Ecological Engineering 99 (2017) 486–495

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Ecosystem services must tackle anthropized ecosystems and ecological engineering

S. Barot[a,*], L. Yé[b], L. Abbadie[a], M. Blouin[c], N. Frascaria-Lacoste[d]

[a] IEES-P, UMR 7618 (CNRS, INRA, UPMC, IRD), CC 237, 4 Place Jussieu, 75252 Paris Cedex 05, France
[b] CUP-Dédougou (Université de Ouagadougou), LERF, IDR, Université Polytechnique de, Bobo-Dioulasso, Burkina Faso
[c] Agroécologie, AgroSup Dijon, INRA, Univ. Bourgogne Franche-Comté, 26 Bd Docteur Petitjean, BP 87999, 21079 Dijon Cedex, France
[d] Ecologie Systématique Evolution, Univ. Paris-Sud, CNRS, AgroParisTech, Université Paris-Saclay, 91400 Orsay, France

ARTICLE INFO

Article history:
Received 23 November 2015
Received in revised form
20 November 2016
Accepted 21 November 2016
Available online 30 November 2016

Keywords:
Ecosystem services
Disservices
Anthropized ecosystems
Ecosystem functioning
Agroecology
Ecological engineering
Nature-based solution
Sustainability
Natural capital

ABSTRACT

The notion of ecosystem service is meant to better link human societies to ecological systems and to serve has a tool for decision making. However, the notion has never been applied in a comprehensive and consistent way to anthropized ecosystems while most ecosystems are indeed anthropized. This means that in initiatives of ecosystem service assessment anthropized ecosystems are either neglected or their services assessed in a misleading way. For example, services from cultivated lands are usually valued through the value of the agricultural production, while this production highly depends on inputs (fertilizers, pesticides, non-renewable sources of energy) and human work that cannot be assimilated to ecological factors. Moreover, these practices have negative impacts such as the emission of greenhouse gases, nutrient leaching to other ecosystems or loss of soil fertility. Hence, we present here a general framework that could be used to assess the ecosystem services provided by anthropized ecosystems. This framework is based on the joint assessment of ecological services, disservices, losses of natural capital and impacts on other ecosystems. We show that this framework is required to assess different practices to manipulate an ecosystem, e.g. low- vs high-input agriculture, or different ecosystems with different levels of anthropization, e.g. manage forest vs. cropland. Indeed, ecosystems function in such a complex way that human manipulations and natural ecological processes are tightly intermingled so that services and disservices arising solely from ecological processes cannot be separated from the result of human manipulations.

1. Introduction

Ecosystem services are now defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al., 1997) or "the benefits people obtain from ecosystems" (MEA, 2005). However, ecosystem services have already a long history (Gómez-Baggethun et al., 2010). The concept has initially been developed in the 1970s to support efforts of conservationists (Ehrlich and Mooney, 1983) and was thus used to raise stakeholder awareness on the pervasive negative impacts of human societies on biodiversity. Indeed, the concept of ecosystem service express the idea that human societies closely depend on natural ecosystems and the organisms they host. Hence, ideally, to convince that an ecosystem or organisms must be protected conservationists just have to show that the ecosystem services they provide are very important for human societies. However, the mainstreaming of ecosystem services during the 1990s goes much further than a metaphor for the broad dependence of human societies on ecosystems. It leads now to technics of economic valuation of services. This allows building tools such as Payment for Ecosystem Services or Market for Ecosystem Services that put services very high on the political and economic agenda. Though these practices have also been criticized (Laurans et al., 2013; Silvertown, 2015), this means that ecosystem services are more and more viewed has an operational and pragmatic tool to help managing ecosystems. However, it seems that the current framework developed for ecosystem services has never been fully adapted to anthropized and managed ecosystems.

The most classical definitions of ecosystem services (see above) do not give any precision on the type of ecosystem/level of artificialization that is acceptable for an ecosystem to provide ecosystem services. It is thus not fully clear whether ecosystem services can

* Corresponding author.
E-mail address: sebastien.barot@ird.fr (S. Barot).

http://dx.doi.org/10.1016/j.ecoleng.2016.11.071
0925-8574/

be assessed for anthropized ecosystems and, if so, there is so far no consensus on the way to assess ecosystem services provided by anthropized ecosystems. For example, a recent review has shown that the concept of ecosystems services has poorly been appropriated by agriculture sciences (Tancoigne et al., 2014). Indeed, since the original main goal was to push towards conservation the framework has originally been applied to ecosystems considered as natural. Some authors suggest that the notion of provisioning services (e.g. food production) can only be applied to rather natural ecosystems (de Groot et al., 2002) but nothing is explained about how croplands should be tackled. Similarly, in the global assessment of the value of ecosystem services (Costanza et al., 1997) nothing is specified about the way anthropized ecosystems are taken into account. For example, rangelands and crop lands provide provisioning services (i.e. food production) but the way these services were assessed is not clear. More recently, cultivated and urban areas have been explicitly excluded from another global assessment (de Groot et al., 2012) because they are human-dominated ecosystems.

Nevertheless, some indicators of services or assessment methods have been proposed for anthropized ecosystems. For example Maes et al. (2012) map the service of water purification taking into account crop lands but do not map the provision services provided by the same agro-ecosystems. Other authors describe and discuss services provided by highly anthropized ecosystems such as urban areas (Bolund and Hunhammar, 1999; Gómez-Baggethun and Barton, 2013), crop lands (Maes et al., 2016) or totally artificial ecosystems such as green roofs (Oberndorfer et al., 2007), but without discussing the issue that in such ecosystems the provided services are also due to non-ecological processes (human work, inputs). In the same vein, in a comprehensive assessment of UK ecosystem services aiming at providing a guide to decision making all services were assessed together and services provided by agriculture were directly assessed using food market values (Bateman et al., 2013). Others acknowledge the problem of assessing ecosystem services that are provided by interactions between ecological systems and human work and non-natural capital but without giving clear solution (Heink et al., 2016; MAES, 2014).

Our first goal is here to enlarge the current framework of ecosystem services to take into account anthropized ecosystems and all types of ecosystem manipulation by humans. This objective appears to us as crucial because all ecosystems are more or less impacted by human activities (Vitousek et al., 1997b). On the one hand, humans impact all ecosystems more or less directly without any conscious will. Even tropical primary forests have been modified by human groups inhabiting them (e.g. Posey, 1985) and are impacted by global changes triggered by human societies. Even Antarctic and Artic areas are touched by different forms of pollution (e.g. Weber and Goerke, 2003) and by climatic changes. On the other hand, about a third of earth terrestrial surfaces are utilized more or less intensively by humans for agriculture (Foley et al., 2011) and the original natural ecosystems have been purposely turned into cropping systems and pastures. This means that the framework for the assessment of ecosystem services is not fully adapted for the majority of ecosystems and may lead to misleading conclusions when applied to managed ecosystems such as crop lands, especially when different ecosystems with different intensity of anthropization or different types of management are compared.

Ecological engineering is traditionally defined as “the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both” (Mitsch and Jørgensen, 2003). Our second goal is to better link the idea of ecosystem services to the field of ecological engineering (Barot et al., 2012; Mitsch and Jørgensen, 2003) and related types of ecosystem manipulations such as agricultural practices informed by ecological sciences (Altieri, 1989; Doré et al., 2011) or nature-based solutions (Eggermont et al., 2015). The framework of ecosystem services has originally been mostly applied to broad choices and issues. Which ecosystems should be protected? What surface of this ecosystem should be protected? The framework has more rarely been used to help making more refine decisions about ecosystem management and the underlying practices. This would allow answering questions such as: Which tree species should be planted in a street? What type of substrate should be used for a green roof? Should a cropping system be based on tillage? Should mixtures of varieties be used to develop a more sustainable agriculture? The framework we need should thus be able to compare in a comprehensive and consistent way the services provided by different ecosystems that may only differ by small differences in the practices used to manipulate the concerned ecosystems. This would in turn allow choosing the best practices to reach a particular goal defined as a targeted basket of ecosystem services. We might thus want to choose (1) the best combination of substrate type and irrigation practices to maximize the capacity of a green roof to store carbon and regulate the emission of greenhouse gases without having any particular requirement in terms of storm water retention or (2) the best combination of wheat varieties and inputs (fertilizers and pesticides) to maintain a high yield even in dry years and conserve soil fertility. This means that the framework we need should also explicitly take into account human work and management practices to allow more sustainable practices depending less on human work and non-natural capital to be chosen (e.g. less irrigation for a green roof or less fertilizer and less pesticide in agriculture), even when they lead to lower provision of the targeted services.

To reach these two goals we have built a new framework starting from the framework described by Villamagna et al. (2013) to which we add (Section 2) the management of ecosystem to increase the provision of some services and a more explicit relation between ecosystem state, ecosystem functioning and the provision of services. We show (Section 3) that in anthropized or managed ecosystems services as often assessed are not truly ecosystem services because they are not solely based on ecological processes. Then we explain (Section 4) why it is not possible to fully disentangle the part of ecosystem services that are based on ecological processes and the part that is based on human work and non-natural capital. Finally, we explain (Section 5) how this framework can be used and how it is linked to the sustainability of the provision of services.

2. Better integrating ecosystem services, ecosystem functioning and the feedbacks with human societies

Our framework (Fig. 1) is based on the “capacity, flow, demand, pressure” framework (Villamagna et al., 2013). Note that we focus here on the capacity of ecosystems to provide services and not on interactions between this capacity and the demand by the society that lead to the actual flow of service. We emphasize that the capacity of provision of services (and disservices) is determined by a feedback loop between the ecosystem state (and its biodiversity) and ecosystem functioning and that this feedback loop is impacted by human activities. Very often this unintentional impact, i.e. pressure, is viewed as negative because many human activities alter the functioning of natural ecosystem (Vitousek et al., 1997b), e.g. through losses of biodiversity. However, human activities also often aim purposely at managing ecosystems or at increasing the provision of some services, i.e. agriculture aims at increasing food production. By definition, ecosystem services and disservices influence human societies (Fig. 1, arrows between services and human societies) and society should adapt their pressures on ecosystems and management practices according to their impact on the provision of services and disservices. This expresses the major objectives