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Integrating ecosystem services and disservices: insights from plant invasions

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ABSTRACT

There is growing interest in ecosystem disservices, i.e. the negative effects of ecosystems on humans. The focus on disservices has been controversial because of the lack of clarity on how to disentangle ecosystem services and disservices related to human wellbeing. A perspective that considers both services and disservices is needed to inform objective decision-making. We propose a comprehensive typology of ecosystem disservices, and present a framework for integrating ecosystem services and disservices for human wellbeing linked to ecosystem functioning. Our treatment is underpinned by three key assumptions: (1) ecosystem attributes and functions are value-free; (2) the perception of benefits or nuisances are however dependent on societal context, and preferences and actions by societal actors may trigger, enhance or alleviate benefits or nuisances derived from ecosystems; and (3) the notion of disservices must account for the role of human management in assessments of ecosystem values, i.e. the social and technological measures that identify, protect, promote or restore desirable levels of services, and concurrently minimise, mitigate or adapt to disservices. We illustrate our ideas with examples from plant invasions as a complex social-ecological phenomenon.

1. Introduction

The concept of *ecosystem services* (ES) has emerged from the recognition that complex interactions in ecosystems can result in flows of energy, matter and information, which contribute to human well-being. Examples include fostering basic needs through food, fibre and energy provision as well as regulation services (e.g. carbon sequestration, pollination, pest control) and contributions to cultural aspects of wellbeing (Agarwala et al., 2014; Díaz et al., 2015; MA, 2005; Smith et al., 2013). The focus on ES has created an additional perspective which differs from, and is complementary to, traditional conservation policies for ensuring the sustainable use and the protection of

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ecosystems (Agarwala et al., 2014; Bonn et al., 2016; Brown and Westaway, 2011). Yet, one of the major recurring points of criticism of the notion of ES is that it often considers only the beneficial outputs of ecosystems and ignores unpleasant, unwanted or economically harmful effects (Lyytimäki and Sipilä, 2009; Lyytimäki, 2014; Schröter et al., 2014). These negative sides of ecosystems have been termed *ecosystem disservices* (EDS). Following Shackleton et al. (2016: p. 590), EDS are "*the ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing*".

EDS can be produced, for example, by biological invasions (Shackleton et al., 2016), and by other ecosystem attributes that are perceived as unwanted (Escobedo et al., 2011; Lyytimäki et al., 2008). They are produced by ecosystem functions, such as wildfires or floods, which pose danger to people and – although they may constitute natural processes – can be mitigated or exacerbated through management (Lyytimäki, 2014). The same ecosystem function may be perceived as ES by some people and EDS by other people (cf. Saunders and Luck, 2016), depending on, among other things, acquired knowledge, people's behaviours, and overall political, economic and social settings (Rasmussen et al., 2016; Shackleton et al., 2016; Stoll et al., 2015). Configuration of anthropogenic pressures as well as provision and perceptions of ES and EDS may vary spatially, temporally and between individuals or societal groups (Chan et al., 2012; Shackleton et al., 2016).

The notion of EDS has its main roots in urban ecosystem research (Dobbs et al., 2014; Escobedo et al., 2011; Lyytimäki, 2014; Lyytimäki and Sipilä, 2009), particularly in work associated with complex human-environment systems that characterise large cities (von Döhren and Haase, 2015). EDS have been used to evaluate the value of green space for urban residents (Lyytimäki and Sipilä, 2009; Lyytimäki et al., 2008) given that urban green spaces can provide many ES but also a range of EDS, from allergenic substances and volatile compounds emitted by vegetation (Dobbs et al., 2014), to blocking of sunlight by trees (Roy et al., 2012), and the presence of wild animals in people's backyards (Lyytimäki, 2014). The notion of EDS has also been extended to agricultural systems (e.g. Ma et al., 2015; Schäckermann et al., 2015) to account for problematic aspects of human managed ecosystems (Ma et al., 2015), to denote increases in production costs e.g. for pest control (Schäckermann et al., 2015; Swinton et al., 2007; Zhang et al., 2007), or other ecological costs arising from animal activities (Kronenberg, 2014; Whelan et al., 2015).

The usefulness of EDS has more recently been discussed for other contexts, namely fisheries and forests (see Shackleton et al., 2016). Yet, EDS have seldom been considered in the context of broader social-ecological challenges (Saunders and Luck, 2016; Shackleton et al., 2016), such as plant invasions. Plant invaders provide both benefits (Tassin and Kull, 2015) and nuisances (Simberloff et al., 2013) for human wellbeing, depending on people's preferences and the spatio-temporal context (Kueffer and Kull, 2017). In some contexts, invasive plants contribute to people's livelihoods, by supporting daily basic needs and economic incomes (Kull et al., 2011), or by enhancing regulating functions, including coastal sediment dynamics and soil protection. In other contexts, however, plant invasions can lead to undesirable outcomes for human wellbeing. Examples include health problems associated with allergenic compounds or skin irritations, wildfires in non-fire prone areas, or competition with another service-providing species (Fenesi et al., 2015; Gaertner et al., 2014). The beneficial or detrimental impacts of plant invasions can be exacerbated by the magnitude, rate and scale of the invasion process (e.g. Eviner et al., 2012). The same species can promote ES at some spatio-temporal extent, e.g. trees confined to private gardens, or contribute to EDS provision at later stages, e.g. trees become widespread in the wild (the "transient disservices"; Saunders and Luck, 2016). This inevitably depends on (the lack of) human management (Brundu and Richardson, 2016).

Previous attempts to categorise EDS have relied on comparisons with pre-established classifications of ES. For instance, Ma et al. (2014) introduced the term 'provisioning and regulating EDS' to account for soil loss in agricultural systems. Price (2014) used 'supporting and regulating EDS' in the context of forestry. Other authors, mostly in reference to urban ecosystems (von Döhren and Haase, 2015), proposed mixed typologies, based on both the origin and consequences of EDS. Escobedo et al. (2011) classified EDS as financial (economic costs triggered by EDS), social (impacts on human health and fear) or environmental (affecting intrinsic ecosystem attributes). Lyytimäki and Sipila (2009) categorised EDS based on their origin (as social, social-ecological or ecological), and based on the impacted societal actors (individuals, communities, or humankind). More recently, Lyytimäki (2014) categorised EDS with respect to weather-related events and ecosystem functions causing harm, as well as human fears and risks, activities, or aesthetic issues. Despite their usefulness in specific cases, the above-mentioned typologies do not yet provide the means for distinguishing between the occurrence of a perceived negative service, i.e. an EDS, and the reduction of an ES. For instace, a lack of an explicit differentiation of reduced ES and genuine EDS led to ambiguity in the literature (Shackleton et al., 2016), e.g. by denoting habitat loss (Zhang et al., 2007) and pesticide output in agricultural systems (Swinton et al., 2007) as EDS. To tackle the conceptual problem that reduced ES are not necessarily EDS, Shackleton et al. (2016) classified EDS based on their effects on the economy, physical and mental health, or aesthetic and cultural issues of human wellbeing.

Although EDS have been accounted in the scientific literature (Shapiro and Báldi, 2014), a comprehensive conceptual framework that incorporates both EDS and ES is lacking (compare Saunders and Luck, 2016; von Döhren and Haase, 2015). In our view, such a framework should address three conceptual issues: (1) nuisances from ecosystem to wellbeing can either be expressed as reduced ES (e.g. decrease of water provision, or reduction of soil erosion protection), or as genuine EDS (e.g., wildfires and pests; see Saunders and Luck, 2016; Shackleton et al., 2016 for reviews); (2) benefits and nuisances should account for human activities, since feedbacks between ecological changes and societal responses may trigger, enhance or reduce either ES or EDS; and, (3) an EDS framework should facilitate deliberation about both positive and detrimental aspects of ecosystems for human wellbeing acknowledging that there is not only one state in nature that *can* or *should* be maintained or restored through management. Some experts might consider that this likely opens a Pandora's Box (Shackleton et al., 2016). For example, conservationists who place an emphasis on native, wild nature may feel threatened by a concept and associated conceptual model that might be used to justify interventions in landscapes that they value for their lack of anthropogenic imprint (following Kronenberg, 2014; Villa et al., 2014). Yet clearly, explicit negotiations of management priorities might increasingly become unavoidable in coupled social-ecological landscapes. In such negotiations EDS recognition might contribute to better informed ecosystem management approaches and possibly optimised investments to increase both biodiversity and human wellbeing (Saunders and Luck, 2016; Shackleton et al., 2016; Stoll et al., 2015).

This paper proposes a general conceptual framework of EDS. The framework encompasses a detailed typology of different EDS, and it proposes a way to explicitly account for the role of social-ecological management in the valuation of ES and EDS. To this end, we highlight the importance of acknowledging the interconnected human-ecological nature of ecosystems. We propose to refine a precautionary approach to ecosystem management through a hierarchy: first identify potential ES and EDS, then protect ES and avoid or minimise EDS, restore and rehabilitate ES, and lastly mitigate and adapt to EDS. We illustrate our framework with plant invasions as a test case. Finally, we synthesise the wider usefulness of our typology and framework for the future study and management of benefits and nuisances arising from ecosystems.