Project Number 282910

ÉCLAIRE

Effects of Climate Change on Air Pollution Impacts and Response Strategies for European Ecosystems

Seventh Framework Programme

Theme: Environment

D15.4 Assessments of the effects of combined air pollution and climate change scenarios on plant species diversity and soil quality

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Dissemination Level		
PU	Public	☐
PP	Restricted to other programme participants (including the Commission Services)	x
RE	Restricted to a group specified by the consortium (including the Commission Services)	☐
CO	Confidential, only for members of the consortium (including the Commission Services)	☐

Executive Summary

This deliverable describes the assessment of the probability of plant species occurrence on a European scale in response to changes in atmospheric nitrogen and sulphur deposition and climate change using the developed combined VSD+-PROPS with European-wide data bases on soils, vegetation and climate.

The PROPS model was further developed to derive occurrence probability functions for vascular plants as a function of abiotic conditions (pH, soil C/N ratio, N deposition, yearly precipitation and yearly average temperature), using an existing database. A set of plant species was assigned to each habitat type based on species lists defined in the Bioscore project, providing typical (desired) species for about 30, mostly vulnerable, habitats, to allow a European assessment with VSD+PROPS.

The PROPS model was applied to assess changes in the occurrence probability of all distinguished plant species at a European scale in response to the ECLAIRE scenario on changes in atmospheric nitrogen (and sulphur) deposition and climate (precipitation and temperature), and simulated soil pH and C/N ratio (computed by the VSD+ soil model in response to those changes). These results were in turn aggregated to a Habitat Suitability index that summarizes plant occurrence probabilities to one diversity measure.

Results showed that the substantial reduction in N deposition that is achieved in the ECLAIRE scenarios results in significant recovery from acidification in western and central Europe, illustrated by an increase in soil pH. Results from the PROPS model indicate that in these areas also the average normalized occurrence probability of desired plant species increases in response to decreased N deposition and increased pH. The impacts of climate change were less significant.

1. Objectives:

The objective of this deliverable is to describe the assessment of changes in the probability of plant species occurrence and habitat suitability index at a European-wide scale in response to changes in atmospheric nitrogen and sulphur deposition and in climate variables (temperature and precipitation) using the further developed VSD+-PROPS model.

2. Activities:

Further PROPS model development

The PROPS model (described briefly in deliverable 15.1) was further developed to derive occurrence probability functions for vascular plants as a function of abiotic conditions (pH, soil C/N ratio, N deposition, yearly precipitation and yearly average temperature), using an existing database (Bioscore; Van Hinsberg et al.). Based on about 800000 relevés (Figure 1), soil pH and soil C/N ratio were estimated for the sites based on relationships between plant species and pH and C/N ratio from a data set consisting of several thousands of relevés with recorded plant species and measured abiotic conditions (Table 1).

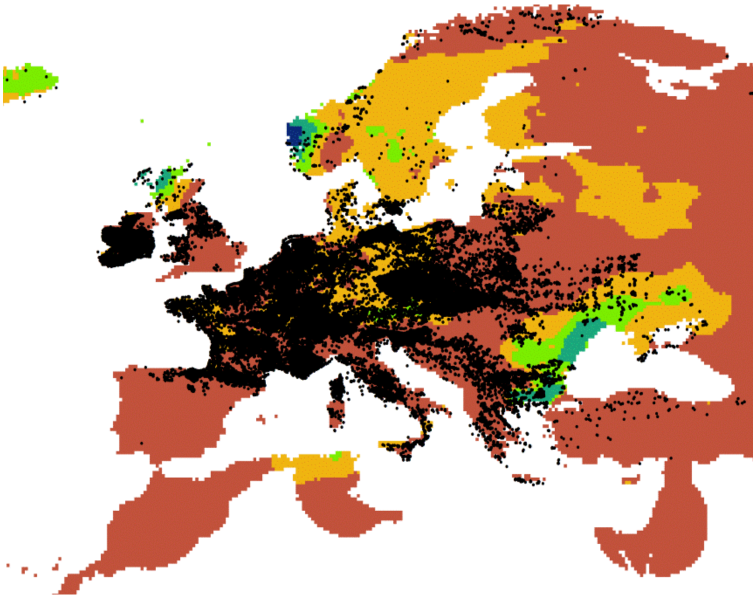

Figure 1: Bioscore plots (black dots) used to derive response functions for vascular plants

Table 1 Number of sites with species composition and measured soil parameters.

Dataset	pH	C/N	Ntot	pH+C/N	pH+Ntot
Netherlands	6781	2421	2943	2355	2815
Austria	630	630	630	630	630
Ireland	411	430	430	411	411
Denmark	760	503	141	503	32
United Kingdom	586	240	240	240	240
ICP-Forest	529	518	528	518	528
Other	189	102	112	102	112
Total	9886	4844	5024	4759	4768

This first dataset with measured soil parameters was split up in a calibration part (90% of the dataset) and a validation part (10% of the dataset, each 10th relevé). For each species in the calibration part of the dataset we fitted one-dimensional probability curves, in response to pH, total soil N content (Ntot), C/N and NO_3. We were able to fit probability curves for 949 species for pH, 736 species for Ntot, 819 species for C/N and 301 species for NO_3.

The response curves, that could be regarded as an alternative for species indicator values (e.g. Ellenberg et al., 1991), were used to calculate soil parameters for the BioScore dataset. For the calculation of the soil parameters we assumed that the most probable value for the soil parameter was that value where all species in the relevé concerned are present. To find that value, we determined the value of the soil parameter where the product of the probabilities of all occurring plant species in the relevé concerned, was highest. At least five plant species with a probability curve had to be present. Tree species and species with more than one optimum were excluded. This procedure was applied to assess soil parameters, which in turn were compared with measurements at these sites.

Linkage of the VSD+-PROPS model with European-wide data bases
The VSD+PROPS model has been linked to newly created European data bases on soil, vegetation, climate and habitat types, including a data base with species per habitat type being linked to a European habitat map based on habitat suitability functions from the Bioscore project. The model is now fully operational for European applications. Details of the linkage were described in detail in deliverable 15.3. For each habitat, the Habitat Suitability Index being the average normalized species occurrence probability for all desired species was computed:

$$HSI = \frac{1}{n}\sum_{k=1}^{n} \frac{p_k}{p_{k,max}}$$

Where *n* is the total numbers of positive (wanted) species, *pk* is the probabilities of occurrence probability of positive (wanted) species *k* and *pmax,k* the maximum probability of occurrence of that species (Rowe et al., 2009). This index has been agreed upon at the 2014 CCE Workshop. The higher the HSI (0-1), the higher the probability that all desired plants can occur at the site.

Application of VSD+-PROPS model at a European-wide scale
For a European assessment using VSD+PROPS, a set of plant species was assigned to each habitat type based on species lists defined in the Bioscore project: these lists provide typical (desired) species for about 30, mostly vulnerable, habitats. The PROPS model was applied to assess changes in the occurrence probability of all distinguished plant species in response to the ECLAIRE scenario on changes in atmospheric nitrogen (and sulphur) deposition and climate (precipitation and temperature), and the resulting calculated changes in pH and soil C/N ratio (calculated with VSDS+). These results were in turn aggregated to a Habitat Suitability index that summarizes plant occurrence probabilities to one diversity measure.

3. Results

Results of the validation indicate that reasonable estimates of pH and C/N ratio can be obtained, although at part of the sites a substantial deviation between the measured and estimated (optimal) values occurs (Figure 2). Results for Ntot and especially for NO_3 were not so good with r^2 values < 0.3, so we used pH and C/N as explaining soil variables in the PROPS model.

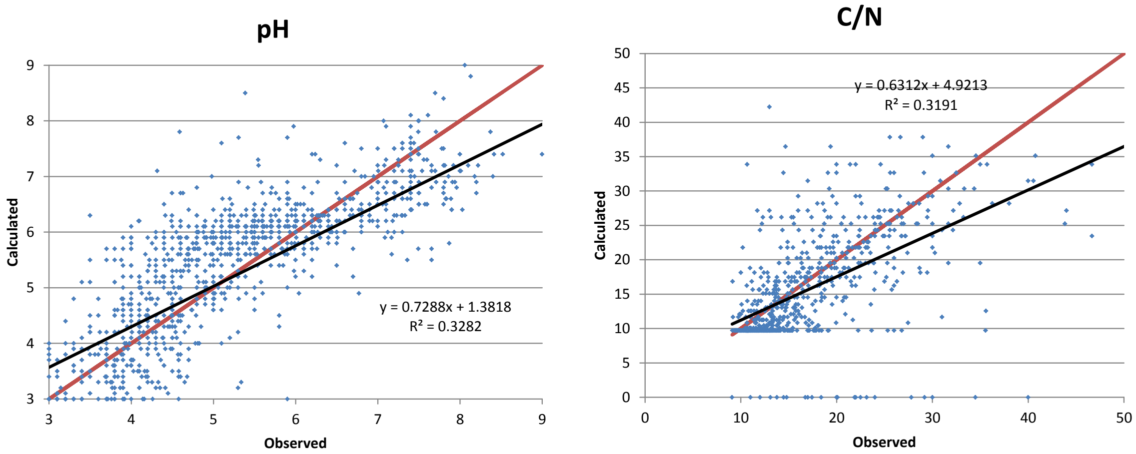

Figure 2 Validation of calculated pH and C/N; red line indicates the 1:1 line, the black line the regression between estimated and observed values.

Climate data (temperature and precipitation) were derived from the ECLAIRE climate data sets using the 1970-2000 long term average yearly values. Response curves were derived for about 5500 European species using advanced statistical procedures. An example of observed data and fitted response is provided in Figure 3 for *Calluna vulgaris* and *Erica tetralix*.

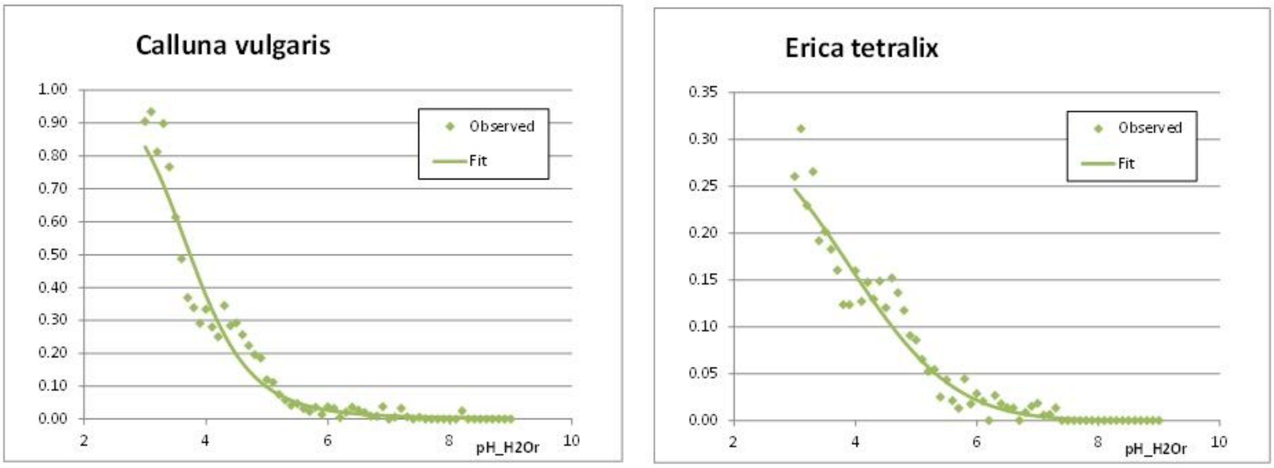

Figure 3. Observed and fitted response of two species to soil pH

Results of the application of VSD+-PROPS model at a European-wide scale

The ECLAIRE scenario leads to a substantial reduction in N deposition in 2050 (Figure 4). Only in areas with intensive husbandry (Netherlands, parts of Germany, Brittany and the Po valley), relatively high N depositions can still be found in 2050.

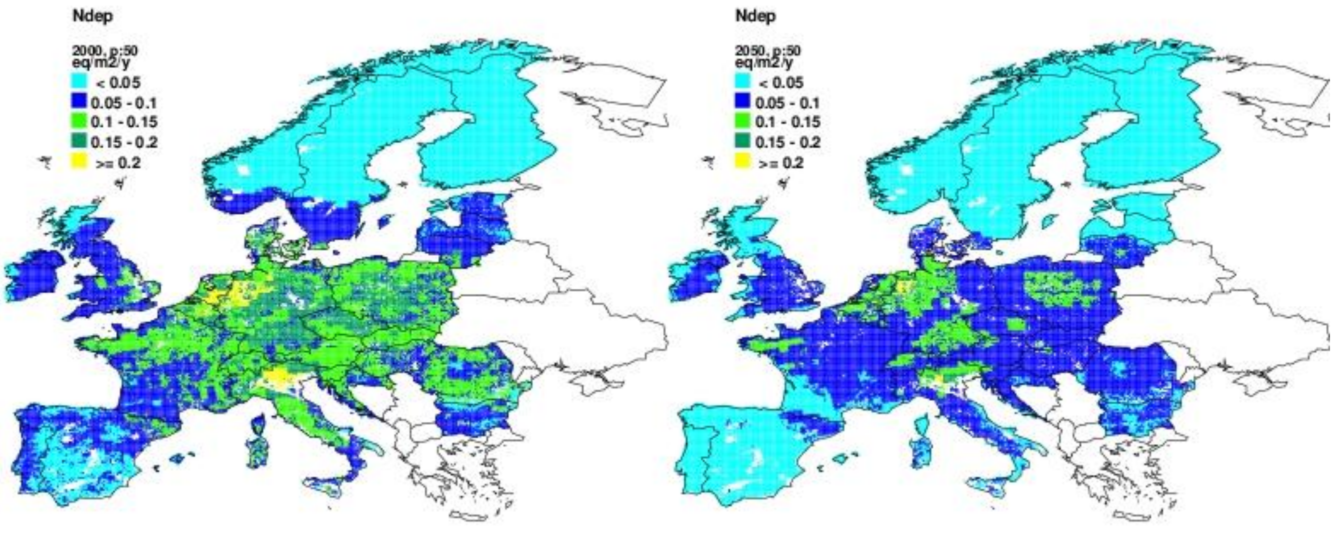

Figure 4. Median N deposition per grid cell in 2000 (left) and 2050 (right)

Since also S deposition is reduced, acidified soil recovers from acidification. This is illustrated by the increase in pH (Figure 5) in areas that were previously acidified because of acid deposition (mainly central and western Europe and southern Scandinavia).

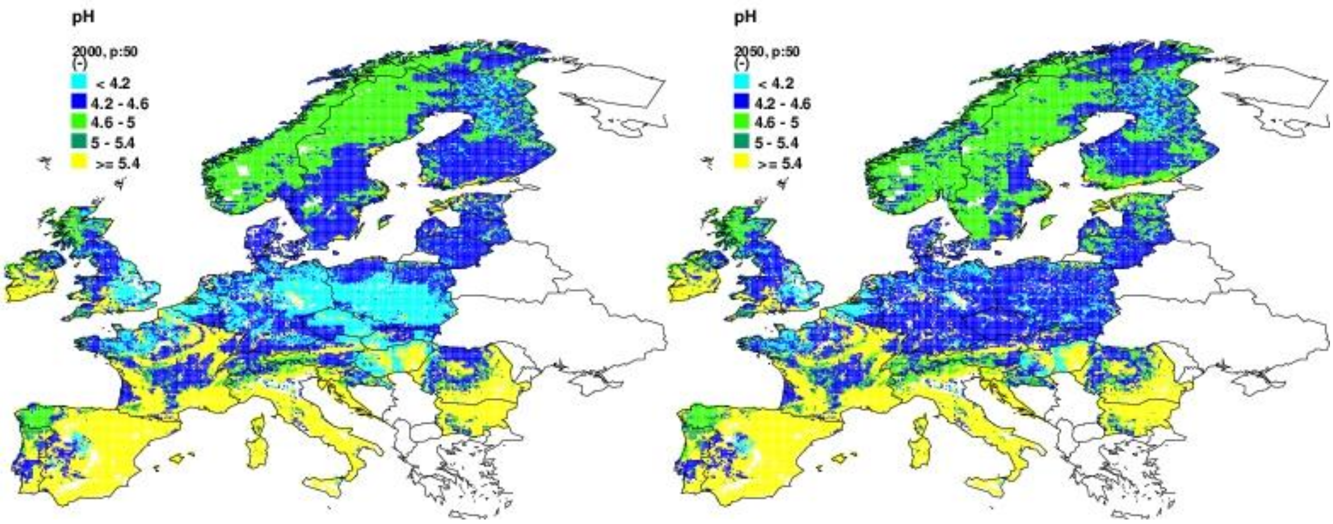

Figure 5. Median pH per grid cell in 2000 (left) and 2050 (right)

The change in soil C/N ratio is much less pronounced as the carbon pool in soils is normally huge compared to the (change in) N inputs, so changes are only gradual (Figure 6). In Europe, both an increase in C/N ratio can occur (in areas were N deposition is strongly reduced) as well as a decrease in areas with ongoing elevated N deposition.

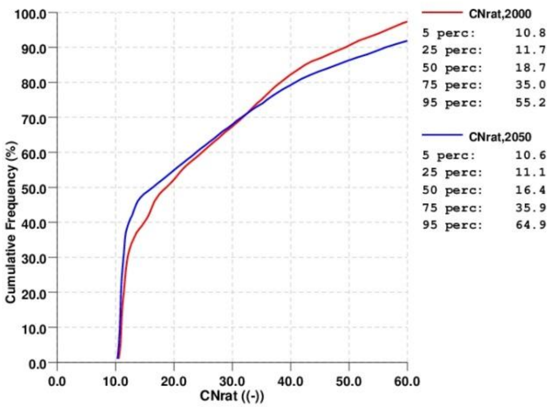

Figure 6. Cumulative frequency distribution of C/N ratio in 2000 and 2050.

Applying the PROPS model for Europe reveals that sensitive systems can react significantly to increased N richness. In dry heath, for example, the Habitat Suitability Index (HSI) decreases with an increased N richness, here expressed as a decrease in C/N ratio (Figure 7) and the HSI increases with lower N richness.

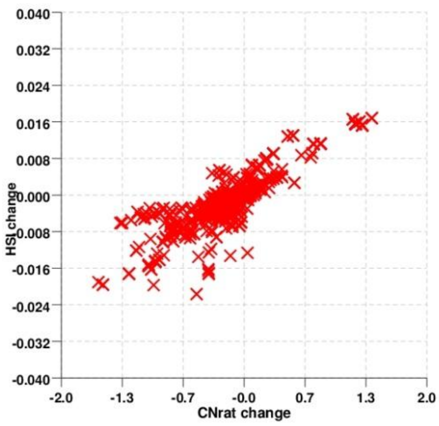

Figure 7. Change in HSI as a function of change in C/N ratio between 2000 and 2050

An overall increase in HSI is achieved under the ECLAIRE scenario in areas where a substantial recovery from acidification is achieved between 2050 and 2000 (Figure 8; compare Figure 5). The changes in temperature and precipitation had less impact on the change in HSI than the deposition changes and related pH increase. The results were subsequently used to compute climate dependent critical nitrogen thresholds, based on criteria for impacts on plant species diversity (see deliverable 16.4).

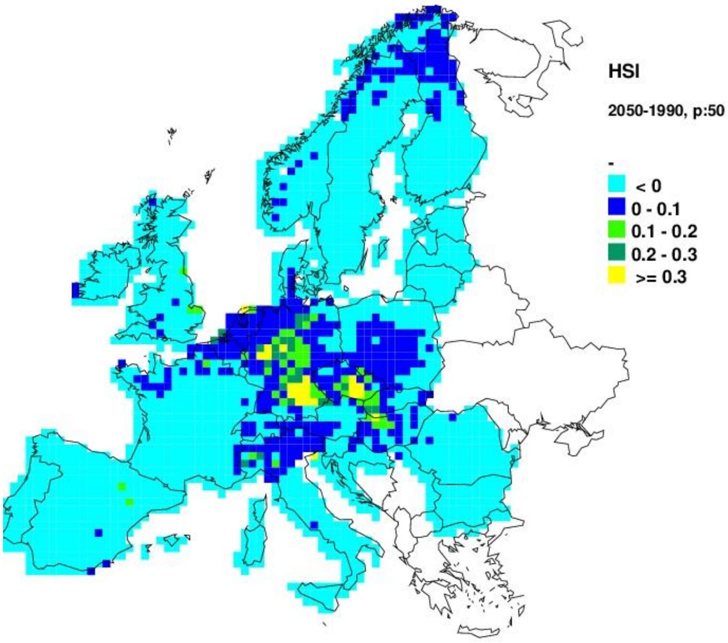

Figure 8. Increase in HSI between 2000 and 2050; median per grid cell in response to the ECLAIRE scenario.

4. Milestones achieved:

This deliverable is linked to milestone MS66: Parametrisation and linking of VSD+ and PROPS at the European scale. This milestone has been reformulated (see explanation below).

5. Deviations and reasons:

The EU scale application was made through the linkage of VSD+-PROPS. Application of MADOC beyond the UK (i.e. the EU scale) was deemed to be a very demanding task which when achieved would not lead to significant further scientific insight. Therefore a more detailed application for one country only, was considered more relevant.

6. Publications:

Quoted in text

Ellenberg, H., Weber, H.E., Dull, R., Wirth, V., Werner, W., & Paulissen, D. 1991. Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica 18:1–248.

Rowe, E., Emmett, B., & Smart, S. (2009). A single metric for defining biodiversity damage using Habitats Directive criteria. Hettelingh, JP, Posch, M., Slootweg, J. Eds. Progress in the modelling of critical thresholds, impacts to plant species diversity and ecosystem services in Europe: CCE Status Report, 101-106.

Van Hinsberg A, Hendriks M, Hennekens S, Sierdsema H, Van Swaay C, Rondinini C, Santini L, Delbaere B, Knol O, Wiertz J, 2014. BioScore 2.0 - A tool to assess the impacts of European Community policies on Europe's biodiversity. First Draft, Dec. 2014

WP15 publications in ECLAIRE
De Vries, W., M. Posch, G.J. Reinds, L.T.C Bonten, J.P. Mol-Dijkstra, G.W.W. Wamelink and J-P. Hettelingh, 2015. Integrated assessment of impacts of atmospheric deposition and climate change on forest ecosystem services in Europe. In W. de Vries, J-P. Hettelingh & M. Posch (eds) Critical Loads and Dynamic Risk Assessments: Nitrogen, Acidity and Metals in Terrestrial and Aquatic Ecosystems. Series: Environmental Pollution, Vol. 25, 662pp. Springer, Dordrecht, Netherlands: 589-612.

Reinds, G.J., J.P. Mol-Dijkstra, G.W.W. Wamelink, M. Posch, L.T.C. Bonten and W. de Vries, 2015. Combined effects of nitrogen deposition, ozone exposure and climate change on plant species diversity in Europe (in prep).

Van Dobben, H.F., M. Posch, G.W.W. Wamelink, J-P. Hettelingh and W. de Vries, 2015. Plant species diversity indicators for use in the computation of critical loads and dynamic risk assessments. In W. de Vries, J-P. Hettelingh & M. Posch (eds) Critical Loads and Dynamic Risk Assessments: Nitrogen, Acidity and Metals in Terrestrial and Aquatic Ecosystems. Series: Environmental Pollution, Vol. 25, 662pp. Springer, Dordrecht, Netherlands: 59-81.

7. Meetings:

Deliverable was discussed at the First annual ECLAIRE meeting in 2014 in Budapest and presented at the UNECE LRTAP CCE workshop in Zagreb 2015.