of multiple ES (e.g., Raudsepp-Hearne et al. 2010). Yet, there have been few attempts to develop and implement a truly integrative ES framework that simultaneously includes multiple ecosystems, stakeholders, ES and EDS. In this paper, we posit that an integrative landscape-based ES framework can support the operationalization of the ES concept for more sustainable and equitable governance of the agroecological transition.

Agricultural landscapes dominate 40% of the world's terrestrial area and are highly heterogeneous and dynamic. Agricultural landscapes are usually composed of a mosaic of crops, grasslands, freshwater and forested systems and result from agro-sylvo-pastoral activities conducted by multiple stakeholders. These activities are related to ES in two ways. On the one hand, agricultural activities depend on the provision of multiple ES, such as soil fertility or pollination. They can also be affected by EDS that are unfavorable to human well-being, such as crop pests or livestock diseases (Shackleton et al. 2016). On the other hand, these agricultural activities shape ecosystems and contribute to the supply of multiple ES (and EDS) that benefit (or affect) society as a whole (Zhang et al. 2007). Recent changes in agricultural practices associated with the industrialization of food production systems have dramatically undermined the capacity of agricultural landscapes to provide the many ES that are keys to both agricultural sustainability and society. As a result, there is now growing awareness of the need to design agricultural landscapes that are (i) multifunctional, i.e., produce biomass (food, wood, fiber or fuel), contribute to biodiversity conservation and deliver multiple other ES (e.g., carbon sequestration, aesthetic landscapes) and (ii) limit ecological processes that are unfavorable to agriculture and society (e.g., the spread of pests). Several authors have explored the role of the ES concept for agriculture, mainly by focusing on field or farm levels and in a *payment for services* way (e.g., Swinton et al. 2007; Robertson et al. 2014).

In this paper, we first examine the ecological and social science literature to see how the landscape approach can contribute to a better understanding of multiple ES provision in agricultural landscapes. We then develop a conceptual framework to facilitate an integrative landscape-based approach for ES governance in agricultural landscapes. In the third section, we use a case study to illustrate how methods from different disciplines can be combined in order to operationalize this CF.

Contributions of the landscape approach to multi-ES research

In this section, we first explain how the landscape approach can contribute to a better understanding of multiple ES supply and flow in agricultural landscapes. We then explain how this approach also makes it possible to consider the multiple stakeholders involved in ES co-production and ES demand.

Contributions of the landscape approach to the understanding of multiple ES supply and flow

The role of space and time heterogeneity

The ecological literature on agricultural landscapes provides significant evidence that some ES supplies result from processes occurring at multiple space and time levels, and that they are often provided by multiple ecosystems. This is particularly true in the case of ES that rely on ecological processes that rely on ecological processes ensured by mobile organisms. Such processes include pollination and biological control (Kremen et al. 2007; Duru et al. 2015), both crucial for the ecological intensification of agriculture (Pimentel et al. 1997; Costanza et al. 1999; Losey and Vaughan 2006; Federico et al. 2008; Maine and Boyles 2015). Indeed, most of the species involved require a combination of resources, i.e., feeding, reproduction and overwintering sites that may not necessarily be found within the same agro or ecosystem. This is also true in the case of large ungulates (e.g., deer), which may modulate nitrogen and nutrient cycling depending on landscape composition (Thompson Hobbs 1996). Additionally, ES supply depends on the continuity of resources within the home range of individuals over time (Schellhorn et al. 2015). For example, temporal variations in food resources availability over time due to crop phenology can influence the spillover of natural enemies and pollinators from semi-natural habitats to crops (Rand et al. 2006; Blitzer et al. 2012). However, these space and time variations also influence EDS supply, thereby complicating the landscape effect. For example, spillover can also concern pathogen fluxes from semi-natural habitats to crops, and ungulates can limit forest regrowth and crop production (Irby et al. 1996; Putman and Moore 2002; Boulanger et al. 2015). Additionally, the abundance of specific crop types may have a negative effect on predation and/or pollination in a given year (e.g., through a dilution effect) but a positive effect the following year due to the positive effect of resource availability on pollinator or predator population dynamics (Marrec et al. 2017).

The role of practices at field and landscape levels

The abundance, diversity and continuity of resources used by organisms depend not only on land cover, i.e., the composition and configuration of land cover types (Fahrig et al. 2011), but also on land use, i.e., agricultural, forestry and water management practices, at different levels in space (Ricci et al. 2009; Pelosi et al. 2010). While there is ample evidence of the effects of land cover on ES supply (see meta-analyses by Bianchi et al. 2006; Chaplin-Kramer et al. 2011; Garibaldi et al. 2011; Veres et al. 2013; De Palma et al. 2016), relatively little attention has been paid to the effects of practices on ES supply. However, practices at both field and landscape level are likely to influence ES supply, with possible non-linear and interacting effects between practices and land cover (Batary et al. 2011). At the landscape level, practices result in what is called hidden landscape heterogeneity, which strongly influences biodiversity and associated ES and EDS—hereafter jointly referred to as E(D)S (Maalouly et al. 2013; Monteiro et al. 2013; Vasseur et al. 2013; Puech et al. 2015; Carrié et al. 2017a). For instance, biological control in a given field is known to be influenced by agricultural practices in adjacent fields (Maalouly et al. 2013; Monteiro et al. 2013). The dynamics of practices, mainly due to crop rotation, also strongly influences E(D)S supply levels (Vialatte et al. 2006; Bertrand et al. 2016; Marrec et al. 2017) as well as their temporal stability over time (Allan et al. 2014). Finally, at the field level, practices may influence ES supply through their effect on adjacent landscape elements. For instance, the combination of pesticides and fertilizers applied in the field strongly influences wild plants growing within the field margins (Schmitz et al. 2014). This may in turn influence resources available for beneficial organisms like pollinators (Bretagnolle and Gaba 2015), and as a result, the quantity and quality of crop production (Holzschuh et al. 2012).

Synergies and antagonisms in ES supply

The supply of multiple E(D)S may be strongly interdependent across both space and time. For instance, the cascading effect of some ecological processes on other processes may result in synergies. In this sense, the density of ungulates (e.g., roe deer) influences N cycling, which may in turn influence the composition of plant communities and, possibly, pollination and biological control. Similarly, the fact that different ecological processes may be driven by the same factors may also result in antagonisms. For instance, an increase in ungulate density may affect N cycling while increasing crop damage (Fuller and Gill 2001; Côté et al. 2004). In addition, management practices may simultaneously orient the supply of multiple E(D)S, either within the same ecosystem or within two adjacent ecosystems. For instance, early sowing often increases water use efficiency by crops in a given field, but increases pest colonization from adjacent ecosystems (McLeod et al. 1992; Vialatte et al. 2006; Raymond et al. 2014). Finally, forest management practices may influence the biological control of both forest pests (Guyot et al. 2016) and crop pests in adjacent fields (Sarthou et al. 2005; Roume et al. 2011).

The ecological literature shows that space and time spatio-temporal heterogeneity, practices, synergies and antagonisms between E(D)S play a key role in ES supply and flow in agricultural landscapes. Such complex ecological interactions have crucial implications for stakeholders, both in terms of E(D)S co-production and E(D)S demand, and for agricultural landscape governance.

Contributions of the landscape approach to the understanding of ES co-production and ES demand

The European Landscape Convention has defined landscape as "an area, as perceived by people, whose character is the result of action and interaction of natural and/or human factors" (European Landscape Convention 2000). This definition stresses two important contributions of the landscape approach to E(D)S research. First, the idea that landscapes result from both human and natural factors means that people are not just E(D)S beneficiaries but also co-producers of E(D)S. Second, by stressing that people have inherently subjective perceptions of landscapes, this definition highlights the immaterial and subjective dimension of E(D)S derived from landscapes. The next two sub-sections are dedicated to these two contributions, and in each, we highlight the implications for E(D)S governance.

ES co-production

Land users as ES co-producers Landscape research emphasizes that landscapes are shaped by stakeholders such as farmers and foresters, whose activities and practices directly modify ecosystems (Plieninger et al. 2015). This implies that E(D)S are not produced by ecosystems alone, and that we should consider these stakeholders as E(D)S co-producers (Spangenberg et al. 2014; Bennett et al. 2015; Lescourret et al. 2015; Fischer and Eastwood 2016). Farmers are obviously key stakeholders of agricultural landscapes, not only as E(D)S co-producers but also as beneficiaries. Their work consists in shaping ecosystems so that they supply provisioning ES (e.g., crop production, fodder), and they are among the local stakeholders who interact most directly with regulation and maintenance ES (e.g., soil fertility and pollination) and are most directly affected by E(D)S (e.g., insect pests and crop raiding by mammals; Zhang et al. 2007). Sustainable and equitable governance of agricultural landscapes will inevitably rely on farmers' practices, and will require understanding their constraints, interests, values, representations and knowledge (Smith and Sullivan 2014). Some authors suggest that conventional agriculture has tended to give more importance to provisioning ES, which has had negative effects on regulating ES (Carpenter et al. 2006; Palomo et al. 2016). Yet, farmers should not be considered as a homogeneous group. A diversity of farming systems, with different practices, generally coexist in a given agricultural landscape (Choisis et al. 2012; Cochet 2012). These different farming systems and practices shape ecosystems differently, and therefore contribute to the supply of diverse sets of E(D)S (Gibon 2005). As a consequence, external driving forces, including agricultural policies, the economic context (e.g., market prices), public opinion (e.g., alarming discourses on biodiversity loss), or rapid demographic changes, influence farmers' strategies and practices differently, with diverse consequences for E(D)S supply (Verburg et al. 2010).

Implications for landscape governance: collaboration for ES supply at the landscape level Most agricultural landscapes are used and shaped by multiple land users (Selman 2006)—although exceptions can be found in places like the Pampas in Argentina where very large farms are managed extensively by single owners or managers (Manuel-Navarrete et al. 2009). When E(D)S depend on the landscape structure, e.g., for pollination, flood control or pest control, their supply results from the actions and practices of multiple stakeholders, often with no premeditated coordination among them. There is an increasing literature stressing the need to encourage collaboration among farmers and other rural land users for a more efficient ES supply at the landscape level (Goldman et al. 2007; Franks 2011; Stallman 2011; Prager et al. 2012; Prager 2015; Opdam et al. 2016). Yet, in Europe, most current agri-environmental schemes involve contracts with individual land owners at the farm level, while promoting collective contracts and incentives would be required for adequate agri-environmental management at the landscape level (Prager et al. 2012). The seminal work of Ostrom on collective action for common-pool resource management provides key insights into such collaborative processes (Ostrom 1990; Ostrom et al. 1994). Many E(D)S are indeed public or common goods (Stallman 2011; Muradian and Rival 2012) that require polycentric governance mechanisms (Ostrom 2010) combining instruments based on the markets, the state and collective action. However, collective action may not necessarily be relevant for all E(D)S because of the transaction costs of collaboration, and because people engage in collective action only if they foresee higher benefits than with individual action (Olson 1971). For example, several obstacles have been identified as impeding the emergence of landscape scale collaboration for pest control, such as the high uncertainties underlying the ecological processes, the existence of an integrated vertical supply chain focused on pesticide use, and the availability of less risky individual alternatives (Salliou and Barnaud 2017; Salliou et al. 2019).

ES demand

Landscape values and ES preferences A branch of landscape research focuses on the many reasons why people value landscapes, from non-material dimensions like aesthetic and place attachment to more tangible benefits like outdoor recreational activities, water regulation or food production (Plieninger et al. 2015). Following the seminal work of Costanza et al. (1997), monetary valuations of ES have long dominated the literature on ES valuation. Although these approaches can provide a pragmatic demonstration of the value of ecosystems and biodiversity, especially for decision makers, they have been highly criticized for paving the way for the commodification of nature (Gómez-Baggethun and Ruiz-Pérez 2011), and for failing to capture the diversity and complexity of people–nature relationships (Raymond et al. 2015). Numerous authors advocated the need to integrate a plurality of values, and to combine biophysical, monetary and socio-cultural valuations of ES (e.g., Dendoncker et al. 2013; Martín-López et al. 2014). Socio cultural valuations of ES aims at revealing “the importance people, as individuals or as a group, assign to (bundles of) ES” (Scholte et al. 2015, p. 68). The idea is to capture how and why different people value various landscape services differently, depending on their livelihoods, interests, personal history and cultural background, as well as their access to these services (Maass et al. 2005; Bieling et al. 2014; Da Ponte et al. 2017; Garrido et al. 2017). However, landscape values and ES preferences constantly evolve, depending for instance on changing individual circumstances, changing contexts, or access to new information (Kumar and Kumar 2008). In many cases, people are actually not aware of the whole range of benefits they get from ecosystems, for instance in the case of poorly visible ES like pollination or insect pest regulation (Salliou and Barnaud 2017), but access to relevant and actionable knowledge on these processes might increase their awareness (Opdam et al. 2016). People's preferences can also evolve through social interactions and group discussions (Raymond et al. 2015). Changes in ES perceptions and preferences can thus be referred to as social learning processes (Röling and Wagemakers 1998; Pahl-Wostl et al. 2007).

Implications for landscape governance: ES trade-offs and social choices Managing multiple ES in agricultural landscapes requires dealing with trade-offs among antagonist ES, i.e., when the supply of a given ES is detrimental to the supply of another ES (Rodríguez et al. 2006). In other words, this means that "we cannot have it all" (Turkelboom et al. 2018), and results in conflicts of interest between stakeholders with different ES preferences (Martín-López et al. 2012). In addition, maintaining some ecosystems for the ES they provide may lead to the maintenance of EDS. This means that "everything has a cost" (Blanco et al. accepted), and results in a balance between ES and EDS that is operated by stakeholders at individual and collective levels. In many cases, trade-offs arise without the stakeholders being aware of them (Rodríguez et al. 2006). For instance, the industrialization of agriculture has progressively increased ES provisioning to the detriment of regulating ES since the 1950s, but it was only in the 1990s that society became aware of it (Rodríguez et al. 2006; Blanco et al. 2018). Yet, these trade-offs generate winners and losers (Daw et al. 2011). They are therefore related to social choices that should be made explicit and collectively negotiated (Barnaud and Antona 2014). Analytical tools such as multi-criteria analysis and cost–benefit analysis can be useful to assess such trade-offs objectively (Koschke et al. 2012), but there is also a need to develop deliberative approaches to capture the *different* perceptions and knowledge and foster social learning processes (Galafassi et al. 2017; Moreau et al. 2019). Such deliberative processes should not be undermined by the power asymmetries in E(D)S related conflicts (Felipe-Lucia et al. 2015; Berbés-Blázquez et al. 2016; Barnaud et al. 2018).

The literature suggests that the landscape level is likely to be the level of organization that will make it possible to (i) integrate different components of E(D)S co-production, i.e., ecological processes, agricultural practices and social structures, (ii) understand interactions between stakeholders, including E(D)S co-producers and beneficiaries, (iii) explain trade-offs, i.e., social choices between E(D)S. Recently, there have been some attempts to better account for the role of landscape composition and configuration as well as the role of synergies and antagonisms between ES. For instance, Kremen et al. (2007) developed a CF integrating the role of landscape structure in ES produced by mobile organisms. Lescourret et al. (2015) proposed a CF integrating the ecological and social dimensions of multi-ES provision in agricultural landscapes. Barnaud et al. (2018) developed a CF highlighting interdependencies among multiple stakeholders and the role of collective action in ES co-production and multi-ES governance. However, these frameworks fail to integrate all the dimensions of ES provision, namely the multi-ecosystem, multi-stakeholder and multi-ES dimensions.

An integrative landscape-based framework for multi-ES governance

To tackle this conceptual challenge, we propose a CF that promotes an integrative landscape-based approach to multi-ES governance in agricultural social-ecological systems (Fig. 1). This CF is composed of four main components leading to the provision of multiple E(D)S: an ecological component, a social component, the institutions that influence social and social-ecological interactions, and the agricultural landscape resulting from land cover and practices. These components are characterized by internal interactions, e.g., competition and predation between taxonomic groups, conflicts and cooperation

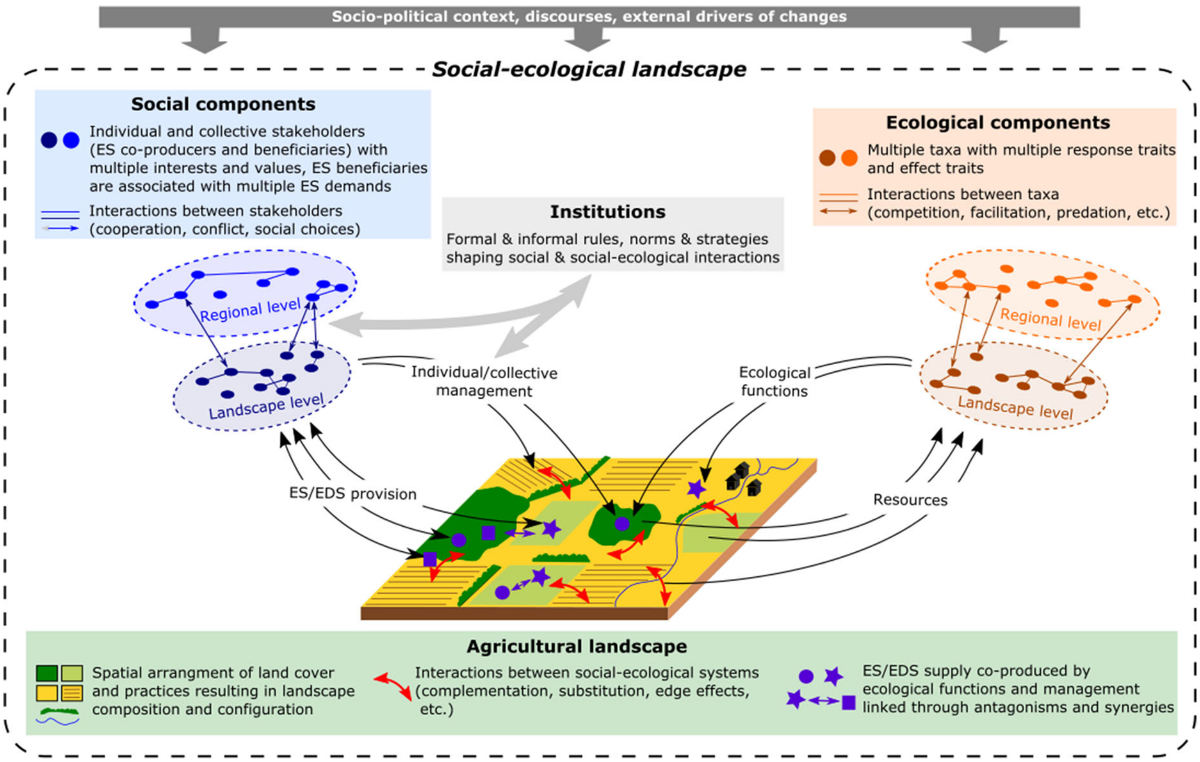


Fig. 1 Conceptual framework for an integrative landscape-based approach to ES governance in agricultural landscapes. (Color figure online)

between stakeholders, complementation or edge effects between socio-ecosystems. Institutions shape social interactions as well as social-ecological interactions. These components are affected by the sociopolitical and economic context, discourses and other external drivers of change such as migration, urbanization or climate change. These components are connected through several processes (1) the landscape provides resources to multiple taxonomic groups that support multi-ES supply, (2) ES beneficiaries interact with ES co-producers to influence their management of the landscape, (3) institutions play a key role in the governance of ES by influencing social and social-ecological interactions, and (4) individual and collective management, together with ecological functions, co-produce E(D)S at the landscape level. The following subsections discuss the four processes of this CF and how they are affected by social-ecological interactions at the level of the landscape.

Biodiversity, functions, ES supply and flow in agricultural landscapes

Multiple interacting ecosystems

Our CF takes into account the fact that the agricultural social-ecological landscape is composed of multiple interacting ecosystems. Landscape structure, resulting from land cover and practices, influences ES supply through its effects on biodiversity and functions. Indeed, the availability in space and time of diverse resources necessary for organisms is crucial for their persistence in agricultural landscapes. Many ecological processes are influenced by landscape structure, e.g., crop colonization by pests (Vialatte et al. 2006), competition for limited resources (Vialatte et al. 2017), pollination of crops and natural vegetation (Holzschuh et al. 2012) or predation of phytophagous species (Alignier et al. 2014; Raymond et al. 2014). The dynamics of biodiversity and its functions imply different dimensions of ES supply in space and over time, that may result in antagonisms and synergies (see examples in the previous section).

Multiple interacting taxonomic groups and functions

Our CF takes into account the fact that ES supply depends on multiple interacting taxonomic groups and functions. In some cases, several taxonomic groups contribute to a single ES, as illustrated by the joint contribution of wild bees and adult hoverflies to pollination. In other cases, a single taxonomic group contributes to several ES. For instance, adult hoverflies contribute to pollination while the larvae of some hoverfly species prey on aphids thereby contributing to biological control. Moreover, taxonomic groups are interconnected through trophic networks, resulting in complex cascading effects. For instance, bird and bat species are predators of both insect crop pests and of their natural enemies. Our CF therefore stresses the importance of using a multi-taxa approach in order to better understand the supply and flow of multiple ES.

Interacting landscape level and regional level processes

Our CF takes into account the fact that ES supply/flow is not only influenced by processes at landscape level, e.g., landscape complementation and spillover, but also by regional processes, e.g., large-scale organismal movements and resource flows. Indeed, potential biodiversity at the landscape level strongly depends on biogeography patterns that define the regional species pool (Begg et al. 2017). Regional species pools may be influenced by large scale processes such as climate change, dispersal, and species invasion. Landscape level and regional level processes may interact and have additive or non-additive effects on biodiversity and E(D)S, and should therefore be studied simultaneously as far as possible (Sirami et al. 2017). As a result, our CF stresses the importance of including both types of processes, in particular when studying changes in biodiversity and E(D)S over time.

From ES demand to ES co-production: social interactions among ES beneficiaries and ES co-producers in agricultural landscapes

Multiple ES beneficiaries

Various stakeholders profit from direct or indirect benefits or are harmed by ES and EDS depending on their own livelihoods, interests and preferences (e.g., Monteiro et al. 2013; Maalouly et al. 2013). These beneficiaries can be identified at both the landscape and regional level. Our CF aims to capture which ES or bundles of ES are important for which type of stakeholders, and why these ES are important to them (Barnaud et al. 2015; Blanco et al. 2018; Moreau et al. 2019; Blanco et al. accepted). Our assessment goes beyond the utilitarian values of ES and incorporates existence values, i.e., the fact that some stakeholders value a component of ecosystems (e.g., a given species) for its own existence rather than because it is useful to them. Moreover, following Daw et al. (2015), our CF distinguishes between ES demand and ES provision, which only occurs when ES demand and ES supply/flow are met (Egarter Vigl et al. 2017). For instance, the provision of ES associated with the aesthetic value of landscape in a National Park only occurs when tourists both value the aesthetic of this landscape and are able to afford the entrance fee to the National Park. Finally, our CF accounts for the fact that ES demand does not automatically translate into ES co-production, even when the co-producers of a given ES are also the beneficiaries of the same ES. Indeed, the translation of ES demand into ES co-production is mediated by individual and collective decisions that are influenced by complex social interdependencies among ES beneficiaries and ES co-producers.

Multiple interdependencies among ES beneficiaries and ES co-producers

Our CF highlights three types of social interdependencies among stakeholders involved in multi-ES governance: (i) between ES beneficiaries and ES co-producers, (ii) among ES beneficiaries, and (iii) among ES co-producers (Barnaud et al. 2018). All these interdependencies can be positive or negative, collaborative or conflicting, and occur in more or less formalized action arenas. Interdependencies between

ES beneficiaries and ES co-producers include situations where ES co-producers, e.g., farmers who plant hedgerows, positively contribute to ES supply, e.g., biodiversity conservation, which benefits other ES beneficiaries, e.g., society as a whole (Prager 2015). Interdependencies among ES beneficiaries are related to antagonisms and synergies among ES. For example, chemical inputs used by a farmer to increase his crop yield may negatively affect the pollinators of his neighbor's apple trees, resulting in an antagonistic relationship between these two ES (crop production and apple tree pollination), which generates a conflict of interest between their respective beneficiaries (the crop farmer and the apple producer). Our CF looks at how these antagonisms are dealt with and how social choices (trade-offs) are made, in more or less explicit and concerted ways, in the context of power relationships (Barnaud et al. 2018). Interdependencies among ES co-producers are of crucial importance in our landscape approach. Many ES are produced at the landscape level, and their production depends on the actions of multiple ES co-producers who contribute to shaping, degrading, or managing these landscapes (Lescourret et al. 2015). For instance, rangelands in mountain areas are often collective rangelands, used and managed by several herders who collectively establish rules and norms that frame the way rangelands are managed (Balent and Gibon 2011). Collaboration among ES co-producers therefore has the potential to increase ES supplies (Prager 2015; Salliou and Barnaud 2017; Salliou et al. 2017). Our CF accounts for the social conditions that facilitate or impede such collaboration. For instance, a case study in south-western France showed that local farmers were not interested in collective action because they were not aware of the role of landscape in pest regulation (Salliou et al. 2017), and consequently not aware of their interdependencies with neighboring farmers, a key pre-condition for collective action (Leeuwis and van den Ban 2004). Similarly, there is a strong societal demand for climate and water quality regulation ES whereas these are provided by the combination of multiple ecosystems managed by multiple stakeholders who are not necessarily the main beneficiaries of these ES. For many farmers, agricultural practices favoring these ES (e.g., the maintenance of hedgerows and grassy strips, the use of diversified crops and reduced chemical inputs) appear too constraining for such small individual benefits, as they generate extra costs for the farmers (Blanco et al. in press). In cases in which ES beneficiaries and ES co-producers are not mutually interdependent, collective action alone may not suffice. Unless the multifunctionality of agroecological infrastructures for crop production at landscape scale is a sufficient incentive for farmers, the translation of ES demand into ES co-production may require monetary subsidies.

Institutions

Interactions among social components, as well as between ecological and social components are shaped by institutions, i.e., the "prescriptions that humans use to organize all forms of repetitive and structured interactions" (Ostrom 2005). Institutions include both formal and informal rules-in-use, norms and strategies. A landscape based approach makes it possible to move beyond individual incentives for farm level management, as currently emphasized by the Common Agricultural Policy (CAP) (Lefebvre et al. 2015). In turn, it is particularly relevant to guide the design and to support 'bricolage' (Cleaver 2002) by institutions for collective ES management involving both ES beneficiaries and ES co-producers by providing incentives and constraints for initiating and sustaining effective collective action (Ostrom 1990, 2005). Yet the right 'institutional fit', i.e., the right set of institutions for a given social-ecological system, may not be sufficient to address social-ecological problems unless institutions are supported by contextual elements within and beyond the landscape, such as social relations (Mosse 1997; Cleaver 2002), environmental discourses and the political and economic context (Clement 2013). Lastly, institutions provide the basis for inclusive deliberative processes that allow stakeholders to debate the benefits and trade-offs of different options for landscape management (Robards et al. 2011).

Landscape management and ES co-production in agricultural landscapes

Multiple interacting ecosystems and stakeholders

Our CF takes into account the fact that the agricultural social-ecological landscape is composed of multiple interacting ecosystems and stakeholders. Ecosystems include different types of agricultural land cover, i.e., crops and meadows, semi-natural cover, i.e., patches of forest or grassland, as well as linear semi-natural elements such as hedgerows, rivers, grassy margins, and human-dominated cover types, i.e., urban areas and roads. Stakeholders who manage these ecosystems include farmers, foresters, hunters, landscape planners, and residents. We consider them as ES co-producers. Stakeholders who benefit from ES in these landscapes include farmers, foresters, hunters, landscape planners, and residents as well as tourists. A single stakeholder often manages several components of the landscape. For instance, farmers usually manage several patches of the same type of land cover, e.g., crop fields, or several patches of different types of land cover, e.g., crop fields, meadows and woodland. Conversely, some landscape components are managed by several stakeholders, either with similar or diverging interests, e.g., collective rangelands in mountain areas used and managed by several herders. While some ES beneficiaries may mainly benefit from one type of ecosystem, e.g., foresters benefit from forest patches, most ES beneficiaries are likely to benefit from several ecosystems or a combination of ecosystems.

Land cover and practices

Stakeholders manage land cover by taking decisions such as crop rotation, grouping fields, wood cutting or removing hedgerows. These practices influence both landscape composition, i.e., the type of ecosystems occurring in the landscape, and landscape configuration, i.e., the spatial organization of these ecosystems. Moreover, stakeholders influence the land use within each landscape component through the nature, frequency and intensity of their practices. These disturbances affect the quality of all the ecosystems that make up the landscape. Both land cover and practices influence the resources that are available in space and over time for the many taxonomic groups present in the landscape (see examples in the previous section). The availability of resources will in turn shape the ecological functions that contribute to the supply of multiple ES at the landscape level. Our CF enables the integration of both land cover and practices to understand the co-production of ES.

Understanding ES co-producers' decision making

Stakeholders' decisions regarding land cover and practices depend on multiple factors. Our CF explicitly integrates the following dimensions of decision making. First, stakeholders' decisions depend on their representation of the social-ecological system (i.e., their mental model), which is itself linked to their interests, values and preferences (e.g., the need for wood for fuel, the need for grassland to feed the cattle; Vuillot et al. 2016; Salliou and Barnaud 2017). These representations and stakeholders' perceptions of their interests and preferences can be studied using discourse analysis, i.e., "a specific ensemble of ideas, concepts, and categorizations that is produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer 1995, p. 60). Discourses shape how environmental problems are framed around specific storylines and narratives. A discursive analysis of landscape representations can reveal the gaps between local perceptions of landscape and ES changes and the dominant discourses in Europe that influence the policy drivers of those changes (Quétier et al. 2010).

Second, stakeholders' decisions are also dependent on their constraints, which can be bio-physical (e.g., slope, elevation), socio-economic (e.g., labor force) and/or? institutional (e.g., land tenure; Gibon et al. 2006). External social, political and economic drivers such as the CAP also play a key role in their decisions (Blanco et al. ref à venir). The proposed landscape based framework provides a single lens to analyze all these processes. For instance, urbanization can affect the co-production of ES and EDS in remote rural locations and this can best be comprehended at the landscape level (Antrop 2000). Our CF therefore integrates social and ecological, as well as internal and external factors that influence the individual decisions and practices of ES co-producers. It also takes into account the fact that these decision-making processes are influenced by social interactions with other stakeholders, i.e., other ES co-producers and ES beneficiaries, and that the dynamics of decision making processes plays a key role in ES governance in agricultural social-ecological systems (Isaac et al. 2007).

Case study: applying the landscape-based framework to a French agricultural region

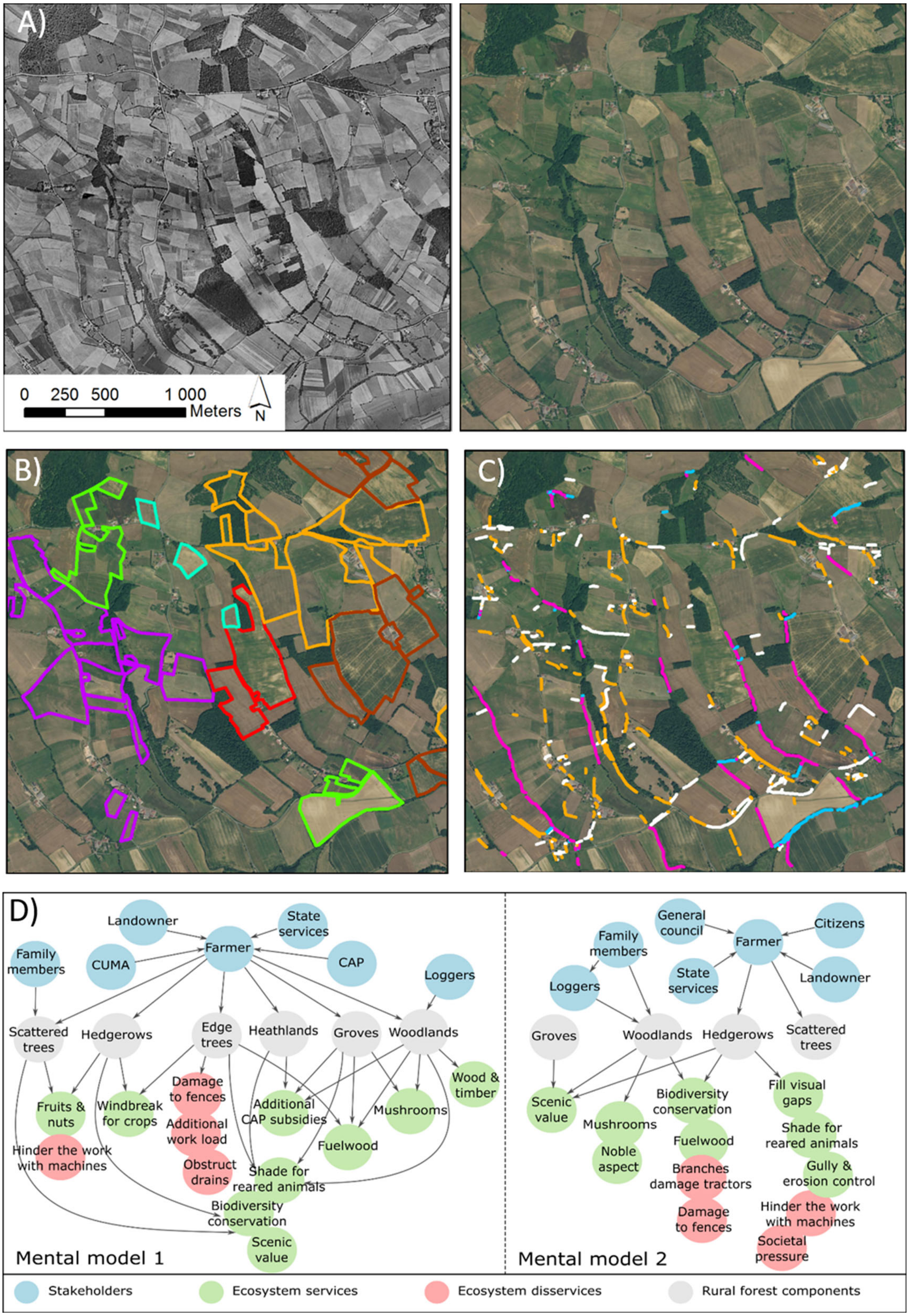
Our case study focuses on the *Vallées et Coteaux de Gascogne*, which is part of the Long Term Socio-Ecological Research site ZA PYGAR (Deconchat et al. 2007). Located in south-western France, this hilly region (250–400 m a.s.l.) covers 220 km^2 (43°17′N, 0°54′E) and the climate is sub-Atlantic with slight Mediterranean influences (mean annual temperature, 12.5 °C; mean annual precipitation, 750 mm).

Land cover and practices

The region is dominated by mixed crop-livestock farming systems and is therefore characterized by a mosaic of small patches of woodland, grasslands and crop fields (Fig. 2a). Permanent grasslands tend to be located on steep slopes while annual crop fields (winter cereals, rapeseed, corn and sunflower) are located in the most productive, drained and irrigable valleys (Choisis et al. 2012; Thierry et al. 2017). Other farms are more specialized, either in cash crops or cattle production, with practices based mainly on chemical inputs. Farm territory may be in one block or highly fragmented and interspersed within other farm territories (Fig. 2b).

Stakeholders: co-producers and beneficiaries of ES

Farmers are the main stakeholders of social-ecological landscapes in this rural region with a low population density. Using in-depth interviews and focus groups for socio-cultural valuation of ES among farmers, we showed that they manage their farm for crop production but also take ethical and social biodiversity values into consideration (Kelemen et al. 2013). Four main types of discourses on ES related to livestock farming were identified among local stakeholders: the first three types of discourses emphasize respectively the productive and economic dimensions of livestock farming, the biodiversity of permanent grassland ecosystems, and the heritage and cultural identity of traditional mixed farming landscapes, while the fourth one questions the need to continue livestock farming (Barnaud et al. 2015). Regarding the perception of ecological processes, beyond the importance of habitat and species diversity, farmers also acknowledge wider landscape processes and value the complexity of ecological systems. By comparing agricultural practices and mental models, we showed that farmers' ways of farming partly relate to farmers' ways of thinking about the landscape: the farmers who are the most aware of ecological interdependencies also manage diverse non-cultivated habitats like permanent grasslands, hedgerows and woodlands in the most ecological way (Vuillot et al. 2016). In addition, we found that farmers had contrasting perceptions of the E(D)S related to rural forests (i.e., farm forests and trees outside forests) depending on the nature of their farming system, which was closely linked to contrasted attitudes towards CAP greening measures (Blanco et al. in press). Permanent grasslands are well integrated in the local mixed crop-livestock farming systems because they provide fodder. Our analysis of historical aerial photos showed that hedgerows have declined but with contrasted trends depending on their location and adjacent land uses (Fig. 2a and c). In-farm hedgerows that were an obstacle to mechanization have declined, whereas boundary hedgerows that provided protection against the wind and served as farm boundaries were reinforced (Sourdril et al. 2012; Blanco et al. 2018). Interviews revealed that farmers also perceived different E(D)S depending on the type of wooded area. For example, they associated 16 ES and 6 EDS with hedgerows, 14 ES and 6 EDS with woods and 8 ES and 7 EDS with isolated trees (Teixeira et al. 2019). In the context of mechanized agriculture, forested areas were particularly resented as they hinder working with tractors. These detrimental effects of rural forests were offset by several ES, such as firewood production for self-consumption or for sale, erosion control or landscape scenic value (Elyakime and Cabanettes 2013; Teixeira et al. 2019). In addition, our research revealed a shift from family-based to market-oriented forest management that contributed to the homogenization of forest management practices in this region (Blanco et al. 2018). The central social network of farmers is made up of land owners who rent out their land to farmers; agricultural advisers from local cooperatives (associated with conventional food systems) and public authorities, who respectively guide farmers in the use of chemical inputs and agricultural practices to limit their negative environmental impacts; river technicians who analyze river water quality and authorize farmers to irrigate. Other stakeholders who interact indirectly or less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Landowner
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State services
Family members
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CAP
Loggers
Scattered trees
Hedgerows
Edge trees
Heathlands
Groves
Woodlands
Wood & timber
Fruits & nuts
Windbreak for crops
Damage to fences
Additional work load
Additional CAP subsidies
Mushrooms
Fuelwood
Hinder the work with machines
Obstruct drains
Shade for reared animals
Biodiversity conservation
Scenic value
Mental model 1
General council
Citizens
Family members
Farmer
State services
Landowner
Loggers
Groves
Woodlands
Hedgerows
Scattered trees
Scenic value
Biodiversity conservation
Fill visual gaps
Mushrooms
Shade for reared animals
Fuelwood
Noble aspect
Branches damage tractors
Gully & erosion control
Damage to fences
Hinder the work with machines
Societal pressure
Mental model 2
Stakeholders
Ecosystem services
Ecosystem disservices
Rural forest components

◀ **Fig. 2** Illustrations of the work conducted for the French case study *Vallées et Coteaux de Gascogne*, part of the Long Term Ecological Research Network. **a** Agricultural intensification between 1953 (BD ORTHO® Historique, IGN) and 2016 (BD ORTHO®, IGN) affect biodiversity and E(D)S by simplifying landscape structure (e.g., loss of semi-natural habitats except woodlots, increasing the size of fields and farms) and changes in farming practices (e.g., reduction of crop diversity and an increase in the use of fertilizers and pesticides). **b** Spatial configuration of agricultural parcels on six farms (one color per farm, resulting from RPG_ANONYME_ASP_2014) showing how they are intermingled. **c** Spatial configuration of two ES supported by hedgerows in agricultural landscapes: regulating water flow, i.e., riparian hedgerows, and windbreaks, i.e., hedgerows facing the prevailing wind (hedgerows with only water flow regulation potential are in blue, hedgerows acting only as windbreaks are in orange, those with both water and wind regulation potential are in pink, those that do not provide these ES are in white). **d** Representation of the variability of social-ecological perceptions by actors (here two farmers) regarding the management of woodlot components (grey circles) by stakeholders (blue circles) and associated ecosystem services (green circles) and disservices (pink circles) (from Blanco et al. 2018). (Color figure online)

frequently with farmers include mayors who are responsible for local urban planning and infrastructure including roads, and interact with public county level institutions; naturalists who aim to preserve local biodiversity; and finally hunters who use several landscape elements to hunt and wish to preserve them (unpublished data).

Formal and informal institutions and consequences for E(D)S production

While the strong promotion of farm specialization by the CAP has marginalized mixed crop-livestock farms in Europe, our analysis of historical farm trajectories revealed that mixed crop-livestock farming persists in the *Vallées et Coteaux de Gascogne* region (Choisis et al. 2012). Anthropological surveys revealed that this was partly linked to a local tradition of maintaining the house centered self-sufficient mixed crop-livestock system and hard environmental conditions (Sourdril et al. 2012). However, under the influence of market globalization and decreasing workforce availability, half the farms in the region have become more specialized, either in cash crops or cattle production, and have relied on drainage, irrigation, increasing the size of their fields and their use of chemical inputs. The comparison of surveys on practices and GIS work showed that these trends have had a considerably impact on the landscape structure (Fig. 2a, Ryschawy et al. 2013). Surveys conducted with mayors, public county level agencies and river technicians showed that they identify water pollution and mudslides as major environmental issues, associated with high public environmental, health and economic costs. They call for changes in local agricultural practices, with the (re)introduction of agroecological infrastructures such as hedges and grassy strips, crop diversification, the use of crop covers and reduced use of chemical inputs. Whereas many farmers have changed their practices and even created local farmers groups to support the agroecological transition of their farms, these initiatives will not result in significant ecological benefits unless they are coordinated at the landscape level (unpublished data).

Ecological processes in the landscapes and the associated ES

Ecological studies conducted in our study area confirmed that cultivated and non-cultivated ecosystems are ecologically connected. For instance, we showed that many beneficial insect species spill over from semi-natural habitats, where they overwinter, to crop fields where they provide ES such as biological control and pollination (Sarthou et al. 2005; Roume et al. 2011; Alignier et al. 2014; Raymond et al. 2014). Crop fields also appear to be interconnected across years by flows of pests and beneficial insects (Raymond et al. 2014; Marrec et al. 2017). Using individual movement tracking, we showed that ungulates contribute to the connectivity of nutrient cycles between woodlots, hedgerows and fertilized croplands in this region (Morellet et al. 2011; Abbas et al. 2012). We showed that while local practices in semi-natural habitats (e.g., maintenance of woodland edges, woodlot structure) or within fields, directly impact populations of ungulates, beneficial insect communities and associated ES, their effect depends on practices at landscape level and on the structure and composition of the landscape (Morellet et al. 2011; Andrieu et al. 2017; Carrié et al. 2017b). Finally, studies conducted on pest-predator networks confirmed that landscape level processes interact with regional level processes and jointly explain the provision of biological control (Andrade et al. 2015).

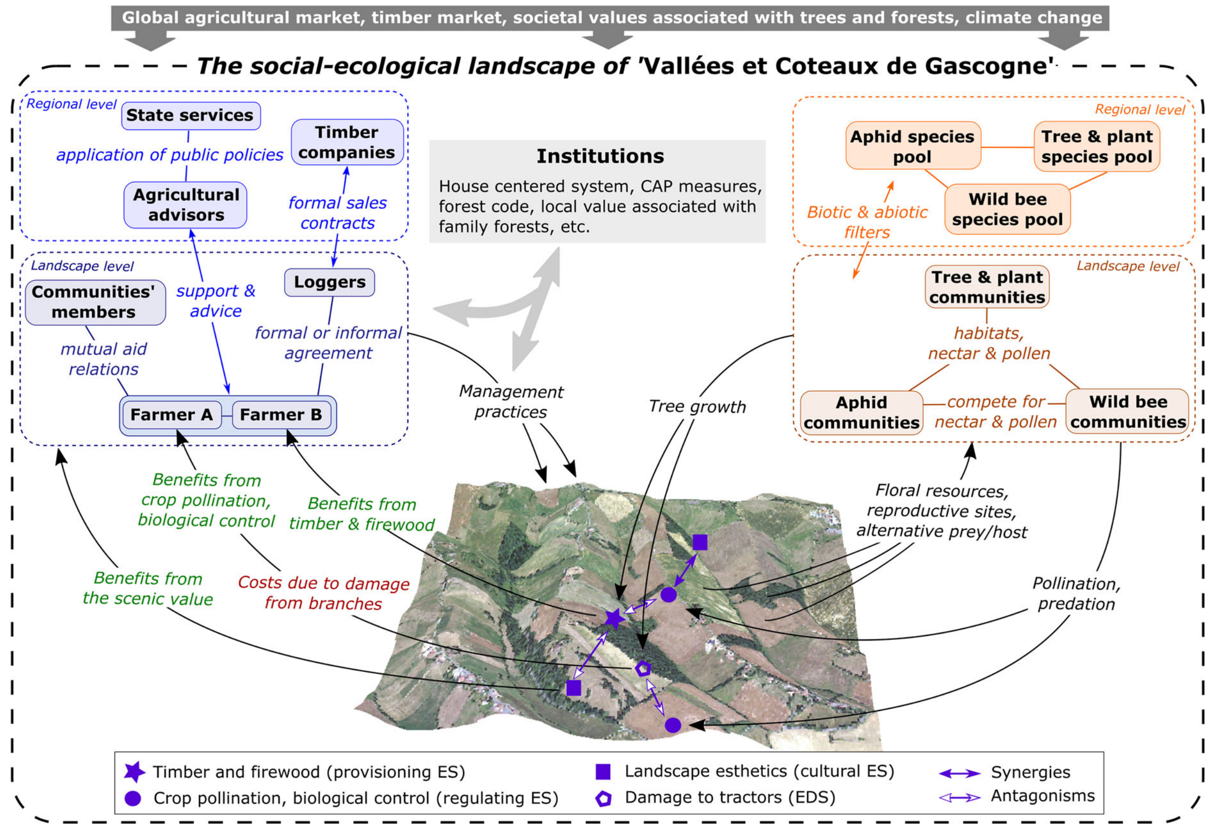

Fig. 3 Example of social and ecological interdependencies in the long term socio-ecological research site ZA PYGAR in south-western France, based on a selection E(D)S and associated key, stakeholders, ecological processes and institutions. Blue panels and arrows code for social actors and their interactions. Orange panels and arrows code for ecological components and their interactions. Black arrows code for the landscape-mediated interactions between ecological and social actors. (Color figure online)

Multiple interdependencies among ES beneficiaries and ES co-producers; consequences for operationalizing ES in decision making

As exemplified by all the above mentioned studies and results, rural landscapes in the *Vallées et Coteaux de Gascogne* region are shaped and transformed by interdependent social and ecological processes. As illustrated in Fig. 3 with an example that emphasizes a few E(D)S, stakeholders and ecological actors, our CF can be applied to explore these complex processes and their interplay.

In this region, farmers appear to be highly interdependent for the production of multiple ES, including food production, pollination, biological control or hunting. Their management decisions concerning agricultural practices and rural forest management directly influence biodiversity and ES levels within each ecosystem. Moreover, spatial interactions between ecosystems as well as temporal interactions across seasons and years also influence biodiversity and ES levels at the landscape level. This is particularly true for outbreaks of insect and mammal pests, water pollution and mudslides. Interviews with farmers highlighted their strong acknowledgement of ethical and social biodiversity values and suggest that soft policy tools could foster biodiversity-sensitive farming methods (Kelemen et al. 2013). Several studies of farmers' mental models in the same region (Vuillot et al. 2016; Blanco et al. 2018) suggest that increasing stakeholders' awareness of their multiple social and ecological interdependencies would be the first step in supporting effective collective action toward agroecological transitions (Fig. 2d). All this interdisciplinary work in the same study area has greatly contributed to the development of a methodological approach to foster concerted management of multiple ES at the landscape level in the context of participatory action research, using the approach proposed by Barnaud et al. (2018). Dynamic E(D)S mapping in the *Vallées et Coteaux de Gascogne* region based on remote sensing and ecological assessments is also underway. This mapping should help inform decisions both in space and over time, which is indispensable for sustainable governance of multiple ES in agricultural landscapes.

Conclusion

We propose a CF to operationalize integrative ES research for multiple ES governance in agricultural social-ecological systems. We posit that this CF will also facilitate dialog between scientists and a large spectrum of stakeholders, including farmers, land managers, agricultural educators, environmental agencies and policy makers.

We currently face two main challenges regarding the assessment of sustainability of agricultural landscapes: long time frames and actual experimental landscapes (Hamilton et al. 2015; Therond et al. 2017). Indeed, research on ES in agricultural landscapes has so far been conducted in landscapes designed and used for many decades to optimize conventional agriculture. Yet little is known about the overall potentialities of multi-ES supply and crop production in agroecological landscapes. Thus, like Landis (2016), we emphasize the crucial need to actually test design concepts at large spatial and temporal scales.

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References

Abbas F, Merlet J, Morellet N, Verheyden H, Hewison AJM, Cargnelutti B, Angibault JM, Picot D, Rames JL, Lourtet B, Aulagnier S, Daufresne T (2012) Roe deer may markedly alter forest nitrogen and phosphorus budgets across Europe. Oikos 121:1271–1278

Alignier A, Raymond L, Deconchat M, Menozzi P, Monteil C, Sarthou J-P, Vialatte A, Ouin A (2014) The effect of semi-natural habitats on aphids and their natural enemies across spatial and temporal scales. Biol Control. https://doi.org/10.1016/j.biocontrol.2014.06.006

Allan E, Bossdorf O, Dormann CF, Prati D, Gossner MM, Tscharntke T, Blüthgen N, Bellach M, Birkhofer K, Boch S, Böhm S, Börschig C, Chatzinotas A, Christ S, Daniel R, Diekötter T, Fischer C, Friedl T, Glaser K, Hallmann C, Hodac L, Hölzel N, Jung K, Klein AM, Klaus VH, Kleinebecker T, Krauss J, Lange M, Morris EK, Müller J, Nacke H, Pašalić E, Rillig MC, Rothenwöhrer C, Schall P, Scherber C, Schulze W, Socher SA, Steckel J, Steffan-Dewenter I, Türke M, Weiner CN, Werner M, Westphal C, Wolters V, Wubet T, Gockel S, Gorke M, Hemp A, Renner SC, Schöning I, Pfeiffer S, König-Ries B, Buscot F, Linsenmair KE, Schulze E-D, Weisser WW, Fischer M (2014) Interannual variation in land-use intensity enhances grassland multidiversity. Proc Natl Acad Sci 111:308–313

Allen TFH, Starr TB (1982) Hierarchy: perspectives for ecological complexity, 2nd edn. University of Chicago Press, Chicago

Andrade TO, Outreman Y, Krespi L, Plantegenest M, Vialatte A, Gauffre B, Baaren Jv (2015) Spatiotemporal variations in aphid-parasitoid relative abundance patterns and food webs in agricultural ecosystems. Ecosphere 6:art113

Andrieu E, Cabanettes A, Alignier A, Van Halder I, Alard D, Archaux F, Barbaro L, Bouget C, Bailey S, Corcket E, Deconchat M, Vigan M, Villemey A, Ouin A (2017) Edge contrast does not modulate edge effect on plants and pollinators. Basic Appl Ecol. https://doi.org/10.1016/j.baae.2017.11.003

Antrop M (2000) Background concepts for integrated landscape analysis. Agrirc Ecosyst Environ 77:17–28

Assessment ME (2005) Millennium ecosystem assessment. Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington, DC

Balent G, Gibon A (2011) Interactions of grasslands with forest at the landscape level: topical issues and challenges attached to land management in agro–silvo–pastoral landscapes. In: Grassland productivity and ecosystems services, pp 239–250

Barnaud C, Antona M (2014) Deconstructing ecosystem services: uncertainties and controversies around a socially constructed concept. Geoforum 56:113–123

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

Barnaud C, Theil L, Choisis J-P, Eychenne C (2015) Les services écosystémiques: une notion savante déconnectée des représentations locales? Une analyse des représentations locales de l'élevage en zone agricole défavorisée. In: Environnement, politiques publiques et pratiques locales. L'Harmattan. Béringuier P, Blot F, Desailly B, Saqalli M, Paris, pp 26–49

Bastian O, Grunewald K, Syrbe R-U, Walz U, Wende W (2014) Landscape services: the concept and its practical relevance. Landscape Ecol 29:1463–1479

Batary P, Fischer J, Báldi A, Crist T, Tscharntke T (2011) Does habitat heterogeneity increase farmland biodiversity? Front Ecol Environ 9:152–153
Begg GM, Cook S, Dye R, Ferrante M, Franck P, Lavigne C, Lövei G, Mansion-Vaquié A, Pell JK, Petit S, Quesada N, Ricci B, Wratten S, Birch A (2017) A functional overview of conservation biological control. Crop Prot 97:145–158
Bennett EM, Cramer W, Begossi A, Cundill G, Díaz S, Egoh BN, Geijzendorffer IR, Krug CB, Lavorel S, Lazos E, Lebel L, Martín-López B, Meyfroidt P, Mooney HA, Nel JL, Pascual U, Payet K, Harguindeguy NP, Peterson GD, Prieur-Richard A-H, Reyers B, Roebeling P, Seppelt R, Solan M, Tschakert P, Tscharntke T, Turner B, Verburg PH, Viglizzo EF, White PC, Woodward G (2015) Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. Curr Opin Environ Sustain 14:76–85
Bennett EM, Peterson GD, Gordon LJ (2009) Understanding relationships among multiple ecosystem services. Ecol Lett 12:1394–1404
Berbés-Blázquez M, González JA, Pascual U (2016) Towards an ecosystem services approach that addresses social power relations. Curr Opin Environ Sustain 19:134–143
Bertrand C, Baudry J, Burel F (2016) Seasonal variation in the effect of landscape structure on ground-dwelling arthropods and biological control potential. Basic Appl Ecol 17:678–687
Bianchi FJJA, Booij CJH, Tscharntke T (2006) Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. Proc Biol Sci 273:1715–1727
Bieling C, Plieninger T, Pirker H, Vogl CR (2014) Linkages between landscapes and human well-being: an empirical exploration with short interviews. Ecol Econ 105:19–30
Blanco J, Dendoncker N, Barnaud C, Sirami C (2019) Ecosystem disservices matter: towards their systematic integration within ecosystem service research and policy. Ecosyst Serv 36:100913
Blanco J, Sourdril A, Deconchat M, Ladet S, Andrieu E (2018) Social drivers of rural forest dynamics: a multi-scale approach combining ethnography, geomatic and mental model analysis. Landsc Urban Plan. https://doi.org/10.1016/j.landurbplan.2018.02.005
Blitzer EJ, Dormann CF, Holzschuh A, Klein A-M, Rand TA, Tscharntke T (2012) Spillover of functionally important organisms between managed and natural habitats. Agric Ecosyst Environ 146:34–43
Boulanger V, Baltzinger C, Said S, Ballon P, Picard J-f, Dupouey J-L (2015) Decreasing deer browsing pressure influenced understory vegetation dynamics over 30 years. Ann For Sci 72:367–378
Braat LC (2018) Five reasons why the Science publication "Assessing nature's contributions to people" (Diaz et al. 2018) would not have been accepted in ecosystem services. Ecosyst Serv 30:A1–A2
Bretagnolle V, Gaba S (2015) Weeds for bees? A review. Agron Sustain Dev 35:891–909
Burkhard B, Crossman N, Nedkov S, Petz K, Alkemade R (2013) Mapping and modelling ecosystem services for science, policy and practice. Ecosyst Serv Complete. https://doi.org/10.1016/j.ecoser.2013.04.005
Carpenter S, Bennett E, Peterson G (2006) Scenarios for ecosystem services: an overview. Ecol Soc 1:1
Carrié R, Andrieu E, Cunningham SA, Lentini PE, Loreau M, Ouin A (2017a) Relationships among ecological traits of wild bee communities along gradients of habitat amount and fragmentation. Ecography 40:85–97
Carrié R, Andrieu E, Ouin A, Steffan-Dewenter I (2017b) Interactive effects of landscape-wide intensity of farming practices and landscape complexity on wild bee diversity. Landscape Ecol. https://doi.org/10.1007/s10980-017-0530-y
Chaplin-Kramer R, O'Rourke M, Blitzer E, Kremen C (2011) A meta-analysis of crop pest and natural enemy response to landscape complexity. Ecol Lett 14:922–932
Choisis JP, Thévenet C, Gibon A (2012) Analyzing farming systems diversity: a case study in south-western France. Span J Agric Res 10:605–618
Cleaver F (2002) Reinventing institutions: bricolage and the social embeddedness of natural resource management. Eur J Dev Res 14:11–30
Clement F (2013) For critical social-ecological system studies: integrating power and discourses to move beyond the right institutional fit. Environ Conserv 40:1–4
Cochet H (2012) The systeme agraire concept in francophone peasant studies. Geoforum 43:128–136
Collins S, Carpenter R, Swinton S, Gragson T, Orenstein D, Grimm N, Grove M, Harlan SL, Knapp A, Kofinas G, Magnuson J, McDowell W, Melack JM, Ogden LA, Robertson GP, Smith MD, Whitmer AC (2011) An integrated conceptual framework for social ecological research. Front Ecol Environ 9:351–357
Conseil de l'Europe (2000) European landscape convention
Costanza R, Andrade F, Antunes P, van den Belt M, Boesch D, Boersma D, Catarino F, Hanna S, Limburg K, Low B, Molitor M, Pereira JG, Rayner S, Santos R, Wilson J, Young M (1999) Ecological economics and sustainable governance of the oceans. Ecol Econ 31:171–187
Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P & van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260. https://doi.org/10.1016/S0921-8009(98)00020-2
Côté SD, Rooney TP, Tremblay J-P, Dussault C, Waller DM (2004) Ecological impacts of deer overabundance. Annu Rev Ecol Evol Syst 35:113–147
Da Ponte E, Kuenzer C, Parker A, Rodas O, Oppelt N, Fleckenstein M (2017) Forest cover loss in Paraguay and perception of ecosystem services: a case study of the Upper Parana Forest. Ecosyst Serv 24:200–212
Daily GC, Polasky S, Goldstein J, Kareiva PM, Mooney HA, Pejchar L, Ricketts TH, Salzman J, Shallenberger R (2009) Ecosystem services in decision making: time to deliver. Front Ecol Environ 7:21–28
Daw T, Brown K, Rosendo S, Pomeroy R (2011) Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. Environ Conserv 38:370–379
Daw TM, Coulthard S, Cheung WWL, Brown K, Abunge C, Galafassi D, Peterson GD, McClanahan TR, Omukoto JO, Munyi L (2015) Evaluating taboo trade-offs in ecosystems

services and human well-being. Proc Natl Acad Sci USA 112:6949–6954

De Palma A, Abrahamczyk S, Aizen MA, Albrecht M, Basset Y, Bates A, Blake RJ, Boutin C, Bugter R, Connop S, Cruz-Lopez L, Cunningham SA, Darvill B, Diekotter T, Dorn S, Downing N, Entling MH, Farwig N, Felicioli A, Fonte SJ, Fowler R, Franzen M, Goulson D, Grass I, Hanley ME, Hendrix SD, Herrmann F, Herzog F, Holzschuh A, Jauker B, Kessler M, Knight ME, Kruess A, Lavelle P, Le Feon V, Lentini P, Malone LA, Marshall J, Pachon EM, McFrederick QS, Morales CL, Mudri-Stojnic S, Nates-Parra G, Nilsson SG, Ockinger E, Osgathorpe L, Parra A, Peres CA, Persson AS, Petanidou T, Poveda K, Power EF, Quaranta M, Quintero C, Rader R, Richards MH, Roulston T, Rousseau L, Sadler JP, Samnegard U, Schellhorn NA, Schuepp C, Schweiger O, Smith-Pardo AH, Steffan-Dewenter I, Stout JC, Tonietto RK, Tscharntke T, Tylianakis JM, Verboven HAF, Vergara CH, Verhulst J, Westphal C, Yoon HJ, Purvis A (2016) Predicting bee community responses to land-use changes: effects of geographic and taxonomic biases. Sci Rep. https://doi.org/10.1038/srep31153

Deconchat M, Gibon A, Cabanettes A, du Bus de Warnaffe G, Hewison M, Garine E, Gavaland A, Lacombe J-P, Ladet S, Monteil C, Ouin A, Sarthou J-P, Sourdril A, Balent G (2007) How to set up a research framework to analyze social-ecological interactive processes in a rural landscape. Ecol Soc. https://doi.org/10.5751/ES-01990-120115

Dendoncker N, Boeraeve F, Crouzat E, Dufrene M, König A, Barnaud C (2018) How can integrated valuation of ecosystem services help understanding and steering agroecological transitions? Ecol Soc. https://doi.org/10.5751/ES-09843-230112

Dendoncker N, Keune H, Jacobs S, Erik G-B (2013) Inclusive ecosystem services valuation. In: Ecosystem services: global issues, local practices, Elsevier, pp 3–12

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R, Chan KMA, Baste IA, Brauman KA, Polasky S, Church A, Lonsdale M, Larigauderie A, Leadley PW, van Oudenhoven APE, van der Plaat F, Schröter M, Lavorel S, Aumeeruddy-Thomas Y, Bukvareva E, Davies K, Demissew S, Erpul G, Failler P, Guerra CA, Hewitt CL, Keune H, Lindley S, Shirayama Y (2018) Assessing nature's contributions to people. Science 359:270–272

Duru M, Therond O, Martin G, Martin-Clouaire R, Magne M-A, Justes E, Journet E-P, Aubertot J-N, Savary S, Bergez J-E, Sarthou JP (2015) How to implement biodiversity-based agriculture to enhance ecosystem services: a review. Agron Sustain Dev 35:1259–1281

Egarter Vigl L, Depellegrin D, Pereira P, de Groot R, Tappeiner U (2017) Mapping the ecosystem service delivery chain: capacity, flow, and demand pertaining to aesthetic experiences in mountain landscapes. Sci Total Environ 574:422–436

Elyakime B, Cabanettes A (2013) Financial evaluation of two models for energy production in small French farm forests. Renew Energy 57:51–56

Fahrig L, Baudry J, Brotons L, Burel FG, Crist TO, Fuller RJ, Sirami C, Siriwardena GM, Martin J-L (2011) Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. Ecol Lett 14:101–112

Fedele G, Locatelli B, Djoudi H (2017) Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosyst Serv 28:43–54

Federico P, Hallam TG, McCracken GF, Purucker ST, Grant WE, Correa-Sandoval AN, Westbrook JK, Medellin RA, Cleveland CJ, Sansone CG, López JD, Betke M, Moreno-Valdez A, Kunz TH (2008) Brazilian free-tailed bats as insect pest regulators in transgenic and conventional cotton crops. Ecol Appl Publ Ecol Soc Am 18:826–837

Felipe-Lucia MR, Martín-López B, Lavorel S, Berraquero-Díaz L, Escalera-Reyes J, Comín FA (2015) Ecosystem services flows: why stakeholders' power relationships matter. PLoS ONE 10:e0132232

Fischer A, Eastwood A (2016) Coproduction of ecosystem services as human–nature interactions—an analytical framework. Land Use Policy 52:41–50

Fisher B, Turner RK, Morling P (2009) Defining and classifying ecosystem services for decision making. Ecol Econ 68:643–653

Franks JR (2011) The collective provision of environmental goods: a discussion of contractual issues. J Environ Plan Manag 54:637–660

Fuller R, Gill R (2001) Ecological impacts of increasing numbers of deer in British woodland. Forestry. https://doi.org/10.1093/forestry/74.3.193

Galafassi D, Daw T, Munyi L, Brown K, Barnaud C, Fazey I (2017) Learning about social-ecological trade-offs. Ecol Soc. https://doi.org/10.5751/ES-08920-220102

Garibaldi LA, Steffan-Dewenter I, Kremen C, Morales JM, Bommarco R, Cunningham SA, Carvalheiro LG, Chacoff NP, Dudenhöffer JH, Greenleaf SS, Holzschuh A, Isaacs R, Krewenka K, Mandelik Y, Mayfield MM, Morandin LA, Potts SG, Ricketts TH, Szentgyörgyi H, Viana BF, Westphal C, Winfree R, Klein AM (2011) Stability of pollination services decreases with isolation from natural areas despite honey bee visits. Ecol Lett 14:1062–1072

Garrido P, Elbakidze M, Angelstam P (2017) Stakeholders' perceptions on ecosystem services in Östergötland's (Sweden) threatened oak wood-pasture landscapes. Landsc Urban Plan 158:96–104

Gibon A (2005) Managing grassland for production, the environment and the landscape. Challenges at the farm and the landscape level. Livest Prod Sci 96:11–31

Gibon A, Mottet A, Ladet S, Fily M (2006) Supporting livestock-farming to sustainable management of natural resources and landscapes: a case study in the Davantaygue valley (Pyrénées, France). In: Book of abstracts of the 57th annual meeting of the european association for animal production 12, 2006; 57 annual meeting of the european association for animal production, Antalya, TUR, 2006-09-17-2006-09-20, pp 98–98

Goldman LR, Thompson BH, Daily G (2007) Institutional incentives for managing the landscape: inducing cooperation for the production of ecosystem services. Ecol Econ 64:333–343

Gómez-Baggethun E, Ruiz-Pérez M (2011) Economic valuation and the commodification of ecosystem services. Prog Phys Geogr 35:613–628

Guyot V, Castagneyrol B, Vialatte A, Deconchat M, Jactel H (2016) Tree diversity reduces pest damage in mature forests across Europe. Biol Lett 12:20151037

Hajer MA (1995) The politics of environmental discourse: ecological modernization and the policy process. Clarendon Press, Oxford

Hamilton SK (2015) The ecology of agricultural landscapes: long-term research on the path to sustainability. Oxford University Press, Oxford

Hein L, van Koppen K, de Groot RS, van Ierland EC (2006) Spatial scales, stakeholders and the valuation of ecosystem services. Ecol Econ 57:209–228

Holzschuh A, Dormann FC, Tscharntke T, Steffan-Dewenter I (2012) Mass-flowering crops enhance wild bee abundance. Oecologia 172:6

Howe C, Suich H, Vira B, Mace GM (2014) Creating win-wins from trade-offs? Ecosystem services for human well-being: a meta-analysis of ecosystem service trade-offs and synergies in the real world. Glob Environ Chang 28:263–275

Irby LR, Zidack WE, Johnson JB, Saltiel J (1996) Economic damage to forage crops by native ungulates as perceived by farmers and ranchers in montana. J Range Manag 49:375–380

Isaac M, Erickson B, Quashie-Sam S, Timmer V (2007) Transfer of knowledge on agroforestry management practices: the structure of farmer advice networks. Ecol Soc. https://doi.org/10.5751/ES-02196-120232

Kelemen E, Nguyen G, Gomiero T, Kovács E, Choisis J-P, Choisis N, Paoletti MG, Podmaniczky L, Ryschawy J, Sarthou J-P, Herzog F, Dennis P, Balázs K (2013) Farmers' perceptions of biodiversity: lessons from a discourse-based deliberative valuation study. Land Use Policy 35:318–328

King E, Cavender-Bares J, Balvanera P, Mwampamba T, Polasky S (2015) Trade-offs in ecosystem services and varying stakeholder preferences: evaluating conflicts, obstacles, and opportunities. Ecol Soc. https://doi.org/10.5751/ES-07822-200325

Koschke L, Fürst C, Frank S, Makeschin F (2012) A multi-criteria approach for an integrated land-cover-based assessment of ecosystem services provision to support landscape planning. Ecol Ind 21:54–66

Kremen C, Williams NM, Aizen MA, Gemmill-Herren B, LeBuhn G, Minckley R, Packer L, Potts SG, Roulston T, Steffan-Dewenter I, Vázquez DP, Winfree R, Adams L, Crone EE, Greenleaf SS, Keitt TH, Klein A-M, Regetz J, Ricketts TH (2007) Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecol Lett 10:299–314

Kumar M, Kumar P (2008) Valuation of the Ecosystem services: a psycho-cultural perspective. Ecol Econ 64:808–819

Landis D (2016) Designing Agricultural Landscapes for Biodiversity-Based Ecosystem Services. Basic Appl Ecol. https://doi.org/10.1016/j.baae.2016.07.005

Larigauderie A, Mooney HA (2010) The Intergovernmental science-policy platform on biodiversity and ecosystem services: moving a step closer to an IPCC-like mechanism for biodiversity. Curr Opin Environ Sustain 2:9–14

Leeuwis C, van den Ban AW (2004) Communication for rural innovation: rethinking agricultural extension. Blackwell Publishing Ltd., Oxford

Lefebvre M, Espinosa M, Gomez y Paloma S, Paracchini ML, Piorr A, Zasada I (2015) Agricultural landscapes as multi-scale public good and the role of the common agricultural policy. J Environ Planning Manag 58:2088–2112

Lescourret F, Magda D, Richard G, Adam-Blondon A-F, Baudry J, Bardy M, Doussan I, Dumont B, Lefèvre F, Litrico I, Martin-Clouaire R, Montuelle B, Pellerin S, Plantegenest M, Tancoigne E, Thomas A, Guyomard H, Soussana J-F (2015) A social–ecological approach to managing multiple agro-ecosystem services. Curr Opin Environ Sustain 14:68–75

Losey JE, Vaughan M (2006) The economic value of ecological services provided by insects. Bioscience 56:311

Maalouly M, Franck P, Bouvier J-C, Toubon J-F, Lavigne C (2013) Codling moth parasitism is affected by semi-natural habitats and agricultural practices at orchard and landscape levels. Agric Ecosyst Environ 169:33–42

Maass JM, Balvanera P, Castillo A, Daily GC, Mooney HA, Ehrlich P, Quesada M, Miranda A, Jaramillo VJ, García-Oliva F, Martínez-Yrizar A, Cotler H, López-Blanco J, Pérez-Jiménez A, Búrquez A, Tinoco C, Ceballos G, Barraza L, Ayala R, Sarukhán J (2005) Ecosystem services of tropical dry forests: insights from longterm ecological and social research on the Pacific coast of Mexico. Ecol Soc 10:1–23

Maine JJ, Boyles JG (2015) Bats initiate vital agroecological interactions in corn. Proc Nat Acad Sci 112:12438–12443

Manuel-Navarrete D, Gallopín GC, Blanco M, Díaz-Zorita M, Ferraro DO, Herzer H, Laterra P, Murmis MR, Podestá GP, Rabinovich J, Satorre EH, Torres F, Viglizzo EF (2009) Multi-causal and integrated assessment of sustainability: the case of agriculturization in the Argentine Pampas. Environ Dev Sustain 11:621–638

Marrec R, Caro G, Miguet P, Badenhausser I, Plantegenest M, Vialatte A, Bretagnolle V, Gauffre B (2017) Spatiotemporal dynamics of the agricultural landscape mosaic drives distribution and abundance of dominant carabid beetles. Landscape Ecol 32:2383–2398

Martín-López B, Gómez-Baggethun E, García-Llorente M, Montes C (2014) Trade-offs across value-domains in ecosystem services assessment. Ecol Ind 37:220–228

Martín-López B, Iniesta-Arandia I, García-Llorente M, Palomo I, Casado-Arzuaga I, Amo DGD, Gómez-Baggethun E, Oteros-Rozas E, Palacios-Agundez I, Willaarts B, González JA, Santos-Martín F, Onaindia M, López-Santiago C, Montes C (2012) Uncovering ecosystem service bundles through social preferences. PLoS ONE 7:e38970

McLeod JG, Campbell CA, Dyck FB, Vera CL (1992) Optimum seeding date for winter wheat in Southwestern Saskatchewan. Agron J 84:86–90

Monteiro L, Lavigne C, Ricci B, Franck P, Toubon J-F, Sauphanor B (2013) Predation of codling moth eggs is affected by pest management practices at orchard and landscape levels. Agric Ecosyst Environ 166:4

Moreau C, Barnaud C, Mathevet R (2019) Conciliate agriculture with landscape and biodiversity conservation: a role-playing game to explore trade-offs among ecosystem services through social learning. Sustainability 11:310

Morellet N, Moorter B, Cargnelutti B, Angibault J-M, Lourtet B, Merlet J, Ladet S, Hewison A (2011) Landscape composition influences roe deer habitat selection at both home range and landscape scale. Landscape Ecol 26:999–1010

Mosse D (1997) The symbolic making of a common property resource: history, ecology and locality in a tank-irrigated landscape in South India. Dev Change 28:467–504

Müller F, de Groot R, Willemen L (2010) Ecosystem services at the landscape scale: the need for integrative approaches. Landscape 23:1–11

Muradian R, Rival L (2012) Between markets and hierarchies: the challenge of governing ecosystem services. Ecosyst Serv 1:93–100

Olson M (1971) The logic of collective action: public goods and the theory of groups, second printing with new preface and appendix (Harvard Economic Studies). Harvard University Press, Cambridge

Opdam P, Coninx I, Dewulf A, Steingröver E, Vos C, van der Wal M (2016) Does information on landscape benefits influence collective action in landscape governance? Curr Opin Environ Sustain 18:107–114

Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. The Political economy of institutions and decisions. Cambridge University Press, Cambridge, New York

Ostrom E (2005) Understanding institutional diversity. Springer, New York

Ostrom E (2010) Beyond markets and states: polycentric governance of complex economic systems. Am Econ Rev 100:641–672

Ostrom E, Gardner R, Walker J (1994) Rules, games, and common-pool resources. University of Michigan Press, Ann Arbor

Pahl-Wostl C, Craps M, Dewulf A, Mostert E, Tabara D, Taillieu T (2007) Social Learning and water resources management. Ecol Soc. https://doi.org/10.5751/ES-02037-120205

Palomo I, Felipe-Lucia MR, Bennett EM, Martín-López B, Pascual U (2016) Chapter six—disentangling the pathways and effects of ecosystem service co-production. In: Woodward G, Bohan DA (eds) Advances in ecological research, vol 54. Ecosystem services: from biodiversity to society, Part 2. Academic Press, Cambridge, pp 245–283

Pelosi C, Goulard M, Balent G (2010) The spatial scale mismatch between ecological processes and agricultural management: do difficulties come from underlying theoretical frameworks? Agric Ecosyst Environ 139:455–462

Peterson G, Harmáčková Z, Meacham M, Queiroz C, Jiménez-Aceituno A, Kuiper J, Malmborg K, Sitas N, Bennett E (2018) Welcoming different perspectives in IPBES: "nature's contributions to people" and "ecosystem services". Ecol Soc. https://doi.org/10.5751/ES-10134-230139

Pimentel D, Wilson C, McCullum C, Huang R, Dwen P, Flack J, Tran Q, Saltman T, Cliff B (1997) Economic and environmental benefits of biodiversity. Bioscience 47:747–757

Plieninger T, Kizos T, Bieling C, Le Dû-Blayo L, Budniok M-A, Bürgi M, Crumley C, Girod G, Howard P, Kolen J, Kuemmerle T, Milcinski G, Palang H, Trommler K, Verburg P (2015) Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. Ecol Soc. https://doi.org/10.5751/ES-07443-200205

Potschin M, Haines-Young R (2013) Landscapes, sustainability and the place-based analysis of ecosystem services. Landscape Ecol 28:1053–1065

Prager K (2015) Agri-environmental collaboratives as bridging organisations in landscape management. J Environ Manage 161:375–384

Prager K, Reed M, Scott A (2012) Encouraging collaboration for the provision of ecosystem services at a landscape scale—rethinking agri-environmental payments. Land Use Policy 29:244–249

Primmer E, Furman E (2012) Operationalising ecosystem service approaches for governance: do measuring, mapping and valuing integrate sector-specific knowledge systems? Ecosyst Serv 1:85–92

Puech C, Poggi S, Baudry J, Aviron S (2015) Do farming practices affect natural enemies at the landscape scale? Landscape Ecol 30:125–140

Putman RJ, Moore NP (2002) Impact of deer in lowland Britain on agriculture, forestry and conservation habitats. Mammal Rev 28:141–164

Quétier F, Rivoal F, Marty P, de Chazal J, Thuiller W, Lavorel S (2010) Social representations of an alpine grassland landscape and socio-political discourses on rural development. Reg Environ Change 10:119–130

Rand AT, Tylianakis J, Tscharntke T (2006) Spillover edge effects: the dispersal of agriculturally subsidized insect natural enemies into adjacent natural habitats. Ecol Lett 9:603–614

Raudsepp-Hearne C, Peterson GD, Bennett EM (2010) Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. Proc Natl Acad Sci USA 107:5242–5247

Raymond MC, Kenter JO, Plieninger T, Turner NJ, Alexander KA (2015) Comparing instrumental and deliberative paradigms underpinning the assessment of social values for cultural ecosystem services. Zenodo. https://doi.org/10.1016/j.ecolecon.2014.07.033

Raymond L, Vialatte A, Plantegenest M (2014) Combination of morphometric and isotopic tools for studying spring migration dynamics in *Episyrphus balteatus*. Ecosphere 5:art88

Ricci B, Franck P, Toubon J-F, Bouvier J-C, Sauphanor B, Lavigne C (2009) The influence of landscape on insect pest dynamics: a case study in southeastern France. Landscape Ecol 24:337–349

Robards MD, Schoon ML, Meek CL, Engle NL (2011) The importance of social drivers in the resilient provision of ecosystem services. Glob Environ Change 21:522–529

Robertson PG, Gross KL, Hamilton SK, Landis DA, Schmidt TM, Snapp SS, Swinton SM (2014) Farming for ecosystem services: an ecological approach to production agriculture. Bioscience 64:404–415

Rodríguez J, Beard J, Bennett E, Cumming G, Cork S, Agard J, Dobson A, Peterson G (2006) Trade-offs across space, time, and ecosystem services. Ecol Soc. https://doi.org/10.5751/ES-01667-110128

Röling NG, Wagemakers MA (1998) A new practise: facilitating sustainable agriculture. In: Röling G, Wagemakers MA (eds) Facilitating sustainable agriculture: participatory learning and adaptive management in times of

environmental uncertainty. Cambridge University Press, Cambridge, pp 3–22
Roume A, Deconchat M, Raison L, Balent G, Ouin A (2011) Edge effects on ground beetles at the woodlot-field interface are short-range and asymmetrical. Agric For Entomol 13:395–403
Ryschawy J, Joannon A, Choisis J-P, Gibon A, Le Gal P-Y (2013) Evaluating innovative scenarios to enhance mixed crop-livestock farms sustainability
Salliou N, Barnaud C (2017) Landscape and biodiversity as new resources for agro-ecology? Insights from farmers' perspectives. Ecol Soc 22:16
Salliou N, Barnaud C, Vialatte A, Monteil C (2017) A participatory Bayesian belief network approach to explore ambiguity among stakeholders about socio-ecological systems. Environ Modell Softw 96:199–209
Salliou N, Vialatte A, Monteil C, Barnaud C (2019) First use of participatory Bayesian modeling to study habitat management at multiple scales for biological pest control. Agron Sustain Dev 39:7
Sarthou J-P, Ouin A, Arrignon F, Barreau G, Bouyjou B (2005) Landscape parameters explain the distribution and abundance of *Episyrphus balteatus* (Diptera: Syrphidae). Eur J Entomol 102:539–545
Schellhorn NA, Gagic V, Bommarco R (2015) Time will tell: resource continuity bolsters ecosystem services. Trends Ecol Evol 30:524–530
Schmitz J, Hahn M, Brühl CA (2014) Agrochemicals in field margins—an experimental field study to assess the impacts of pesticides and fertilizers on a natural plant community. Agric Ecosyst Environ 193:60–69
Scholte SSK, van Teeffelen AJA, Verburg PH (2015) Integrating socio-cultural perspectives into ecosystem service valuation: a review of concepts and methods. Ecol Econ 114:67–78
Selman P (2006) Planning at the landscape scale, vol 12. RTPI library series edition, Routledge, New York
Shackleton CM, Ruwanza S, Sanni GKS, Bennett S, Lacy PD, Modipa R, Mtati N, Sachikonye M, Thondhlana G (2016) Unpacking Pandora's box: understanding and categorising ecosystem disservices for environmental management and human wellbeing. Ecosystems 19:587–600
Sirami C, Caplat P, Popy S et al (2017) Impacts of global change on species distributions: obstacles and solutions to integrate climate and land use. Glob Ecol Biogeogr 26:385–394
Smith HF, Sullivan CA (2014) Ecosystem services within agricultural landscapes—farmers' perceptions. Ecol Econ 98:72–80
Sourdril A, Andrieu E, Cabanettes A, Elyakime B, Ladet S (2012) How to maintain domesticity of usages in small rural forests? lessons from forest management continuity through a french case study. Ecol Soc. https://doi.org/10.5751/ES-04746-170206
Spangenberg JH, Görg C, Truong DT, Tekken V, Bustamante JV, Settele J (2014) Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int J Biodivers Sci Ecosyst Serv Manage 10:40–53
Stallman HR (2011) Ecosystem services in agriculture: determining suitability for provision by collective management. Ecol Econ 71:131–139
Swinton S, Lupi F, Robertson GP, Hamilton S (2007) Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. Ecol Econ 64:245–252
Teixeira FZ, Bachi L, Blanco J, Zimmermann I, Welle I, Carvalho-Ribeiro SM (2019) Perceived ecosystem services (ES) and ecosystem disservices (EDS) from trees: insights from three case studies in Brazil and France. Landscape Ecol. https://doi.org/10.1007/s10980-019-00778-y
Termorshuizen WJ, Opdam P (2009) Landscape services as a bridge between landscape ecology and sustainable development. Landscape Ecol 24:1037–1052
Therond O, Duru M, Roger-Estrade J, Richard G (2017) A new analytical framework of farming system and agriculture model diversities. A review. Agron Sustain Dev. https://doi.org/10.1007/s13593-017-0429-7
Thierry H, Vialatte A, Choisis J-P, Gaudou B, Parry H, Monteil C (2017) Simulating spatially-explicit crop dynamics of agricultural landscapes: the ATLAS simulator. Ecol Inform 40:62–80
Thompson Hobbs N (1996) Modification of ecosystems by ungulates. J Wildl Manag 60:695
Turkelboom F, Leone M, Jacobs S, Turkelboom F, Leone M, Jacobs S, Kelemen E, García-Llorente M, Baró F, Termansen M, Barton DN, Berry P, Stange E, Thoonen M, Kalóczkai Á, Vadineanu A, Castro AJ, Czúcz B, Röckmann C, Wurbs D, Odee D, Preda E, Gómez-Baggethun E, Rusch GM, Pastur GM, Palomo I, Dick J, Casaer J, van Dijk J, Priess JA, Langemeyer J, Mustajoki J, Kopperoinen L, Baptist MJ, Peri PL, Mukhopadhyay R, Aszalós R, Roy SB, 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
Vasseur C, Joannon A, Aviron S, Burel F, Jean-Marc M, Baudry J (2013) The cropping systems mosaic: how does the hidden heterogeneity of agricultural landscapes drive arthropod populations? Agric Ecosyst Environ 166:3–14
Verburg PH, van Berkel DB, van Doorn AM, van Eupen M, vanden Heiligenberg HARM (2010) Trajectories of land use change in Europe: a model-based exploration of rural futures. Landscape Ecol 25:217–232
Veres A, Petit S, Conord C, Lavigne C (2013) Does landscape composition affect pest abundance and their control by natural enemies? A review. Agric Ecosyst Environ 166:110–117
Vialatte A, Simon J-C, Dedryver C-A, Fabre F, Plantegenest M (2006) Tracing individual movements of aphids reveals preferential routes of population transfers in agroecosystems. Ecol Appl Publ Ecol Soc Am 16:839–844
Vialatte A, Tsafack N, Hassan DA, Duflot R, Plantegenest M, Ouin A, Villenave-Chasset J, Ernoult A (2017) Landscape potential for pollen provisioning for beneficial insects favours biological control in crop fields. Landscape Ecol 32:465–480
Villamagna AM, Angermeier PL, Bennett EM (2013) Capacity, pressure, demand, and flow: a conceptual framework for analyzing ecosystem service provision and delivery. Ecol Complex 15:114–121

Vuillot C, Coron N, Calatayud F, Sirami C, Mathevet R, Gibon A (2016) Ways of farming and ways of thinking: do farmers' mental models of the landscape relate to their land management practices? Ecol Soc. https://doi.org/10.5751/ES-08281-210135

Wu J (2013) Landscape sustainability science: ecosystem services and human well-being in changing landscapes. Landscape Ecol 28:999–1023

Zhang W, Ricketts T, Kremen C, Carney K, Swinton S (2007) Ecosystem services and dis-services to agriculture. Ecol Econ 64:253–260