Ecological Indicators 90 (2018) 226–230

Contents lists available at ScienceDirect

Ecological Indicators

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

Short Note

How good are the ecological assumptions and predictions made in the past? Insights from a dynamic modelling approach applied to changing landscapes

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ARTICLE INFO

Keywords:
Passerines
Landscape
Stochastic dynamic methodology
Ecological indicators
Ecological models' evaluation

ABSTRACT

Worldwide landscape changes and the uncertainty about its impacts on species abundances, distributions and on ecosystems structure and functioning, have been increasing the value of modelling tools in a very obvious way. Thirteen years ago, the first holistic stochastic dynamic methodology (StDM) application was published (Ecological Indicators 3(4), 285–303 by Santos and Cabral (2004)) intended for predicting ecological indicators trends in face of realistic scenarios of land use/land cover changes. The application of this StDM framework provided some basis to simulate landscape changes and predict the subsequent response of pertinent ecological indicators. Nevertheless, the results reliability could only be evaluated with subsequent independent information checking. In this work, based on independent data obtained thirteen years after, we compare the simulated land use changes and predicted responses of the selected ecological indicators with the respective real trends. The comparisons made confirmed that the implemented scenario was realistic and the ecological indicators' response mostly accurate. This allowed for demonstrating the proposed frameworks potential and its use in landscape planning and managing of agro-environmental measures. Our approach also provides a promising and intuitive baseline to support risk assessments for land use changes, derived from ecological models linked with ecological monitoring, crucial to guide decision makers and environmental managers.

1. Introduction

In lieu of technical and political decision, modelling tools can be very useful to predict the outcome of alternative scenarios, guiding current management options from expected future targets and simulating conditions that are difficult or impossible to understand otherwise (e.g., Schmolke et al., 2010; Santos et al., 2013). Ecological models contain the essential characteristics for solving problems and enhanced ecological studies by creating quantitative simulations and predictions that simultaneously attempt to capture the structure and composition of ecosystems (Jørgensen, 2008). Following the rapid development of computing technology, detailed ecological simulations have become more available. Albeit ecological models have been used in a wide variety of applications related to ecosystem functioning (e.g., Evans et al., 2013) they are usually considered "academic" and in many ways unreliable, i.e., unable to describe, in a comprehensible and "realistic" way, the structural changes when ecosystem conditions are substantially altered (Rykiel, 1996). Consequently, the evaluation of the assumptions and parameters of a model, but mostly the evaluation of the predicted results is critical for assuring modelling credibility and "real world" applicability (Schmolke et al., 2010).

Dynamic and spatially explicit dynamic models designed to predict future landscape patterns and trends could support decision-making for integrated assessments of socio-ecological impacts on biodiversity, namely the influence of internal processes under scenarios induced by external drivers (Santos et al., 2013). These type of models are increasingly considered essential to strategic spatial prioritisation and planning in highly dynamic socio-ecological systems such as agricultural landscapes (e.g., Lomba et al., 2015; Santos et al., 2016b). Southern European countries hold areas of complex agricultural landscapes that are considered significant hotspots of biodiversity (Bugalho et al., 2011; Lomba et al., 2015). Nevertheless, current multifactorial changes occurring in these landscapes, induced either by agricultural intensification or abandonment (e.g., Van Eetvelde and Antrop, 2004), result in large-scale modifications on habitat composition and fragmentation. These changes may imply serious risks for the biodiversity, ecosystem integrity and services of actual socio-ecological systems (e.g., Santos et al., 2016b). The combined influence of land use/land cover changes (LUCC) on passerine richness functional guilds (FG) at the "Terra Quente Transmonta" agricultural landscape (Northern Portugal),

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https://doi.org/10.1016/j.ecolind.2018.03.023
Received 13 September 2017; Received in revised form 15 February 2018; Accepted 9 March 2018
1470-160X/

considered key ecological indicators of biodiversity and integrity, was assessed by Santos and Cabral (2004). That work proposed a novel spatio-temporal modelling methodology, the stochastic dynamic methodology (StDM), in order to predict relevant ecological trends in changing landscapes. The StDM is a hybrid modelling protocol combining statistical and dynamic modelling with geostatistical techniques to address complex spatially-explicit emergent problems, from the individual habitat patch to the whole landscape context (e.g., Santos et al., 2013, 2016a). While the parameters of the dynamic model within StDM can be calibrated directly from field knowledge of ecosystem characteristics and bibliographic information (ecologically driven) others, namely the holistic parameters, have to be estimated using statistical algorithms. The statistical parameters, if sustained by a database that includes representative gradients, emerge from spatio-temporal ecosystem properties, might be used for simulation and prediction. This methodology minimizes drawbacks linked with model construction, such as parameterization and complexity, since part of the variables and parameters result from statistical estimation (Santos et al., 2013, 2016a). Explicitly, the response variables emerging from the statistical analysis correspond to the core state variables under study while the explanatory variables are the pertinent environmental factors (ecological-driven). The StDM framework has been successfully tested in several types of ecosystems affected by gradients of change, namely in agroecosystems (Santos et al., 2013, 2016a).

Santos and Cabral (2004) also stated that the evaluation of the overall methodology and results, namely the simulated trends in Land use/Land cover (LULC) and the ecological indicators responses could only be achieved using chronosequential data. In order to evaluate the StDM credibility in simulating landscape changes and the consequent ecological responses, as published thirteen years ago, the objectives of the present demonstration were to: (1) compare the predicted and current real landscapes, as well as the respective composition of passerines' functional guilds (FG); (2) discuss concepts of the stochastic dynamic methodology and possibilities for depicting the consequences of alternative landscape scenarios on ecological integrity; and (3) explain the interest and feasibility of using the StDM framework in guiding rural landscape management challenges and policy options.

2. Material and methods

2.1. Study area and simulated scenario

Field work associated to the model simulations performance evaluation was carried out in the study area described by Santos and Cabral (2004): "Terra Quente Transmontana" (Mesomediterranean thermoclimatic belt and Carpetano-Leonese biogeographic region – http://www.globalbioclimatics.org/form/maps.htm) region (41°30′N, 7°10′W), located in north-eastern Portugal (Appendix A). A typical mixture of olive and almond orchards, cereal fields and fallow land, cistus sp. and cytisus sp. shrublands, cork oak woodlands dominated the landscape (Appendix A). The main LUCC predicted were the decrease in areas of cereal and fallow and the increase of areas occupied by olive and almond orchards (Santos and Cabral, 2004). Additionally, the landscape simulated trends predicted a change in the passerine functional guilds' richness, namely arboreal guilds' richness was expected to increase while the pseudo-steppe guilds' richness was expected to decrease. The model conceptualization and the characterization details of the study area are available in Appendixes E–G.

2.2. Passerine point-counts and land use/land cover monitoring

Twenty-two 25 ha (500 m × 500 m) plots were surveyed once during May and June of 2017, for monitoring passerines and fitting together passerine functional guilds (FG) – bird species were identified using 10 min unlimited-radius point count until 5 h after sunrise under appropriate weather conditions; bird species were convened in guilds in accordance with preferential diets and habitats using reference information. Each plot was monitored for assessing LULC in 2001/2002 and 2017, considering information provided by the Corine Land Cover (CLC) (http://land.copernicus.eu/pan-european/corine-land-cover), Google Earth sequential images (https://www.google.com/intl/pt-PT/earth/) and confirmed in 2017 by specific field works oriented towards this purpose. LULC were classified as olive and almond orchards (Ola), shrublands (Shr), cereals and fallow (Cfa), pastures (Pas), fallow land (FAL), vegetable gardens (Veg), vineyards (Vin), fruit orchards (Fru), cork-oak woodlands (Cor), riverine woods (Riv), other woods (Oth) and urbanised areas (Urb) (Appendix B).

2.3. Simulating land use/land cover trends and predicting functional guilds' richness for 2017

Using as starting point the original estimated LULC values for each plot in 2001 and considering the landscape trends simulated by Santos and Cabral (2004), i.e., an increase in olive and almond orchards (Ola) at the expense of cereals and fallows (Cfa) (Appendixes E–G), dynamic projections of LULC for 2017 were obtained (Model_LULC). Alongside the model simulations for the FG richness responses were also considered for 2017 (Model_FG) (see also Appendixes E–G).

2.4. StDM framework performance

The real data of LULC and FG richness recorded in 2017 (Real_LULC and Real_FG, respectively) were used for assessing the StDM simulations performance (Section 2.2). For this, statistical differences between each variable simulated (Model_LULC and Model_FG) and the respective real data (Real_LULC and Real_FG) were compared by using the Wilcoxon signed rank test (Wilcoxon, 1945). Results were considered accurate if the simulated and real data were not statistically different from each other. Complementary to the previous "variable specific" performance assessment, overall simulations were evaluated using Model II regression analyses (Standardized Major Axis regression-SMA using the software SMATR 3.0; Warton et al., 2012). The Model II regression 95% confidence limits for intercept and slope were determined for each analysis to assess the averaged Model_LULC/Model_FG proximity in relation to the respective averaged Real_LULC/Real_FG (Sokal and Rohlf, 1995). The StDM simulations and predictions were considered accurate when (1) a statistically significant correlation occurred between both sets of data; (2) the intercept of the common regression line was not statistically significantly different from 0; and (3) the common regression slope line was not statistically significantly different from 1 (Sokal and Rohlf, 1995; Warton et al., 2012).

3. Results

3.1. General results: land use/land cover and passerine guilds monitored in 2017

The dominant LULC monitored in 2017 (Real_LULC) were olive and almond orchards (Ola), cereals and fallows (Cfa) and Shrublands (Shr) (Appendixes A and B). We recorded 31 passerine species, distributed in 11 arboreal insectivorous, 7 arboreal granivorous, 7 pseudo steppe insectivorous and 6 pseudo steppe granivorous (Appendixes B and C).

3.2. StDM simulations and predictions

The decline of cereal and fallow (Cfa) areas, through a conversion to olive and almond orchards (Ola) was originally assumed as the main trend in the modelled landscape (Model_LULC) (Appendixes E–G). This scenario predicted changes in the functional guilds richness (Model_FG): arboreal guilds were expected to increase while pseudo-steppe guilds were expected to decrease in most plots. Independent data were obtained for 2017 concerning the landscape characterization (Real_LULC) and the passerine community functional composition