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Assessing and mapping global climate regulation service loss induced by Terrestrial Transport Infrastructure construction

Léa Tardieu [a,b,1], Sébastien Roussel [c,d,*], Jean-Michel Salles [e,2]

[a] Montpellier SupAgro, UMR1135 LAMETA, 2 Place Viala, bâtiment 26, F-34060 Montpellier, France
[b] EGIS Structures et Environnement, 78286 Guyancourt, France
[c] Université Montpellier 3 Paul Valéry, 34199 Montpellier, France
[d] Université Montpellier 1, UMR5474 LAMETA, Avenue Raymond Dugrand, F-34960 Montpellier, France
[e] CNRS, UMR5474 LAMETA, 2 Place Viala, bâtiment 26, F-34060 Montpellier, France

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ABSTRACT

The purpose of this paper is to broaden the Terrestrial Transport Infrastructure (TTI) assessment process into the field of Ecosystem Services (ES), *i.e.*, the benefits people derive from ecosystems. Taking into account ES in an *ex ante* assessment of public infrastructure projects is of critical importance for the improvement of transportation decision-making tools, such as Environmental Impact Assessment (EIA) and Cost–Benefit Analysis (CBA). For EIA, the integration of an ES based approach opens the possibility of measuring a loss in ES supply (and its economic value); this provides a means of selecting among different possible pathways for the infrastructure. For CBA, since the ES loss induced by the selected pathway is expressed in monetary terms, it can be integrated as a standard social cost in the analysis, permitting a more efficient control of natural capital loss. We illustrate these points by assessing the loss of a global climate regulation service due to the soil tillage and sealing caused by a TTI construction, using the example of a high-speed rail in Western France. We select three optional routes among the proposed routes and analyse which route has the least impact on the global climate regulation service and its economic value.

1. Introduction

Terrestrial Transport Infrastructures (TTI) are often considered as essential for economic development due to their contribution to time gains, comfort, safety, and regional accessibility, yet they have major impacts on the natural areas they cross. These impacts can involve direct, indirect and cumulative effects (Tricker, 2007). The conversion of natural areas into artificial areas, as a result of TTI construction, causes habitat loss and fragmentation with consequent declines in biological diversity (Quintero and Mathur, 2011). As a consequence, the compromise between social gains from TTI construction and the ecological and social losses induced by the environmental alteration requires analysis.

Recent improvements to Environmental Impact Assessment (EIA) of TTI construction projects provide much-needed guidance to public policies. In many countries, TTI projects are assessed regarding several criteria (flora, fauna, fragmentation, etc.) in order to avoid or minimize their environmental impact. However, and despite improvements to the process, the criteria used remain mostly qualitative. Moreover, the approach consists of weighting the different impacts with impact scores and assessing the overall impact by summing these scores (Geneletti, 2005). These scores are thus of critical importance, and as Geneletti (2006) argues, the process acts as if the scores have additive properties. In addition, at the present time, the loss of an Ecosystem Service (ES), *i.e.*, the benefits people derive from ecosystems, due to TTI construction is not quantified and is usually regarded as having little influence on the main infrastructure choices, such as time gains or the perceived economic viability of the project (Chevassus-au-Louis et al., 2009). The process of TTI projects' evaluation is usually performed through Cost–Benefit Analysis (CBA). When CBA is used to enlighten decision-making for projects that impact the natural environment, monetary indicators of external effects have to be included in the assessment process for a greater efficiency.

Economists have developed a variety of methods that allow the construction of monetary indicators of non-market value loss associated with environmental and ecosystem impacts (TEEB,

* Corresponding author at: Université Montpellier 1, UMR5474 LAMETA, Avenue Raymond Dugrand, F-34960 Montpellier, France. Tel.: +33 4 34 43 25 49.
E-mail addresses: lea.tardieu@supagro.inra.fr (L. Tardieu), roussel@lameta.univ-montp1.fr, sebastien.roussel@univ-montp3.fr (S. Roussel), sallesjm@supagro.inra.fr (J.-M. Salles).
[1] Tel.: +33 4 99 61 27 23.
[2] Tel.: +33 4 99 61 26 68.

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2010). Taking into account ES in an *ex ante* assessment of public infrastructure projects is thus of primary importance if decision-making process associated with project selection is to be improved. Assessing ES changes and losses associated with a TTI project can improve both (a) the process of choice for the least impact route for the TTI in terms of ES supply, demand and economic values in the EIA, and (b) the integration of natural capital loss as a social cost in the CBA.

However, to our knowledge, there is only one study which attempts to quantify the economic costs and benefits of TTI projects in terms of their impact on ES supply (SETRA, 2010[3]). In this paper, our objective is to broaden the scope of TTI project assessment to incorporate ES loss in order to provide for more efficient control of natural capital loss. To do so we assess the loss of a global climate regulation service associated with the destruction of habitats that contribute to carbon sequestration and storage by the construction of a high-speed railway in Western France. We select three optional routes among all the routes proposed in the discussed project, and analyse the loss in global climate regulation service and the economic value associated with each route. Studying the global climate regulation service allows us to avoid several methodological issues since the "land-take" [4] of the TTI on the service is reasonably well-known, and the marginal value of the damage is not modified by the loss amount. Obviously, other services will be impacted, and must be integrated in the analysis, but their measurement requires additional methodological advancement (*e.g.*, impact areas may exceed the area directly transformed by the TTI, consideration of beneficiaries and substitutes). Focusing on this service allows us to illustrate how to integrate ES generally in this type of analysis.

The paper is organized as follows. In Section 2 we highlight the importance of evaluating ES loss due to the TTI construction *stricto sensu* in all stages of the TTI project assessment process. In Section 3 we describe the method used to assess and map the social loss of the global climate regulation service in order to select the route with least impact on this service (*ceteris paribus*) and its economic value. In Section 4 we present our results which are discussed in Section 5. Concluding remarks are formulated in Section 6.

2. Transport infrastructure environmental externalities and ecosystem services loss

Transport infrastructure construction has increased rapidly in recent years, and continues to destroy and fragment natural ecosystems. In metropolitan France, the railroad network is currently about 31,000 km while the highway network now reaches roughly 1 million km. In addition, public policies dedicated to planning and mobility involve a further 2000 km of projected lines through 14 new high-speed rail projects before 2020.

Two assessment tools are used in transportation decision-making: Environmental Impact Assessment (EIA), intended to analyse and limit the impacts on the natural environment, and Cost–Benefit Analysis (CBA), intended to improve the benefits/costs ratio of the project. TTI projects involve a number of environmental externalities that alter ecosystem processes and functions and therefore ES supplied to human beings. The integration of ES assessment in the process could thus enhance the efficiency of both these tools.

2.1. Transport infrastructure impacts on Ecosystem Services (ES)

The effects of linear infrastructure construction on ecosystems and biodiversity are now well identified and can be classified in terms of either their direct or indirect impacts (Vanpeene-Bruhier and Dalban-Canassy, 2006). Direct impacts include all the losses of environmental features attributable directly to the infrastructure construction. This encompasses the loss of habitat and ecosystem area due to the conversion of the original land cover into an artificial surface (Geneletti, 2006). Indirect impacts include all the indirect losses of environmental features and processes induced by the interruption or the disturbance of ecological networks at different scales. Indirect impacts mostly involve (a) habitat fragmentation, *i.e.*, the break-up of natural areas into smaller and more isolated units which lose viability due to their small size (Geneletti, 2004), and (b) physical, thermal, visual or chemical barrier effects which can disrupt the flux of material and species within and between ecosystems and meta-populations (Vanpeene-Bruhier and Dalban-Canassy, 2006).

All these impacts can directly or indirectly affect ES supply. Direct impacts can disturb all types of ecosystem functions, bringing a total loss of ES in the area of influence of the infrastructure (provided that the impacts are not mitigated in the area). Indirect impacts are more complex and difficult to document; they mainly affect functions and processes related to species movements, habitat functions (lifecycle maintenance and gene pool protection), game provisioning (deer, roe deer, and so on) and pollination services. Indirect impacts may also affect the scenic beauty of the landscape.

2.2. Integration of ecosystem services in an Environmental Impact Assessment (EIA)

EIA practitioners have to consider increasingly ES in their assessment. However they lack guidance on how to address ES, and thus their integration in EIAs is still at its early stage and is rarely carried out explicitly (Landsberg et al., 2011; Geneletti, in press; Honrado et al., in press; Partidario and Gomes, in press). EIA key role consists in supporting the development of projects by assessing the environmental impacts that are likely to results from their construction. Integrating ES in EIAs would promote a more coherent assessment of environmental and socio-economics impacts; this would help to identify spatial and temporal trade-offs between humans and ecosystems (Geneletti, 2011). Following Geneletti (in press), Honrado et al. (in press), and Partidario and Gomes (in press), this integration requires in particular modelling ES in an explicit spatial manner.

Geographical Information Systems (GIS) is widely used as a supporting tool in various stages of the Environmental Impact Assessment (EIA) process (Atkinson and Canter, 2011). It is used mainly to describe the baseline conditions of the project (hydrology, soils, topography, etc.), describe the impacts and predict their magnitude, assess the relative impact of alternative routes and thus the choice of the project with the lowest impact, and finally to identify areas where mitigation measures should be applied (Joao and Fonseca, 1996).

Analysis of the spatial dimensions, distribution and welfare associated with ES has only recently been considered (Heidkamp, 2008; Kozak et al., 2011). Because linear infrastructures change territorial configuration and biophysical conditions, they modify in an overlapping way the ES quantity and quality and their supply to human beings, the benefits people derive from these services, and the values people attach to these benefits. The initial

[3] However, this study lacks of spatial analysis and average economic values per hectare have been used for all services studied (only temperate forests and grasslands). Moreover, the study retained the same impact area for all ES.

[4] The "land-take" is a hypothesis on a buffer that extends along the infrastructure axis where vegetation and land cover are supposed to be lost (Geneletti, 2006).