The BIOSCORE 2 project: Developing a Model to Compare Biodiversity Effects of European Nature Policy Scenarios

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Abstract—The concept, model framework and first results of BIOSCORE 2 are described. The model allows making projections of future nature quality and biodiversity situations in Europe, based on empirical relations between species occurrence and environmental pressure factors like land use change, intensification, air pollution, water use, fragmentation, climate change and nature management.

Keywords—Modelling, Spatial Statistics, R, ArcGIS, Databases, Environmental Pressures, Climate Change, Land Use, Nature Policy, Scenario, Biodiversity, Generalised Boosted Model (GBM), General Linear Model (GLM)

I. INTRODUCTION

The European Union has subscribed to the Convention on Biological Diversity (CBD) treaty, which aims to halt biodiversity loss. A main EU-policy to achieve this is the implementation of the Birds and Habitats Directives. An earlier target to achieve the target of halting loss by 2010 was not met, and now a new target is set for 2020 and a vision for 2050. The question is, are the current policy instruments likely to be successful? If not, what policy alternatives could be considered? And how could one assess the potentials of such alternatives? These questions will gain rising political interest in the near future, when the European Union will publish its Natura 2000 Fitness Check, the mid-term evaluation of EU’s main nature policy instrument. The recent EEA State of Nature Report (European Commission, 2015) shows that large proportions of both the nature 2000 areas (60%) and of the species (77%) still have unfavorable status, and progress to favorable status is slow.

In order to answer questions like these on the European scale, a model is needed that gives insights in the effects of diverse policy measures on biodiversity. Such models are scarce and available models often focus on individual environmental pressures like climate change or land use changes. The BIOSCORE 2 model that has been recently developed aims to provide insights in the effects of changes in a number of important pressures. The pressures themselves are not calculated in BIOSCORE, but need to be derived from other available models such as IMAGE and CLUE. These pressures are climate change, land use change, air pollution by nitrogen and sulphur deposition, intensification of agricultural use, water use, habitat fragmentation, forest and nature management, disturbance by roads and urbanization. These factors have been selected based on a review of both scientific papers and policy documents.

II. CONCEPT OF THE BIOSCORE 2 MODEL

A. Basic principles

BIOSCORE can be considered to be a habitat suitability model. Its basic concept is that the occurrences of plant and animal species will be influenced if important environmental factors influence their habitat quality. Various pressures may affect this habitat quality positively or negatively. Local sub-optimal habitat quality for a species will lead to a lower Chance of Occurrence (COO) of the species on that location. For each species, the optimal values of environmental factors and tolerance to individual pressures will be different. So a change in one pressure will affect COO’s of species in different ways.

To derive species specific dose-response functions BIOSCORE 2 uses a combination of spatial regression modeling techniques. We make use of both Maxent and Boosted Regression Trees (BRT) in a suite of R-scripts called TRIMMAPS (Hallman et al, 2014). Both are machine-learning techniques, able to handle non-linear relationships and account for synergistic effects of different factors. Maxent is widely used in ecological studies, including effects of climate change. BRT is used less widely, but is better equipped to use presence-absence data. Both methods use species distribution maps and maps of environmental factors as input.

Since the dose-response functions will vary across species, we looked at a large number of species from different groups. In the current version of BIOSCORE, dose-response functions are included from birds (250), mammals (100), plants (850) and butterflies (100). All species that have been selected are relevant with respect to European policies. The selected species are protected under the Bird or Habitat directives, typical species of protected Habitats and/or Red List species.

III. THREE-STEP APPROACH OF THE BIOSCORE 2 MODEL

Figure 1 shows a schematic of the model steps in BIOSCORE 2 and how these fit in the well-known DPSIR chain. It...
calculates effects of pressures (e.g., acidification) on states (abundance and numbers of species) and their impact on biodiversity targets. The effects of pressures are calculated by means of dose-response functions for about 1300 selected species. This process is subdivided in three subsequent steps.

First, in a multivariate analysis, the responses of each species to a set of climate and soil factors are calculated. These factors include average temperature, temperature sum in growing season, precipitation, annual moisture index, evapo-transpiration, isothermality and soil type (clay-sand-peat). The climate maps were taken from the BIOCLIM website, and were produced by the CSIRO Mk3 model and IPCC IV A1/B scenarios (Kriticos et al, 2012) for the year 2050. Maps of these factors were combined with recorded occurrences of each species in a GBM (Generalized Boosted Model) analysis.

Step 1 produces not only dose-response functions, but in combination with climate maps also maps of the potential distribution per species, for a future year. By using climate data from 2010 and 2050 we could compare the predicted species distribution maps against available distribution maps and maps in available climate atlases.

In step 2, we determined the preferences of each species for a set of (CORINE) land use classes by comparing species distribution maps and land use maps. Again, when the derived dose response functions are applied on land use maps we could map available habitats within the predicted species distribution range. As to be expected, specialized species were limited more severely than cosmopolitan species.

In step 3 the effects of environmental pressures on the available habitats are calculated. This is done for the levels of atmospheric deposition of nitrogen and sulphur, water use intensity, agricultural land use intensity or total nitrogen input, occurrence of roads and infrastructure, and habitat fragmentation. As input for these calculations, a series of pressure maps were used (see next section). Again, by combining the derived dose-response functions with available environmental maps we can calculate COO’s per species.

For a number of relevant pressure factors, maps were selected (see fig 2).

**Figure 1 Conceptual scheme of BIOSCORE 2**

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**Figure 2 Maps of environmental pressures that were used to derive dose-effects curves for each species.**

In order to evaluate the effects of these pressures on species occurrences, an approach was chosen that is different from the one with the climate factors. We have a strong interest in evaluating and testing the individual effects of each pressure factor. It is relevant to compare policy options for Europe that address reductions of individual pressures, and be able to understand and explain the effects of such policy options in details. Therefore, we derived the response curves of each species to each pressure with a different spatial statistics method: GLM (Generalized Linear Modeling).
IV. MODEL FRAMEWORK AND DATA

The BIOSCORE 2 model is implemented in a cross-platform concept. Spatial statistics are being calculated with TRIMMAPS, a combination of standard R-packages and dedicated R-scripts. Current and future distributions of land use (based on CORINE), species and pressures are calculated and maintained in ArcGIS. For scenario management, data preparation, processing of results and indicator production a SQL-server database with a MsAccess front-end is used.

The amount of data that is handled is rather large. Modelling the whole of the European terrestrial area in 5*5 km grid cells with underlying information of land use in 1*1 km grids, requires 250,000 units of calculation, for each of 1300 species. Data storage needed for one run is about 12 GB. Parallel processing on several machines is possible as the model calculates no changes in interactions between the selected species (these are assumed to be constant).

V. APPLICATION IN EUROPEAN NATURE OUTLOOK

The BIOSCORE 2 model will first be applied in the context of a European Nature Outlook. In this project, four different scenarios are being developed for the future of nature and biodiversity in the EU in 2050. These scenarios will be based on different perspectives on nature. These perspectives represent different sets of values, goals and measures regarding to nature and biodiversity. In addition the Outlook will examine the effects of a reference scenario for 2050.

In the various European scenario studies major changes in climate, land use and land use intensity have been expected to occur towards 2050.

The climate data in our reference scenario are based on BioCLIM 2050. As in most scenarios land temperature in Europe is projected to increase. The largest temperature increases during the 21st century are projected over eastern and northern Europe in winter and over southern Europe in summer. Heat waves are projected to become more frequent and last longer across Europe over the 21st century. As in most climate model projections continued precipitation increases are presumed in northern Europe (most notably during winter) and decreases in southern Europe (most notably during summer).

The land-use and land intensity changes in our reference scenario are based on the recent Volante “Best land use in Europe” scenario (Volante, 2012), in which the trends between 2010 and 2040 have been extended towards 2050. In most studies, agricultural area in the EU is projected to decrease slightly or remain at the same level, while production increases. Underlying drivers are the growth in population and GDP next to changes in trade (including trade policies), climate and agricultural and biofuel policies that finally define the production and agricultural area needed. The reference land-use scenario used in this study shows a decrease of 3.5% in cropland, a 5.0% decrease in pasture and an increase in agricultural intensity. Based on an inventory of recent scenario studies, Tucker et al. (2014) expect that such past trends of polarization in land use (i.e. intensification on one hand and abandonment at other locations) are likely to continue. The losses of agricultural land are consequences of urban expansion and abandonment of (marginal) agricultural lands (i.e. mosaic landscapes).

As in all recent scenario studies, the reference scenario assumes also a future increase of built-up area in Europe. The built-up area in the used reference scenario increased with 15% relative to the situation in 2010. Growth is found in major cities, both in Western Europe (e.g. London, Dutch Randstad and Berlin) and in Eastern Europe (e.g. Budapest, Prague, cities in Poland). In addition the scenario assumes further urban sprawl, because there are currently no policies to restrict this process.

Scenario studies often assume a further increase of forest area in the EU, either based on an extrapolation of past trends (UNECE/FAO 2011), or derived from land use projections. In the chosen Volante scenario, the area of forests increases by 6.5% between 2010 and 2050. As in other scenarios, this increase is a result of the change in agricultural land and not a result of active (re)planting of forests due to, for example, a growing demand for wood or biomass. Abandoned agricultural land is assumed to undergo a succession into forests. The increase in urbanization and the land abandonment causes a decline in the area of semi-natural vegetation, although it is assumed in the reference scenario that protected Natura 2000 sites are maintained and protected from land conversions.

The above mapped changes in land use have been translated in GIS to other BIOSCORE input maps such as habitat fragmentation and proximity to urban area. The input maps of proximity to roads have not been altered. Input on the levels of atmospheric deposition of sulfur and nitrogen have been based on the Current Legislation scenarios of IIASA. In this scenario all current legislation is included, such as best practices for industry, fuel and emission standards in transport and national legislation including elements of EU law, i.e. the Nitrate and Water Framework Directives. It is assumed that all of these regulations will be fully complied within all Member States according to the foreseen time schedule. Progressing implementation of air quality legislation together with the structural changes in the energy system will lead to a decline of SO2 emissions and depositions in the EU towards 2030, followed by stabilization afterwards since no further reduction policies are assumed. According to the scenario the total SO2 emissions will in 2030 be almost 70% below the 2005 level. Also for NOx emissions, implementation of current legislation will lead to a reduction of about 60%. With respect to NH3 only slight changes in total emissions in the EU-28 are expected up to 2050, although NH3 emissions are also subject to targeted controls in the agricultural sector and will be affected as a side impact of emission legislation for road transport.

VI. PRELIMINARY MODEL RESULTS

The calculations of the effects of all changes in 2050 as mentioned above are in progress at the moment that this paper is being written. Until now BIOSCORE 2 has produced potential distribution maps for about 1300 species in Europe, based on 5*5 km grids and underlying 1*1 km. These maps of chances of occurrence were post-processed to indicators like average gain/loss of change of occurrence. These indicators
can be analyzed on a variety of geographic details, e.g. region, nature type, species group, Natura 2000 area, etc. The presented results in table 1 focus on the terrestrial area of EU28.

Table 1 shows the preliminary results of the combined effects of the changes in various environmental factors in 2010 and 2050 for some important indicators. Results show that the computed average species occurrence decreases to a level of about 80% of the situation in 2010. Although found in species of all groups, the average change in occurrence varies largely among species groups. The largest decrease is found in plant species, whereas butterflies on average increase. Further analysis may clarify whether this is due to rise of temperature. Although the average change in occurrence indicates an overall decrease in 2050, a large number of species actually show increasing or stable occurrences.

Based on analyses of changes in habitat types losses are relatively large in semi-natural grasslands and for example dune habitats, whereas species of various forest habitats increase (data not shown). The changes also vary across the various biogeographical regions of Europe. Especially in the Boreal and Alpine regions a relative large number of non-native, but protected species increases.

Table 1. Preliminary results of BIOSCORE 2: comparing the current situation with a reference scenario for 2050 (Business-as-usual).

<table>
<thead>
<tr>
<th>Nature Type</th>
<th>Average occurrence relative to base year</th>
<th>Percentage of species with a decrease</th>
<th>Percentage of species with a large decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>0,71</td>
<td>75%</td>
<td>62%</td>
</tr>
<tr>
<td>Birds</td>
<td>0,96</td>
<td>48%</td>
<td>40%</td>
</tr>
<tr>
<td>Butterflies</td>
<td>1,08</td>
<td>31%</td>
<td>19%</td>
</tr>
<tr>
<td>Mammals</td>
<td>0,94</td>
<td>61%</td>
<td>47%</td>
</tr>
<tr>
<td>Total</td>
<td>0,79</td>
<td>65%</td>
<td>53%</td>
</tr>
</tbody>
</table>

VII. CONCLUSIONS AND DISCUSSION

Preliminary results of BIOSCORE show that a future change in the occurrence of protected species is on average negative. This finding is inline with the conclusions from the recent European State of the Environment which state that “underlying drivers of biodiversity loss are not changing favorably” (European Commission, 2015). In the business-as-usual scenario for 2050 of the last Global Biodiversity Outlook, Europe’s terrestrial biodiversity measured as mean species abundance (MSA) was also projected to decline (CBD, 2014). In that study the MSA that potential natural vegetation could support in 2050 relative to 2010, was expected to drop 24%, a value close to what is now calculated with BIOSCORE.

In accordance with the conclusion by the State of the Environment, results of BIOSCORE indicate that it will be very challenging for Europe to meet the overall target of halting the loss of biodiversity by 2020. The positive trends in a large number of protected species as computed with BIOSCORE, on the other hand, is promising and might be a result of nature conservation in Natura 2000, lowering of the atmospheric deposition levels or the increase in forest area in reference scenario. However, increases in occurrences of these species might also be caused by to climate change.

The preliminary results of BIOSCORE need to be further tested and analyzed to unravel the effects of the changes in the various environmental factors. As many of the direct, and all of the indirect influences on biodiversity loss, arise from a range of sectors and policies, such analyses might reveal possibilities for economic sectors as well as regional policies to reduce the pressures on Europe’s biodiversity. As such the BIOSCORE 2 model seems to provide policy relevant insight in policy-relevant effects of changes in various environmental conditions. However, at the same time model improvement must go on and for example more species groups need to be incorporated.

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