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Metacoupling supply and demand for soil conservation service

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To date most soil conservation service studies heavily focus on measuring soil conservation service supply from the natural system without considering corresponding beneficiaries (i.e. demand), and feedback from the human system. In this paper, we presented an updated soil conservation service assessment framework as a two-way analysis of supply and demand, identifying the impacts of soil conservation on human-wellbeing and the feedback of human activities on soil conservation supply observed at different scales, from local (intracoupling) to regional (telecoupling). Soil conservation services supply can be calculated as the maximum allowable erosion rate minus the current soil erosion rate while soil conservation demand needs consider targets such as the Sustainable Development Goals. Because of the disturbance effect transmutation, ecosystem management may trigger possible unprecedented negative effects on the target processes and/or non-target processes. Tradeoff analysis between soil conservation services and other ecosystems services at multiple scales are therefore necessary for regional sustainable development.

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Introduction

Soil erosion has the potential to change soil structure, negatively affects soil fertility and poses a threat to food security [1]. Because erosion also affects the lateral fluxes of soil carbon (C) and soil distribution process, it ultimately affects the global C cycle [2]. Although soil erosion is a natural process, recent evidence has demonstrated that human activities have accelerated global soil erosion rates [3,4]. Soil conservation service, defined as the capacity of ecosystem to prevent soil loss and to store sediment [5,6], is receiving more and more attention, including the modeling and mapping of soil conservation service change, as well as the linking between landscape structure and soil loss process [7,8].

Soil conservation service is often calculated using the Revised Universal Soil Loss Equation (RUSLE) [9], which provide information on soil conservation capacities (i.e. how much soil can be conserved by the ecosystem). However, the challenge for soil conservation service assessment is on how to measure such service for its beneficiaries [10]. Therefore, further studies are required to identify the corresponding beneficiaries or benefiting areas and to build a feedback between nature and human system, in order to understand the impacts of changes on soil conservation supply to human well-being, as well as on human demand to soil conservation supply. To address the issues, we proposed a soil conservation service assessment framework that combines supply and demand of the soil conservation service as an integrated function. Following the framework, we proposed a new method to quantify soil conservation service supply and provided an overview about the supply and demand of soil conservation service from local to regional scale.

A general framework for soil conservation service assessment

Ecosystem services (ESs) are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing [11]. The crucial feature of ecosystem service concept is the link between ecosystem and human well-being, which considers both the products/functions provided by ecosystem and the beneficiaries which derive benefits from the ecosystem [12]. Ecosystem conditions and processes only become services once they are actually used or consumed by human beneficiaries [13]. As for soil conservation service, the ecosystem has the capacity to control erosion and facilitate sedimentation, depending on ecosystem structure and land management, especially the existing vegetation cover and root system. This capacity should be called the potential soil conservation service supply provided by ecosystem. Only after people use this service supply to maintain agricultural productivity or to improve water quality, we can say that it is the actual soil conservation service because the soil conservation service provision is used by beneficiaries to meet people's demand and to contribute to human well-being [14•].

Research on soil conservation services is closely related to soil erosion. There are many studies on soil erosion evaluation and the benefits gained from soil conservation. Yet most studies about soil conservation service pay more attentions on measuring soil conservation service supply, without considering the corresponding beneficiaries or benefiting areas. According to a recent review article, which reviewed 101 soil conservation service research articles, no measures emerged to quantify either the ES or the cascading benefits following the most accepted framework of 'ecosystem properties-ecosystem functions-benefits to humans-value' [15••].

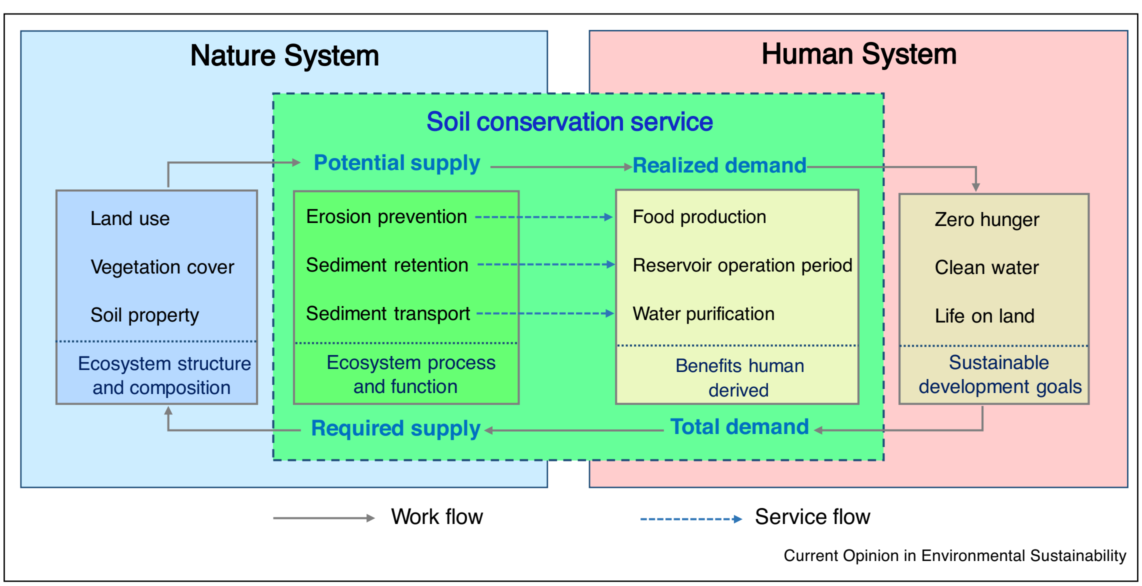
Based on the aforementioned background, we presented a framework which coupled the service supply from nature system and demands from human system (Figure 1), and the work can be divided into three parts: first, evaluation on soil conservation supply and its benefits; second, evaluation on soil conservation demand; and third, analysis of soil conservation supply-demand, and subsequent measures or policy to improve service supply.

The first step in soil conservation assessment is to connect the changes in ecosystem structure to soil erosion-transport-export process that provides the soil conservation service supply [16], and to evaluate the potential soil conservation supply. In another word, we need to know how much soil can be retained by the ecosystem, and to characterize the benefits from soil conservation supply [17], such as any increase in food production, extended reservoir operation period, and improvement on water quality. The second step is to evaluate and to map the soil conservation demand by considering, for example, the Sustainable Development Goals (SDGs) of United Nations Development Programme. Based on these goals (e.g. Zero Hunger, Clean Water, or Life on Land), we need to identify how much soil erosion should be controlled (total demand of soil conservation service). In the third step, we can compare soil conservation service demand and actual soil conservation service supply, and identify the required supply in areas with low service provisioning. Then, some appropriate management measures or policy can be taken or made to improve the potential service supply which will in turn improve the actual service supply, meet demand from human system, and contribute to target (e.g. SDGs). This framework of soil conservation service provides a mechanism to couple human system and nature system which includes a two-way (feedback) analysis between soil conservation supply and demand.

Rethinking the method of quantifying soil conservation service supply

According to the framework proposed above, quantifying soil conservation service supply is the first and an important step in providing reliable information on how different land use and global change affect the service supply. In most studies, soil conservation service provision is

Figure 1



A general framework to couple human–nature systems by soil conservation service assessment.