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Indicators of ecosystem services in a military Atlantic Forest area, Pernambuco—Brazil

Helder Guimarães[a], Ricardo Braga[b], André Mascarenhas[c,d,*], Tomás Barros Ramos[c]

[a] Universidade Estadual de Pernambuco, Rua Barão de Itamaracá, 430, Apt 201, Espinheiro, Recife, PE CEP 52020-070, Brazil
[b] Associação Águas do Nordeste, Rua Joaquim Xavier de Andrade, 44, Casa Forte, Recife, PE CEP 52.061-350, Brazil
[c] CENSE, Center for Environmental and Sustainability Research, Department of Environmental Sciences and Engineering, Faculty of Sciences and Tecnology, Universidade Nova de Lisboa, Campus da Caparica, Caparica 2829-516, Portugal
[d] Lab. of Landscape Ecology, Department of Geography, Humboldt-Universität zu Berlin, Unter den Linden 6, Berlin 10099, Germany

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ABSTRACT

The use of Ecosystem Services (ES) indicators can help designing, implementing and monitoring public environmental policies. Such indicators may be used as a support tool for natural resources management, like in forest areas, which are important ES providers. In this context, military areas are particularly challenging due to the nature of the activities conducted and the need to conciliate them with ecological protection, without undermining military readiness. It is argued that in addition to technical issues, considering stakeholders' opinions is beneficial for the selection and design of ES indicators. The main aim of this research is to develop forest ES indicators supported by a participatory indicator selection process. A case study is made of an Atlantic Forest area in the Northeast of Brazil, under the jurisdiction of the Brazilian Army. To accomplish that aim, a questionnaire survey was sent to a group of stakeholders in order to evaluate an initial set of proposed 44 indicators for several forest ES. Through a weighting of stakeholders' scores, 25 ES indicators for the Atlantic forest were obtained. The selected indicators portray the study area mainly as a provider of regulating, cultural and habitat services and less of provisioning services, which can be related with military and nature protection restrictions on the use of provisioning ES. Nevertheless, the three top-rated indicators dealt with water availability, regulation and quality (for human consumption). Together with the predominance of water-related ES that was observed (ten out of 25 indicators), this points out the relevance of forest water-related ES in the study area. On the other hand, the specificity of the military context was not clearly reflected by the indicators selected, since most of them are applicable in areas or contexts other than a military one. Alongside indicators expressing the benefits provided by nature, stakeholders' scorings reveal recognition of the importance of biodiversity and resilience of the area. This stresses the importance of biodiversity and resilience to support ES supply, but is also linked with one of the major challenges for managing a military area with high natural value: that of conciliating military activities (that support military readiness) with nature protection. Other forest areas under military or similar particular jurisdiction, often representing a major fraction of national forests, could learn from this approach and identify areas for priority response measures. These indicators could be also a driver to increase and improve environmental management of military training activities and safeguarding natural resources in important ES providing areas like Atlantic forests.

1. Introduction

The concept of Ecosystem Services (ES) emerged with the need to demonstrate that natural areas fulfil essential functions in the processes of maintaining life and supporting human activities, as opposed to the idea that preserved or intact ecosystems are unproductive or represent obstacles to economic development (Daily, 1997; Campanili and Schaffer, 2010). This means that every ecosystem delivers a series of benefits, such as water, wood and food production, landscaping, climate regulation and air purification, all of which are appropriated by humans. Hence ES are fundamental for human survival and for social and economic development. ES can be defined as flows of

* Corresponding author at: CENSE, Center for Environmental and Sustainability Research, Department of Environmental Sciences and Engineering, Faculty of Sciences and Tecnology, Universidade Nova de Lisboa, Campus da Caparica, Caparica 2829-516, Portugal.
E-mail addresses: helder.prof@gmail.com (H. Guimarães), rbraga@hotlink.com.br (R. Braga), andre.mascarenhas@fct.unl.pt, andre.mascarenhas@hu-berlin.de, andre.mascarenhas@gmail.com (A. Mascarenhas), tabr@fct.unl.pt (T.B. Ramos).

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materials, energy, and information from stocks of natural capital, which are combined with both manufactured and human capital services to produce human welfare (Costanza et al., 1997). These services are generated by all ecosystems at different scales. Ecosystems can be cultivated, urban, polar, marine or coastal land, inland waters, forests and woodlands, dry lands, islands or mountains (de Groot et al., 2010). Among them, forests provide several benefits such as regulating local and global climate, protecting watersheds, preventing soil erosion, and cycling nutrients (Ninan and Inoue, 2013).

Forest ES have been analysed in different research studies (see Mori et al., 2017 for a recent overview). In a review of studies that have estimated the value of forest ES, Ninan and Inoue (2013) present evidence from a cross section of forest sites, countries and regions across the world indicating these values to be significant. They also suggest that policies to conserve ecosystems and their services should emphasise local contexts and values. Alamgir et al. (2016) have found that despite the high capacity of rainforests to supply single and multiple ES, environmental factors such as elevation, rainfall and temperature gradients along with forest structure are determinant factors for ES delivery in different forest types. Indicators have been developed, as for biodiversity of plantation forests (Coote et al., 2013), identifying for example conifer canopy, proximity to old woodland and stand age as important indicators. Other ecological indicators (Turnhout et al., 2007) considered important to forest sustainable management in face of climate change include for example above-ground forest biomass carbon (Chen et al., 2011). The importance of analysing different indicators of forest ES over time, as well as to integrate the preferences of the stakeholders involved in forest management, is stressed by Diaz-Balteiro et al. (2017).

Indicators are variables which provide aggregated information on certain phenomena (Wiggering and Müller, 2004). They convey "value-added messages" in a simplified and useful manner to different stakeholders. An indicator can be derived from a single variable to reflect some attribute or from an aggregation of several variables (indices) (Ramos and Caeiro, 2010; Ramos, 2009). ES can act as ecological indicators and can be understood as impacts within the Driving Forces-Pressures-State-Impacts-Responses (DPSIR) framework (Müller and Burkhard, 2012). They also meet criteria for being adequate human-environmental system indicators, hence representing an appropriate instrument for decision-making and management (Kandziora et al., 2013). Overall, as synthesized by Hauck et al. (2016), ES indicators can be considered "boundary objects" that provide an information support to facilitate discussions and connections among different stakeholders, when dealing with environmental issues. ES indicators have been developed for several purposes and contexts, like supporting EU biodiversity policy (Maes et al., 2016), freshwater recreational fishing (Villamagna et al., 2014), outdoor recreation (Paracchini et al., 2014), or for urban environments (Alam et al., 2016). However, a multitude of challenges, uncertainties and data gaps remain ahead for research on ES indicators (Müller and Burkhard, 2012; Kandziora et al., 2013; Maes et al., 2016).

Quantifying ES as well as developing their indicators need a great deal of information that is sometimes neither easily accessible nor available (Villamagna et al., 2013a). Similarly, there are many obstacles that may prevent the analysis and use of ES data. This includes a lack of ecological and social knowledge on how these services are formed and put to use and how they vary in time and space. Moreover, standardized quantification and mapping of the main components of ES may be absent (Crossman et al., 2013; Villamagna et al., 2013b).

The analysis of ES indicators may help when designing public environmental policies. Similarly, the reporting of ES may support the decision-making process and improve communication with stakeholders (Mascarenhas et al., 2016). Moreover, identifying these indicators may contribute as an administrative tool towards managing and conserving natural areas (Viegas et al., 2014). Balancing the demands of government policy and regulations with private initiatives, while protecting natural resources has become a major challenge in environmental management. Also, beyond simply protecting the ecosystem from any potential harmful impact, an environmental approach may be considered as a form of investing in the sustainable management of ecosystems (Loomis and Paterson, 2014). All definitions and classifications of indicators, as well as of ES, depend strongly on the characteristics of the investigated ecosystem and the context of the decision in which they are being applied (Müller and Burkhard, 2012). Consequently, ES indicators are policy-relevant representations that identify gaps and communicate trends and information on the sustainable use of these services and the benefits derived from maintaining them for future generations (Layke et al., 2012).

For an effective development and use of ecological indicators, quality as well as acceptance is very important and the inclusion of stakeholder perspectives can be an important contribution to both (Turnhout et al., 2007). It is mandatory to have a flexible and consistent indicator selection process keeping multiple types of end-users in mind (van Oudenhoven et al., 2012). Several authors have stressed the need to integrate 'technical' and 'participative' approaches in indicator selection and development processes (Ramos and Caeiro, 2010; Ramos, 2009; Reed et al., 2005, 2006). The ES indicator development should not be only a scientific or technical process, but it should also address the different values, interests, aspirations, knowledge and beliefs of the involved stakeholders (Hauck et al., 2016).

Overall, and despite the above-mentioned studies on ES indicators, there is a lack of research on how to select ES indicators in practice in order to improve and facilitate data collection for indicators, processing, analysis and reporting. Also, participatory approaches are becoming well covered by research initiatives on general sustainability indicators but are still poorly explored for ES indicators. Therefore, ES indicator approaches, frameworks and case studies should be further researched to analyse how can they best contribute to the process of assessing ES and communicating, understanding and exploring their potential weaknesses and strengths. Although the amount of work conducted for ES in forest areas, ES indicators, and in particular in forest areas managed by military authorities, is almost an unexplored issue, Lillie and Fittipaldi (2010) highlight the importance of these special lands, stating that the adoption of an ES approach in the military sector can help establishing priorities for restoring, acquiring and retaining areas of ecological importance and in the process minimize the potential decline in military readiness. As discussed by Diehl et al. (2016) and Saarela and Rinne (2016), particular contexts and actors, including their cultural sensibilities, norms and customs, are core elements for the justification and analysis of an indicator, and the uniqueness of the military environmental and social context (see e.g. Myhre et al., 2013; Ramos et al., 2007) is an example of how these differences should be considered.

In this context, the main aim of this study is to select a set of ES indicators for forest areas, through a participatory process. The proposed approach was tested in a fragment of Atlantic Forest in the Northeast of Brazil, under the jurisdiction of the Brazilian Army.

2. Methods

2.1. Study area: fragment of Atlantic forest located in the Marshal Newton Cavalcante Instruction Camp

The Brazilian Army is directly responsible for around 22,000 km^2 (about 0.71% of the Brazilian territory), an area bigger than countries such as Israel and El Salvador. Included in these are the most different biomes, such as Atlantic Forest, Caatinga, Amazon Forest, Brazilian Cerrado and Pantanal (Guimarães, 2013).

The study area is a forest located inside the Marshal Newton Cavalcante Instruction Camp of the Brazilian Army (CIMNC), which was created in the 1940s. It is located in the Northeast Region of Brazil (Fig. 1). Originally, the area consisted of ten sugarcane plantations, the