Journal of Environmental Management 152 (2015) 145–157

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Combining direct and indirect impacts to assess ecosystem service loss due to infrastructure construction

Léa Tardieu [a, *], Sébastien Roussel [a, b], John D. Thompson [c], Dorothée Labarraque [d], Jean-Michel Salles [e]

[a] UMR 5474 LAMETA, Université Montpellier 1, Avenue Raymond Dugrand, F-34960 Montpellier, France
[b] Université Paul-Valéry Montpellier 3, Route de Mende, F-34199 Montpellier, France
[c] UMR 5175 CEFE, CNRS, 1919 Route de Mende, BP 5051, F-34033 Montpellier, France
[d] Egis Structures & Environnement, 33-43, Avenue Georges Pompidou, F-31130 Balma, France
[e] UMR 5474 LAMETA, CNRS, 2 Place Viala, Bâtiment 26, F-34060 Montpellier, France

ARTICLE INFO

Article history:
Received 13 June 2014
Received in revised form
14 November 2014
Accepted 21 January 2015
Available online

Keywords:
Ecosystem services
Environmental impact assessment
Landscape connectivity
Linear infrastructure
Threshold behaviour

ABSTRACT

The destruction of natural habitats and the associated loss of Ecosystem Services (ES) are rarely jointly assessed and quantified in Environmental Impact Assessment (EIA). Based on a terrestrial transport infrastructure project, the objective of this paper is to quantify the potential loss of ES associated with direct and indirect impacts, and illustrate their contribution to decision-making for route options. We first quantify how much of each type of ES is generated by different land units in the absence of the infrastructure (baseline conditions). We then estimate ES loss caused by infrastructure construction in a way that discriminates among different types of ES and losses because some ES, in addition to losses that are directly proportional to the surface impacted, can show additional indirect losses associated with landscape connectivity. In addition, we illustrate how the assessment of threshold effects in particular ecosystem types that may be most sensitive to their occurrence can affect the estimation of ES loss. We compare implementation options to provide an example of how choices can be improved by assessing ES loss associated with a combination of direct and indirect impacts. This kind of analysis could be used more generally to assess development projects simply by adapting the framework of analysis to the type of project and the ecosystems concerned.

1. Introduction

Ecosystem Services (ES) are derived from the ecological functioning of ecosystems and are typically conceptualized as flows of goods and services that benefit human societies (Daly and Farley, 2003). Land use change associated with human population growth and land development during the 20th century continues to alter and destroy natural ecosystems, with consequent degradation of ecological processes and natural ecosystems across the Globe (Millennium Ecosystem Assessment, 2005; Sala et al., 2000). There is thus increasing concern on how the impacts of such activities on ecosystem functions affect the capacity of ecosystems to provide ES (Broekx et al., 2013; Geneletti, 2013; Kumar et al., 2013). However, although methodologies for the classification, quantification and valuation of ES are developing rapidly, most studies are restricted to general evaluations that are rarely directly integrated into the decision-making processes (Laurans et al., 2013).

Currently, after the regulatory avoidance of sites designated for nature conservation, decisions are often made on the basis of environmental vulnerability, technical aspects of the infrastructure construction, security, and short-term economic criteria (clearing, elevation, house protection). In cases when projects affect areas that do not contain emblematic or protected habitats and species, that currently provide a basis for avoiding, reducing or compensating effects of infrastructure projects, short-term economic criteria are most often given priority over environmental concerns. Assessing ES loss could thus allow for a broader identification of significant environmental impacts (Landsberg et al., 2011) and thus improve efforts to inform decisions among the different options (Geneletti, 2011). This is important because project managers and developers are increasingly constrained by requirements to integrate larger-scale environmental impacts, without having at their

* Corresponding author. 2 Place Pierre Viala (Bat 26), 34060 Montpellier, France.
E-mail address: lea.tardieu@supagro.inra.fr (L. Tardieu).

http://dx.doi.org/10.1016/j.jenvman.2015.01.034
0301-4797/

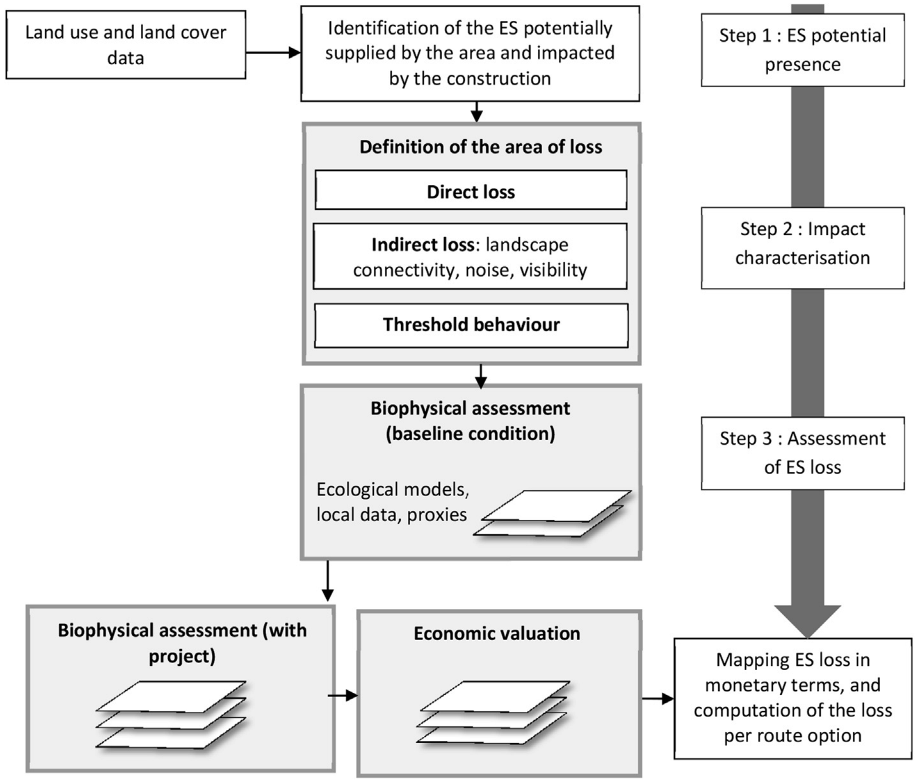

Fig. 1. Methodological framework summary.

disposition sufficiently clear and applicable tools to do so (Broekx et al., 2013; Geneletti, 2013). Identifying the loss of ES associated with infrastructure construction is thus a major current challenge to the improvement of environmental planning (Geneletti, 2013; Kumar et al., 2013; Tardieu et al., 2013).

The impacts of land conversion are direct on ecosystems due to the loss and reduction of the surface areas of natural ecosystems (Fahrig, 2002), with subsequent ES loss (Gascoigne et al., 2011; Kreuter et al., 2001). However, although integrating ES loss associated with infrastructure projects represents a potentially critically element for the improvement of Environmental Impact Assessment (EIA), it is nevertheless a complicated task that requires careful attention. First, the disturbance influence of the project on surrounding wildlife, vegetation, hydrology, and landscape often go beyond the converted area and can cause significant indirect impacts on ecological function (Trocmé et al., 2002) and ES provision (Mitchell et al., 2013). Second, species responses and ecosystem function may show a non-linear response to land conversion due to threshold behaviour (Groffman et al., 2006; Swift and Hannon, 2010). ES loss will thus depend on the type of ecosystem, the spatial extent of impacts on different ecosystems and how impacts affect spatial interactions among ecosystems and their components.

In this study, our overall objective is to test the feasibility of assessing ES loss involved by different implementation options of a major linear infrastructure. Our applied framework focuses on the comparison of ES loss for different route options for a high-speed railway project[1] in Western France. To provide a broad and comprehensive assessment of ES loss in terms of biophysical quantities and economic values, we jointly assess direct losses of ES provision due to the ecosystem conversion and indirect losses associated with disruption of landscape connectivity. In addition we make a preliminary attempt to assess non-linear responses due to threshold effects by classifying ES according to how they may be impacted by such effects with a detailed study of two ES to illustrate the pertinence of this approach. The ES loss assessment we propose can be adapted to the assessment of different types of linear infrastructures (highways, waterways) by adapting land takes to the local ecological and landscape context.

2. Methodological options and data collection

Our methodological framework is displayed in Fig. 1 with successive steps for analysis. The rationale of our step-by-step approach can be summed up as follows. First, the ES potentially supplied and impacted within the area are identified, by referring to ES potential presence (step 1). Second, the impact characterisation step leads to the definition of the area of loss through direct and indirect loss which includes additional loss due a threshold response of ecosystems (step 2). Third, the assessment of ES loss is quantified is valued in monetary terms associated with the biophysical change between a situation without the project (baseline conditions) and a situation with the project (step 3). Finally, the last step is the spatial mapping of ES loss in monetary terms and the calculation of economic losses associated with alternative route options (Tardieu et al., 2013).

We illustrate our approach through the examination of part of a contemporary infrastructure project concerned by different route options for a high-speed railway project in Western France that crosses a principally rural territory with and natural and semi-natural areas. Our study considers different route options in two zones crossed by the project. The route options were chosen

[1] We cannot disclose more information on the case study due to contractual commitments with *Egis – Structures & Environment*.