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Analysis

A soil change-based methodology for the quantification and valuation of ecosystem services from agro-ecosystems: A case study of pastoral agriculture in New Zealand

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ABSTRACT

This paper tests the steps required to transform a theoretical natural capital/ecosystem service framework for soils into an operational model. Each of the services provided by a volcanic soil under a pastoral dairy use are quantified and valued. The six guiding principles underpinning the method developed include differentiating soil services from supporting processes; identifying key soil properties and processes behind each service; distinguishing natural capital from added/built capital; identifying how external drivers affect natural capital stocks; analysing the impact of degradation processes on soil properties and basing the economic valuation on measured proxies. Proxies to quantify ecosystem services focus on the part played by soil in generating each service. This new approach highlights the importance of soil change in quantifying services, and goes beyond simply determining the status of soil natural capital. The total value of the ecosystem services provided by a volcanic soil under dairy in the Waikato region in New Zealand was estimated at $16,390/ha/year on average over 35 consecutive years. The services with the highest value were the filtering of nutrients and contaminants (58–63% of total value), followed by the provision of food and then flood mitigation. Regulating services had an economic value 2.5 times more important than provisioning services.

1. Introduction

The adoption of an ecosystem service approach to resource management has gained considerable traction globally in the last decade (Banwart, 2011), despite on-going debate over the nature and definition of ecosystem services (Boyd and Banzhaf, 2007; Braat and de Groot, 2012; Fisher and Turner, 2008). The attractiveness of the approach in land management and decision making stems from its integrative nature (Banwart, 2011; Faber and van Wensem, 2012). It offers the ability to explore the influence of land use and management practices on natural capital stocks, on the processes that build and degrade these stocks, and on the flow of ecosystem services from the use of these stocks (Dominati et al., 2010a). However, the steps from a theoretical framework to an operational model remain a challenge.

Existing frameworks for ecosystem services (Balmford et al., 2011; Costanza et al., 1997; de Groot et al., 2002; McBratney et al., 2014; MEA, 2005; TEEB, 2010) have a number of shortcomings in their interpretation of the role of soils in the supply of ecosystem services (Dominati et al., 2010a,b; Robinson and Lebron, 2010; Robinson et al., 2012). This limits application and use for exploring sustainable land management within ecological boundaries (Rockstrom et al., 2009). Until recently soil frameworks detailing the ecosystem services provided by soils (Daily et al., 1997; Wall et al., 2004) did not make the link between natural capital stocks and the provision of ecosystem services. Dominati et al. (2010a,b) tackled this challenge by developing a framework that links a change in the status of a soil property (natural capital), due to drivers such as climate or management, to a change in the provision of ecosystem services (Fig. 1). Haines-Young and Potschin (2010) presented the same idea of a "service cascade" coming from the ecological infrastructure. Moreover, Robinson et al. (2013) argued that "ecosystem frameworks should incorporate stocks (natural capital) showing their contribution to stock-flows and emergent fund-services as part of the supply chain".

The absence of a set of standardised definitions for each service is another on-going challenge in the quantification of ecosystem services (Dominati et al., 2010a; Rutgers et al., 2011). There is general agreement that standardised methods for the quantification of soil ecosystem services are overdue (Dominati et al., 2010b; Faber and van Wensem, 2012; Haygarth and Ritz, 2009; McBratney et al., 2014; Robinson and Lebron, 2010; Robinson et al., 2009; Rutgers et al., 2011). Boyd and

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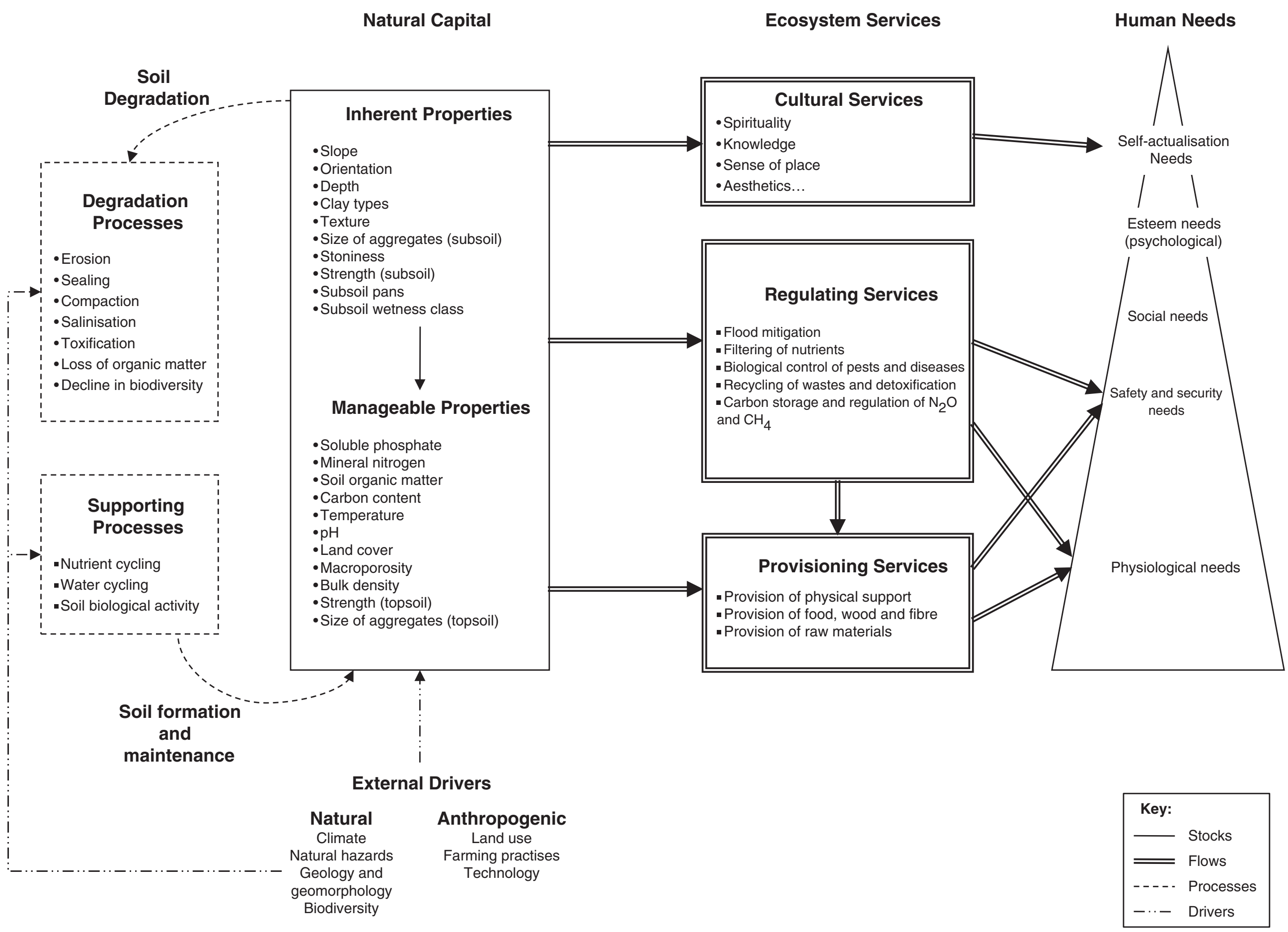

Fig. 1. Conceptual framework linking soil natural capital, soil processes, the provision of ecosystem services and human needs (Source: Dominati et al., 2010a).

Banzhaf (2007) and Wallace (2007) argue for the use of ecosystem components, that is natural capital stocks, rather than processes, as proxies for services, as there is more information on the structure and composition of ecosystems than on the processes involved in ecosystem functioning. Robinson et al. (2013) also favours a focus on soil stocks as a basis for the quantification of soil ecosystem services, for two reasons: flows can be inferred from stocks, and a stock approach to soils is coherent with historical soil surveys and land resource inventories that are available or readily measurable (Balmford et al., 2011; Dominati et al., 2010a; Robinson and Lebron, 2010; Robinson et al., 2009; Rutgers et al., 2011). However, because of the nature of ecosystem services, intangible flows which cannot be stockpiled (Robinson et al., 2013), a time dimension needs to be introduced. Moreover, it is argued here that when quantifying the provision of each service separating the contribution of soil natural capital from the contribution of added capital (infrastructures, inputs such as fertilisers or irrigation water) is important to assess whether stocks of natural resources are being sustained.

The failure to fully appreciate the contributions of soils to human welfare beyond food production (McBratney et al., 2014) can be traced to the fact that there is still a poor understanding of the full range of ecosystem services they provide, and as a consequence, these services are not adequately quantified or valued and, therefore not included in financial balance sheets alongside commercial services and built capital (Braat and de Groot, 2012; Costanza et al., 1997). Only in the last 15 years, have attempts been made to place economic values on ecosystem services (Costanza et al., 1997) and agro-ecosystems (Breure et al., 2012; Porter et al., 2009; Sandhu et al., 2008). Methodologies and operational models that can quantify and value the contribution of soils to the whole range of ecosystem services are required to satisfy the growing appeal of an ecosystem service approach for resource management (Braat and de Groot, 2012; Robinson et al., 2012).

This paper describes a new methodology using the conceptual natural capital/ecosystem services framework developed by Dominati et al. (2010a) to quantify and value in details the contribution of soils to the provision of ecosystem services. To illustrate how this can be done in context, the provision of fourteen services (Table 1) from a volcanic soil under a pastoral dairy agro-ecosystem was considered.

2. Material and Methods

In this study, the conceptual framework of Dominati et al. (2010a) is applied to the quantification and economic valuation of the contribution of soils to the delivery of fourteen ecosystem services (Table 1). Dominati et al's (2010a) framework categorises ecosystem services as provisioning, regulating and cultural (MEA, 2005; TEEB, 2010). Because the same ecological processes are at the origin of several goods and services that contribute to human welfare (Boyd and Banzhaf, 2007; Fisher and Turner, 2008; Wallace, 2008), it is important, yet challenging, to separate individual services so as to avoid the problem of double counting. This is why Dominati et al's (2010a) framework talks about supporting processes, not services, aligning with the TEEB framework (TEEB, 2010). Such differentiation provides the opportunity to isolate where each service is provided and how best to measure it.

Because the provision of ecosystem services from natural capital stocks (here soil) can only be assessed when these stocks are put to a use (Dominati et al., 2010a; McBratney et al., 2014), the methods developed for applying Dominati et al's (2010a) framework were tested on a Horotiu silt loam (HR), an alluvial soil from volcanic parent material,