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Spatial assessment of habitat conservation status in a Macaronesian island based on the InVEST model: a case study of Pico Island (Azores, Portugal)

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ABSTRACT

A methodological approach for the conservation status assessment of Azorean natural habitats in Pico Island (Portugal) is presented, using the InVEST Habitat Quality model. This spatial analysis-based study was focused on a selected group of 33 endemic plant species occurring in Pico Island and protected under the Habitats Directive's Listed Habitats for Macaronesia Region. The InVEST model combines information present in a Land Cover map with data on threats to habitats and habitats response, producing habitat quality and degradation maps as outputs, both represented in a score ranging from 0 to 1. Results showed that at higher altitudes habitats present better quality status, mostly due to the absence of the main threats such as Invasive Alien Species and Pasturelands. The study also showed that most areas with higher conservation quality are covered by the Pico Island Natural Park (a set of protected areas). Habitat patches showing higher degradation levels are located outside of the protected areas, supporting the increasing need for an integrated island-based conservation approach. This model valuation scheme might be used as an effective decision-support tool to prioritise areas for conservation actions and management in all nine Azorean Island Natural Parks, as well as in other small Macaronesian islands.

1. Introduction

The geographic, biophysical and socioeconomic specific characteristics of small oceanic islands make land, coastal and marine planning and management in these territories more challenging in scientific, technical and technological terms (Gil, 2016). Oceanic islands host a high proportion of endemic species, many of which are in danger as a consequence of recent human habitation (Whittaker and Fernández-Palacios, 2007). Planning and management systems of protected areas need to be adjusted to the specific context of small islands so that they can ensure maximum effectiveness in the spatial organisation and the fulfilment of inherent conservation and sustainable development objectives (Calado et al., 2014). In Macaronesian islands the main threat for nature conservation (and therefore sustainable development) is Land Use/Land Cover (LULC) change (e.g. Cardoso et al., 2013; Gil et al., 2018; Fernandes et al., 2014), mostly driven by urban development (e.g. García-Romero et al., 2016) and spread of Invasive Alien Species (IAS) (e.g. Costa et al., 2013; Gil et al., 2013; Lourenço et al., 2011). In such territories, the balance between socio-economic development and nature conservation can prove to be complex, generating relevant conflicts in local socio-ecological systems, especially those involving conservation areas (e.g. Baños-González et al., 2016; Bragagnolo et al., 2016; Calado et al., 2016; Fernandes et al., 2015, 2017). In this context, it is important to study the related LULC impacts, trying to identify possible threats to the sustainability of these territories to plan and manage them properly.

This study presents a valuation methodological approach that was centred on natural areas occupied by endemic species, which constitute a fundamental component of the island ecological structure, using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)

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Habitat Quality model approach (Kareiva et al., 2011; Tallis et al., 2016). InVEST model is a powerful tool that has been developed to improve the knowledge and to understand the behaviour of ecosystems functioning. The growing number of studies that apply InVEST to assess different natural systems demonstrates it (e.g. Guerry et al., 2012; Haines-Young et al., 2012; Duarte et al., 2016; Terrado et al., 2016). Nevertheless, to our knowledge we present a new InVEST Habitat Quality ecosystem study-case application: a small oceanic island, enhancing the versatility of this modelling tool, being an innovative approach on the Azorean Archipelago natural habitats conservation and management. Under this modelling scheme, habitat valuation scores are not a function of habitat importance or rarity, since all habitat types are treated equally. This generates a key set of information that is useful for making an initial assessment of conservation needs: the relative extent and degradation of different habitats. Therefore, IHQ can be used for prioritisation of areas within the scope of land planning and management (Kareiva et al., 2011).

Some relevant studies have already been carried out focusing other particular conservation strategies of endemic plant species in the Azores (e.g. Costa et al., 2013; Dias et al., 2005; Elias et al., 2016; Elias and Dias, 2009; Silva and Smith, 2004). However, we propose a conservation status valuation of 33 endemic plant species' natural habitats with confirmed presence in Pico Island through a spatial-based assessment, combining a LULC map with information on the spatially represented threats and its associated pressures over habitats. With InVEST model results on the habitats quality and degradation assessment, together with the specific methodological approach on Pico Island, the degree to which land use and management affects the subsistence of endemic vegetation was assessed in an island-system landscape level. In the same way, it was possible to establish a basic correlation with the protected area effectiveness and delimitation afterwards. Therefore, we aim to provide a potentially useful conservation tool within the scope of sustainable land planning and management for the Azorean Archipelago islands, regarding the uniqueness of the endemic values it sustains.

2. Material and methods

2.1. Study site

The Azores archipelago consists of nine volcanic islands located between 37–40°N and 25–31°W in the North Atlantic Ocean (Fig. 1), belonging to the European part of Macaronesia biogeographic region (Azores, Madeira and the Canary archipelagos). In 2007, the Protected Areas Network of the Azores archipelago was re-classified according to the International Union for Conservation of Nature (IUCN) Category System. Since then, each island of the Azores Archipelago has a single Island Natural Park – INP, which comprises several protected areas, each one corresponding to a category based mainly on its conservation objectives. In a general way, this was a process to improve the management of the protected areas and to promote the international recognition of conservationist, landscape and scientific values of the Azores (Calado et al., 2009). Regarding this, an overlay analysis between the model output maps and the INP map was performed. Given the scope of the assessment, there was no distinction between the different categories of protected areas existing within the Pico INP, which was therefore considered as a single protected area with 15 710 ha (Costa et al., 2013).

Pico Island, the second largest of the archipelago (see Fig. 1), was selected as study site since it shows vast natural spaces while presenting reduced agricultural occupation and low population density, without important urban centres. The good state of conservation of the island's natural environment seems to play a crucial role in Pico's attractiveness for tourism and for scientific research (Fonseca et al., 2014), where the most singular point of the island is the Mountain of Pico (the central volcanic formation that reaches 2351 m high). This island presents the highest plant diversity in the archipelago, mainly due to a higher number of altitudinal vegetation belts (Dias et al., 2005), where the existing protected areas are expected to contribute highly to its maintenance (Calado et al., 2009).

2.2. Azorean endemic plant species at Pico Island

The Azorean endemic plant species' data in Pico Island was obtained from ATLANTIS (Borges et al., 2010a), a regional database which gathers biodiversity-related information of the Azores Islands using a 500 m spatial grid, which draws on literature dating back to the 19th century, for approximately 5000 species. Considering occurrence data evaluation, each record is classified as secure or doubtful according to the reliability of the source and where the precision of the distribution is qualified according to the following evaluation scheme: 1) very precise locations, usually point UTM data; 2) localities not exceeding 25 km2; 3) imprecise localities; 4) island occurrence (generally old publications). For our study, we considered 33 endemic vascular plant species, regarded in classes of precision (1) and (2), from a total of 57 different species. We defined that only species occurring at Habitats Directive (HD) listed habitats in the Azorean islands, according to the report of Dias (2008), would be considered. This way, we gathered information on species' important habitats through a consistent methodology (See Table 2 – Correspondence between LULC classes defined as habitat and Habitats Directive listed habitats, and Table 3 - Assessment of relative impact of each threat class and correspondent spatial impact). Afterwards, each species was studied regarding its protection and legal conservation status, according to the European Habitats Directive, Bern Convention and IUCN Red List assessments, in order to allow further conservation assessment integrated with the model 'Habitat quality level' at results section. Both analyses are presented in Table 1.

2.3. The InVEST habitat quality model

The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) is a free and open-source software, which contains spatially explicit ecosystem services modelling systems designed to quantify, map, and value trade-offs between multiple services from nature that contribute to sustain and fulfil human life (Kareiva et al., 2011). The InVEST Habitat Quality model (IHQ) (version 3.3.3., with model theory and equations description freely available at http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/habitat_quality.html) processing is based on Land Use/Land Cover (LULC) data interpretation and re-classification, combining a LULC map with data on threats to habitats and habitats response, producing habitat quality and degradation maps as outputs. For this study, we choose IHQ since it can focus on different facets of biodiversity attributes and dynamics, including habitat vegetation-based representation which was our purpose. Thus, the required model inputs are the LULC map and the definition of the following two sets of combined information values: 1) the "Relative impact of each threat and correspondent impact across space" (correspondent, i.e., the maximum distance that a threat affect the quality of a habitat for the organisms groups) and 2) the "Relative sensitivity of each habitat to each threat". As a conservation approach we followed the same assumptions as the IHQ model (Tallis et al., 2016): 1) a positive relationship exists between habitat quality and biodiversity; 2) habitat quality is a proxy for quantity and quality of available resources; and 3) habitat quality decreases with the proximity of anthropogenic land use, but the intensity of this decrease varies according to the land use class (represented by the "Relative sensitivity of each habitat to each threat"). In general, the impact of a threat on habitat decreases as the distance from the degradation source increases, where grid cells that are closer to threats will experience higher impacts, so we defined it as a linear distance-decay function (Eq. (1)). Considering the LULC raster map of the study area, the impact (i_{rxy}) of a pixel (y) with a certain threat class (r) over a