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Using dynamic sustainability indicators to assess environmental policy measures in Biosphere Reserves

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ABSTRACT

The assessment of different policy options represents a major tool for decision-makers in Biosphere Reserves, to develop more-resilient strategies for sustainable development and to visualise unintended consequences of these policies.

In this work we analyse eight measures proposed by different agents in order to meet the main objectives of environmental sustainability, included in the Action Plan of the Fuerteventura Biosphere Reserve (Spain). We quantified the effects of these measures in terms of the sustainability thresholds of 10 environmental indicators, also proposed by the Action Plan, which was integrated in the Fuerteventura Biosphere Reserve dynamic model. Their behaviours under these measures allow determination of whether the objectives will be met in the period 2012–2025. Although some indicators would improve under these measures, fitting certain objectives, some negative effects on other indicators confirm the existence of trade-offs among these objectives. For instance, grazing limitation would improve the proportion of high-quality vegetation but would negatively affect the Egyptian vulture population, which would even fall below its sustainability threshold. The definition of thresholds for each indicator allows decision-makers to establish a way to prioritise among the eight measures analysed. The results show that these measures are insufficient to meet the sustainability thresholds of four indicators (the landscape indicator, the proportion of renewable energy, the per capita primary energy consumption and carbon dioxide emissions). Focusing on the remaining six indicators and following the rule "*Threshold out, measure out*", seven out of the eight measures would exceed some thresholds and should be avoided. Only one option, aimed at growing fodder to feed cattle on restored traditional agricultural lands, would not exceed any of these thresholds. However, this measure also presents certain negative effects regarding indicators related to flagship species (the houbara habitat and the Egyptian vulture population), which would require compensation measures.

1. Introduction

Biosphere Reserves (BRs) provide an example of an integrated sustainability framework which explicitly acknowledges that complex socio-economic and ecological systems are inextricably linked (Levrel and Bouamrane, 2008). The BRs are considered as "learning laboratories for sustainable development" (Ishwaran et al., 2008), since they can be platforms for policies and practices that facilitate the emergence of knowledge-based management arrangements to demonstrate integrated and innovative approaches to conservation and sustainable development (Nguyen et al., 2011).

Given the multi-dimensional and dynamic nature of BRs, there is a clear need for a systemic approach in addressing this complexity (Hjorth and Bagheri, 2006). System dynamics (SD) provide a framework for managing changes, through the understanding of the dynamic interactions, delays and feedbacks embedded in complex systems (Rasmussen et al., 2012; Martínez-Fernández et al., 2013; Zhao and Zhong, 2015).

The use of SD allows decision makers to anticipate the long-term consequences of their decisions and actions, as well as the unintended consequences and uncertainty of policies and strategies (Guan et al., 2011). For this purpose, scenario development is one of the major tools used to visualise and compare the potential outcomes of a variety of policies and to develop conservation strategies that are more resilient to global change.

von Geibler et al. (2010) stated that the differentiation between sustainable and non-sustainable development requires the analysis

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Table 1
Matrix SWOT[a] regarding the environmental dimension in Fuerteventura Biosphere Reserve.

Strengths	Weaknesses
1. A unique location, with beaches of natural beauty and a relatively-stable political environment as advantages.	1. Hyper-arid climate and water scarcity.
2. Fuerteventura is not a crowded destination (Santana and Hernandez 2011).	2. Soils show very low organic C concentrations, typical arid region with sparse vegetation and extremely-low biomass production, which represent a serious constraint to agricultural production (Tejedor et al., 2002).
3. Ecosystem services derived from traditional agro-landscapes, such as "gavias" (Díaz et al., 2011).	3. Scarce contribution of renewable energy sources to the total energy. 4. Vulnerability of its ecosystems to climate change (Lloret and González-Mancebo, 2011; Cropper and Hanna, 2014).
Opportunities	**Threats**
1. Great potential to increase the renewable energy contribution.	1. Degradation of landscape and high-quality natural vegetation (Rodríguez-Rodríguez et al., 2005).
2. Promotion of fodder production aimed at satisfying domestic demand.	2. Abandonment of traditional activities (Dorta-Santos et al., 2014)
3. Improvement of water management to maximise the water reuse.	3. Dependence on fodder importation. 4. Rising dependence on external, non-renewable energy resources. 5. Rising concern about key species conservation.

[a] SWOT: strengths, weaknesses, opportunities and threats.

of the interactions between indicators within a socio-ecological system. Nevertheless, these interactions cannot be addressed using traditional, static catalogues of indicators. The integration of sustainability indicators into a dynamic model system allows one to assess how any variation in one indicator may lead to a series of responses in other indicators (Liu et al., 2014; Zhang et al., 2015).

In this work, we address the environmental sustainability of an island Biosphere Reserve: Fuerteventura (The Canary Islands, Spain) as a "lab" to test a real Action Plan. For some objectives of environmental sustainability, collected in the Biosphere Reserve Action Plan (AP, 2013), we assess some measures set out in order to meet these objectives. We used a set of environmental indicators, also proposed by the Action Plan, which were integrated in the Fuerteventura Biosphere Reserve dynamic model (FSM) – calibrated for the 1996–2011 period (Banos-González et al., 2013, 2015) – to analyse how they would behave under different measures during the 2012–2025 period and to assess whether the objectives of the AP would be met.

Therefore, this work tries to answer the following questions:

(1) How do the indicators analysed react under a set of environmental measures?
(2) What is the degree of uncertainty in the expected model response under the measures analysed?
(3) Do these environmental measures meet the objectives of the Biosphere Reserve Action Plan?
(4) How can thresholds and trade-offs assist the decision process?

2. Methodological approach

2.1. Study area

The growth of tourism on the arid island of Fuerteventura (The Canary Islands), which has an average annual rainfall below 120 mm, has been later than on the other islands of the archipelago (Díaz et al., 2010). Nevertheless, tourism has already become the main driving force of the socio-economic and environmental changes on the island (Santana-Jiménez and Hernández, 2011).

Due to these recent changes and the vulnerability of its ecosystems, Fuerteventura is considered a relevant case for study, in order to drive the management and decision-making process towards more-sustainable development.

Regarding the environmental dimension, Table 1 summarises the main strengths, weaknesses, opportunities and threats identified in the Biosphere Reserve.

2.2. Threats, targets and indicators of environmental sustainability

In order to address these threats, a set of 10 environmental sustainability indicators of the Fuerteventura Biosphere Reserve Action Plan, addressing the key environmental targets of this Plan, were selected and included in the FSM.

Table 2 shows these targets, the threats which they are intended to address and the 10 indicators used for their assessment. These

Table 2
Threats, the objectives intended to address them and the indicators used in the assessment of these objectives.

Threat number according to Table 1	Objectives	Indicators
1	To maintain the landscape and the high-quality natural vegetation.	High-quality vegetation proportion Overgrazing indicator Landscape indicator
2	To restore abandoned traditional agricultural areas.	Proportion of active gavias Landscape indicator
3	To minimise the dependence on fodder importation.	Fodder importation needs proportion Landscape indicator
4	To reduce the dependence on external, non-renewable energy resources.	Primary energy use per capita Renewable energy proportion Per capita CO_2 emissions
5	To conserve key species.	High-quality vegetation proportion Houbara habitat proportion Egyptian vulture population proportion