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Undervalued and under pressure: A plea for greater attention toward regulating ecosystem services

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ABSTRACT

Regulating ecosystem services (ES) fundamentally underpin biosphere integrity, human safety, and the provision of most other ES. However, the pathways by which regulating ES generate benefits for people are complex and vary spatially and temporally. Emerging ES decision-making frameworks underemphasize regulating services because they focus on ES that have more obvious links to human wellbeing (e.g., in close proximity to beneficiaries with very short time lags). Lack of attention towards regulating ES can lead to unintended management trade-offs that create risk for human wellbeing and can cause immediate and delayed impacts on cultural and provisioning ES. Therefore, a remaining challenge for ES frameworks is to address the full ensemble of processes and feedbacks whereby ecosystems contribute to human wellbeing over time, including through regulating services. We address this challenge by *(i)* reviewing the complexities associated with regulating ES components—capacity, ecological pressures, and demand, *(ii)* exploring the spatial and temporal variability that influence regulating ES components, including the flow of service benefits, and *(iii)* illustrating the interdependency of regulating ES components through examples of ES that are linked hydrologically. We conclude that ES capacity, pressure, demand and the flow of benefits are distinct, but intricately linked components that influence how regulating ES provide benefits and improve human wellbeing. We pose that ES assessment frameworks could be improved by including indicators of regulating ES that differentiate between the capacity to provide a regulating ES, the demand for the same, and the actual service that is conveyed, the latter of which is influenced by underlying capacity and ecological pressure. These indicators should also be spatially and temporally explicit to fully incorporate the dynamic influence of temporal variability, spatial scale, and landscape configuration on regulating ES and the benefits they yield.

1. Introduction

The ecosystem services (ES) approach can help identify, value, and manage the attributes of nature that are important for human wellbeing. It provides a structured way to examine the links between ecosystems and human wellbeing to inform policy and decision-making (MA, 2005). Emerging ES decision-making frameworks, such as the United Nations (UN) Experimental Ecosystem Accounting, focus on ES with clear links to human wellbeing, such as food and clean water (UN et al., 2014, Schaefer et al., 2015, World Bank, 2016). The UN framework excludes “intermediate services”, which includes the regulating and supporting ES classes identified by the Millennium Ecosystem Assessment (MA, 2005). These classes are considered important yet unacceptable for accounting frameworks as they represent background processes without clear links to human wellbeing (Boyd and Banzhaf, 2007; Fisher et al., 2009). Regulating ES are often considered intermediate services (Wallace, 2007; Haines-Young and Potschin, 2010), and ES frameworks have yet to adequately connect regulating services with their societal benefits. A remaining challenge for ES frameworks is to adequately account for the full ensemble of processes and

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feedbacks through which ecosystems contribute to human wellbeing over space and time (Carpenter et al., 2009; Syrbe and Walz, 2012; Rist et al., 2014; Biggs et al., 2015), including through regulating services.

ES are often considered something consumed or experienced by people that result in benefits (Wallace, 2007). Regulating services were originally defined by the MA as the 'benefits obtained from regulation of environmental conditions through ecosystem processes' (MA, 2005). Regulating ES act against pressures, defined here as the effects and impacts of natural events or human activities that carry risks for human safety, environmental quality, and/or the provision of other ES. Regulating ES maintain environmental quality through diverse mechanisms (Villamagna et al., 2013), including those identified by the Common International Classification for Ecosystem Services (CICES). These mechanisms include the maintenance of physical, biological, and chemical conditions (e.g., water quality, climate regulation, habitat protection) as well as the mediation of harmful wastes (e.g., filtration, bio-remediation, detoxification) and flows (e.g., soil erosion control, flood protection, landmass stabilization) (Haines-Young and Potschin, 2013). Regulating ES mainly provide indirect benefits to human wellbeing through maintaining environmental quality. The fact that regulating ES are not directly consumed or experienced by people makes them prone to be overlooked and undervalued (Villamagna et al., 2013), despite their critical value to society.

Underemphasizing regulating ES in assessments and ES accounting limits the attention given to the underlying ecosystem processes and attributes (i.e., the regulating service capacity) that maintain the resilient provision of most other ES (Rist et al., 2014; Biggs et al., 2015). Failing to measure regulating ES or negotiating around them in evaluation efforts to avoid double-counting benefits (e.g., Boyd and Banzhaf, 2007; Fisher et al., 2009; UN et al., 2014) may leave scientists and decision-makers with an incomplete understanding of the ecosystem components that underlie important benefits people derive from ecosystems. In this article, we combine approaches from recent literature on the spatial and temporal contexts of ES (Costanza, 2008; Fisher et al., 2009; Syrbe and Walz, 2012) together with a spatial hydrologic approach (Brauman et al., 2007; Verhoeven et al., 2008; Andersson et al., 2014; Barquín et al., 2015) to illustrate the benefits of regulating ES using a watershed perspective.

Underlying the capacity of an area to regulate ecosystem condition is the configuration of regulating landscape features and ecosystem processes, which we collectively refer to as regulating ES providing units (SPUs), based on the SPU concept (*sensu* Kremen, 2005; Kontogianni et al., 2010; Andersson et al., 2014). For example, within a single watershed, the configuration of vegetation, soils, and topographic features influence numerous soil chemistry reactions and hydrologic processes that contribute to regulating capacity. Individual SPUs are distributed variably across landscapes. Their individual capacity to regulate, based on physical and biochemical processes, and their spatial configuration collectively influence the regulating capacity of a given service providing area (SPA; Syrbe and Walz, 2012). It is therefore important to account for these features spatially by mapping their location as well as potential areas that connect them to beneficiaries (Kontogianni et al., 2010; Syrbe and Walz, 2012).

In this article, we address current challenges limiting the inclusion of regulating ES in mainstream assessment frameworks by *(i)* reviewing the complexities of measuring and managing three regulating ES components of capacity, ecological pressures, and demand, and *(ii)* exploring the spatial and temporal variability that underpins these three regulating ES components and influences the overall flow of benefits from regulating ES, and *(iii)* illustrating the interdependency of regulating ES components through examples of ES that are linked across hydrologic networks (herein: 'hydrologic ES', Brauman et al., 2007). Hydrologic networks, given their high connectivity, temporal dynamism, and sensitivity to environmental impacts, present a model system to parse out the complex interactions among multiple regulating ES, interacting pressures, and societal demands. We pose and discuss improvements to regulating ES indicators, including the need to have separate indicators to assess regulating ES components. We emphasize that regulating ES indicators must also be spatially and temporally explicit to fully incorporate the dynamic influences of temporal variability, spatial scale, and landscape configuration on regulating ES and the benefits they yield.

2. Under emphasis on regulating ecosystem services

Underestimating the value of regulating ES may lead to ES management that falls short of its mandate to support human wellbeing. Further, the lack of attention toward and undervaluation of regulating ES can lead to management trade-offs that create risk for human safety and can cause delayed impacts on cultural and provisioning ES. Management trade-offs that favour provisioning ES at the expense of regulating ES may result in shifts in ecosystem condition and function beyond which regulating ES capacity becomes impaired, leaving ecosystems susceptible to further pressures (Gordon et al., 2008; Rist et al., 2014). Meanwhile, due to difficulties measuring regulating ES, declines in ES regulating service capacity are generally not noticed until their degradation manifests as negative impacts to human wellbeing (Barbier et al., 2011). This can ultimately result in missed opportunities to enhance the capacity of landscapes to mediate ecological pressures as they arise (Kremen and Ostfeld, 2005; Connell and Ghedini, 2015). Many environmental regulations tend to focus on limiting pollution, a form of ecological pressure that directly affect water, food, and biodiversity (Daily, 2000; Greiber and Shiele, 2011) rather than protecting an ecosystem's regulating capacity to handle these pressures (but see exceptions: European Union Common Agricultural Policy and Biodiversity Strategy; Plieninger et al., 2012; van Zanten et al., 2014; Hodge et al., 2015). Mangrove protection is a prime example. In coastal areas, flood and tsunami risk can be mitigated by mangrove forests and coral reefs (Barbier et al., 2008; Koch et al., 2009), yet mangrove conversion (and the associated loss in flood protection) often goes unmonitored until the devastating impacts of a tsunami on coastal communities occur (Sanford, 2009; World Bank, 2016).

The loss of regulating ES capacity is often masked by the implementation of technological substitutes (e.g., sea walls, dams, drinking water treatment facilities), which can alleviate some of the damage caused by anthropogenic and natural pressures (Beier et al., 2015; Steffen et al., 2015). These substitutes buffer society from the early warning signals of regulating ES degradation, but are put in place reactively focusing on damage control, rather than proactively protecting the elements of nature that provide the services (regulating SPUs). Further, technological substitutes are limited in that they generally are implemented to solve a single problem, rather than facilitating the supply of a multitude of benefits that may be realized from natural regulating ES (Villamagna et al., 2013). As pressures are growing and interacting in synergistic and sometimes unpredictable ways (Buma, 2015; Friess et al., 2015; Piggott et al., 2015), some environmental policy has begun to acknowledge the limitations of technological implements and instead urges a greater awareness for the importance of regulating and compensatory processes (see Koch et al., 2009; Connell and Ghedini, 2015; World Bank, 2016). Ultimately, a better understanding of regulating ES may hold the key to enhancing ecological resilience (Rist et al., 2014; Sutherland et al., 2014).

The lack of quantifiable metrics limits the inclusion of regulating ES in accounting frameworks (UN et al., 2014). To enhance their inclusion in ES assessment frameworks, the complex links between social demands for regulating ES and the service providing units that comprise the regulating service could be better addressed. Although much ES literature now differentiates between ES capacity, flows of ES benefits, and ES demand (Villamagna et al., 2013; Bagstad et al., 2014; Tomscha et al., 2016; UN et al., 2014), consistent and reliable metrics to quantify these components for regulating services, especially demand (Wolff et al., 2015) remain poorly developed (but see Syrbe and Walz, 2012;