Project Number 282910

ÉCLAIRE

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

Seventh Framework Programme

Theme: Environment

D16.4 Maps of critical N load and critical ozone uptake exceedances at European scale

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Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	☐
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

The objectives of this deliverable were to map exceedances of critical ozone doses and critical loads (CLs) of nitrogen (N) and sulphur (S) at European scale, based on novel thresholds for

- the phytotoxic ozone dose (POD) in view of net annual increment impacts
- the N and S loads in view of plant species diversity impacts (‘biodiversity’)

POD thresholds were earlier based on relationships between total biomass reductions and POD_1, but more recently, relationships have been derived with net annual increment (NAI) reductions, which is more relevant for the assessment of carbon sequestration. These new thresholds, together with databases on tree species occurrences, can be used to map exceedances of critical POD values as well as corresponding NAI reductions for any past and future (scenario) year at a European scale; and examples are shown in this deliverable.

Critical N and S loads for plant diversity (‘biodiversity’) were derived on the basis of a Habitat Suitability (HS) index that summarizes plant occurrence probabilities into a single diversity measure. Plant occurrences were computed with an updated version of the PROPS model. By defining a critical HS index value, critical loads were computed for (almost) every soil-vegetation unit with the simple mass balance (SMB) model. Using the European background data base on soil, land use and climate characteristics, biodiversity N and S CLs were computed for the whole of Europe, and exceedances thereof can now be routinely calculated for any given deposition scenario and year (examples are shown in this deliverable). Furthermore, the European N-S CLs, and parameters derived thereof used in optimisation, have been provided for work with the GAINS model carried out under Component 5.

1. Objectives:

The objectives of this deliverable were to map exceedances of critical ozone doses and critical loads of nitrogen (N) and sulphur (S) at European scale based on novel thresholds for

- the phytotoxic ozone dose (POD) in view of productivity impacts
- the N and S loads in view of plant species diversity impacts

Here we shortly describe how we derived the various thresholds and critical loads, and how they were used to map threshold exceedances at European scale.

2. Activities:

Assessment of thresholds for the phytotoxic ozone dose (POD) for different tree species and their exceedances
Critical thresholds of ozone have shifted from limits on the accumulated ozone concentration above a threshold (AOT) to the phytotoxic ozone dose (POD, in $mmol.m^{-2}$). POD thresholds were earlier based on relationships between total biomass reductions and POD_1, where POD_1 is the hourly mean stomatal flux of ozone accumulated over a threshold of 1 $nmol.m^{-2}.s^{-1}$. More recently, relationships have (also) been derived between net annual increment (NAI) and POD_1, these being more relevant for the assessment of carbon sequestration (see Deliverable 12.3: 'Delivery of novel thresholds for key dose-response relationships'; Emberson et al. 2015). These new ozone thresholds, both developed by the ICP Vegetation network under the LRTAP Convention and further investigated in several ECLAIRE work packages, have been compiled and scrutinized for their applicability in large-scale (European) assessments. As an example, European maps of POD threshold exceedances and NAI reductions for birch are given below.

Assessment of critical loads for nitrogen and sulphur in view of plant species diversity impacts and their exceedances
In order to assess CLs of N and S with respect to plant species diversity ('biodiversity'), a criterion (and a threshold value) is needed. In this context, the so-called Habitat Suitability (HS) index has been introduced and agreed upon in discussions at various meetings under the LRTAP Convention. This index summarizes plant occurrence probabilities into one diversity measure. The vegetation model PROPS (reported in D15.1 and also referred to in D16.3) has been updated and now predicts plant occurrence as a function of soil pH, C:N ratio, N deposition, precipitation and temperature. Using a European data base on soil, climate and land use characteristics ('European background database', held and updated at the CCE/RIVM) critical load functions of N and S were computed for (almost) every soil-vegetation unit, using the simple mass balance (SMB) model to link pH to S and N deposition for given C:N ratio and climate. Examples of maps of these CLs and their exceedances, using deposition/climate scenarios agreed within ECLAIRE, are given below.

3. Results:

3.1 Phytotoxic ozone dose (POD) thresholds in view of productivity impacts and their exceedances

Whereas earlier the phytotoxic ozone doses were related to yield (total biomass) reductions (see Deliverable D16.2), these are now related to net annual increment (NAI). E.g., NAI (in %) for beech/birch is linearly related to POD_1 (in $mmol/m^2$) by NAI = $100–1.01·POD_1$. Assuming an acceptable NAI reduction of 5% leads to a critical POD_1 threshold of $5/1.01 \approx 5$ $mmol/m^2$ for beech/birch.

Using data from a database on the coverage of 20 tree species (groups) on a 0.01°×0.01° grid (about 0.5 km×1km) covering Europe (see Deliverable D16.2) the exceedance of this POD threshold for birch is shown in Fig.1 for the years 2000 and 2050 (the latter under the common ECLAIRE scenario RCA3-ECHAM5_A1B-r3) on the rotated Lon-Lat grid (grid size: 0.44°×0.44°) used for all European modelling within ECLAIRE.

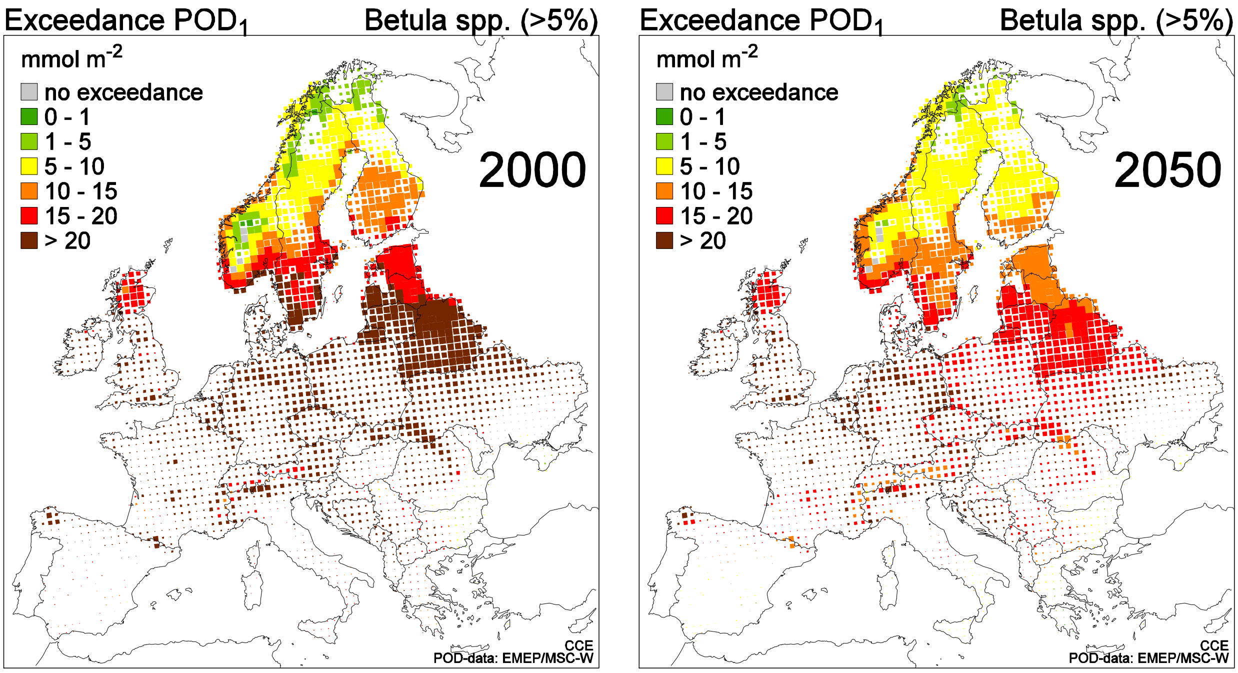

Figure 1: Exceedance of the POD_1 critical threshold (averting a NAI reduction of > 5%) for birch (*betula* spp.) in the year 2000 (left) and 2050 (right) under the RCA3-ECHAM5_A1B-r3 scenario (Note: the size of the coloured grid cells reflects the coverage of birch within the resp. grid cell).

Using the linear relationship between POD_1 and NAI, Fig.2 shows the corresponding NAI reductions for birch in the years 2000 and 2050.

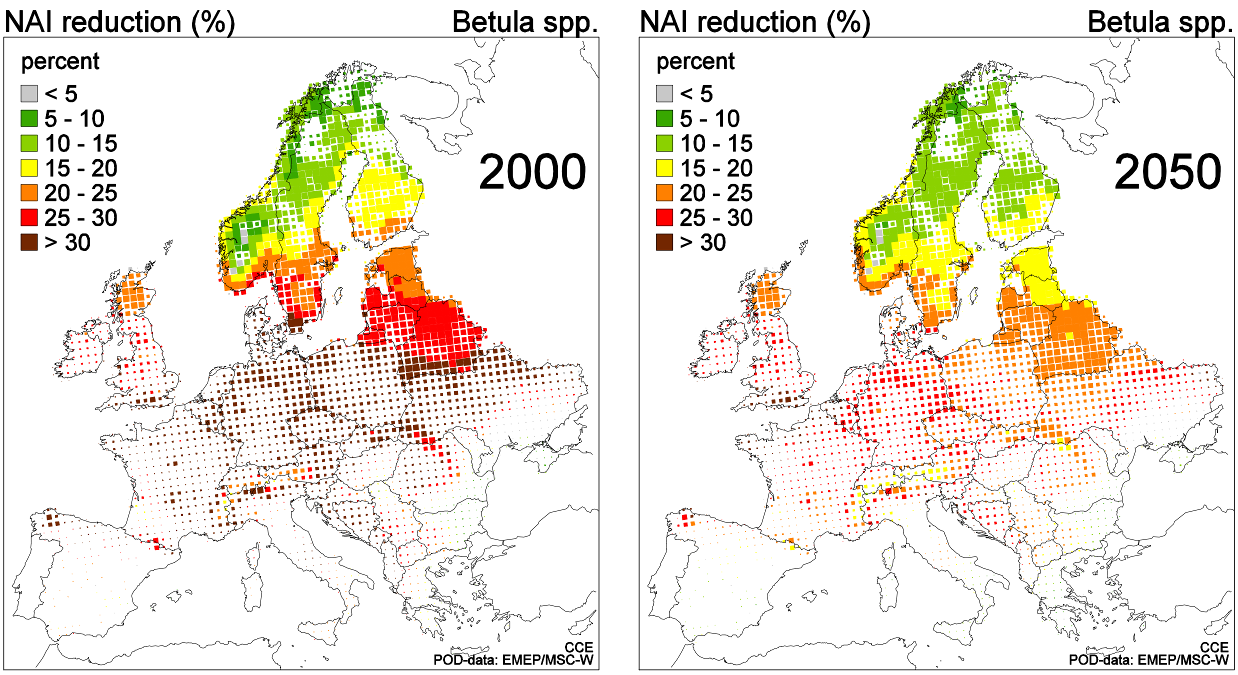

Figure 2: NAI reductions for birch (*Betula* spp.) in the year 2000 (left) and 2050 (right) under the RCA3-ECHAM5_A1B-r3 scenario (Note: size of coloured grid cells reflects coverage of the species).

Analogous relationships have been compiled for other tree species (groups) and crops. Note, that current thresholds are independent of geographical location and local (soil) parameters.

3.2 Critical N and S loads in view of plant species diversity impacts and their exceedances

Critical loads of N and S for plant species diversity

Basis for computing CLs of N and S for 'biodiversity' is the model PROPS, which computes probabilities of plant occurrences as a function of 5 abiotic parameters (pH, C:N ratio, N deposition, precipitation and temperature; see also D15.4). Fig.3 shows isolines of such probabilities for the species *Calluna vulgaris* in the C:N-pH plane and the N_{dep}-pH plane (with the 3 other parameters constant). Overall, the database currently holds parameters for about 3,900 European plant species.

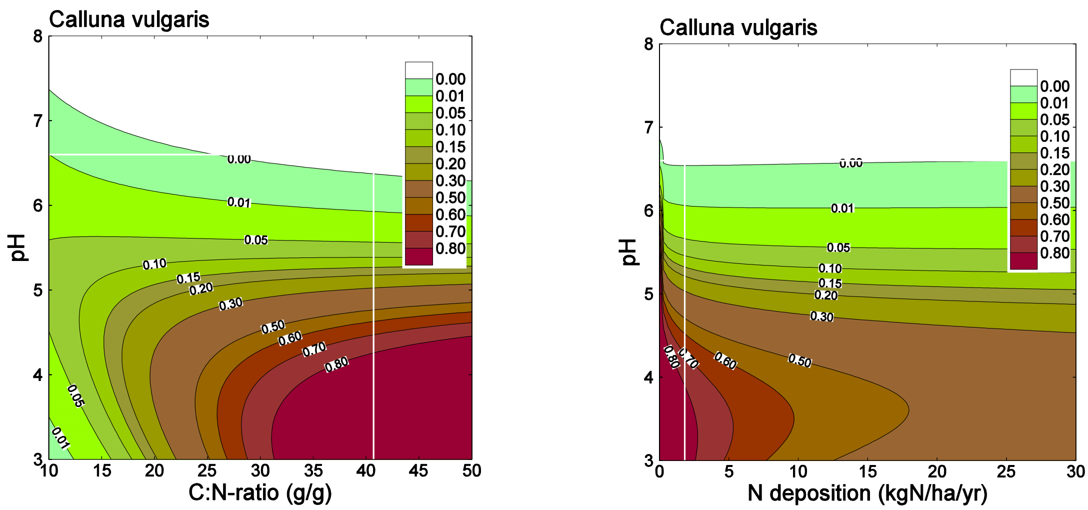

Figure 3: Left: Normalised isolines of the occurrence probabilities as function of soil C:N and soil solution pH for species *Calluna vulgaris*. Right: Isolines in the N_{dep}-pH plane for the same species. Both for fixed precipitation and temperature (and N_{dep} resp C:N).

Every habitat is 'characterised' by a number of 'typical' species (see D15.4 for more details). Using the parameters of those species and the abiotic site characteristics, one can compute the HS indices for the respective habitat for a range of N and S deposition, in this way determining for which pair (N_{dep},S_{dep}) the HS index is optimal. Taking this HS_{opt} as starting point, a simple procedure has been developed to derive a critical load function (CLF) in the N_{dep}-S_{dep} plane, which is graphically illustrated in Figure 4.

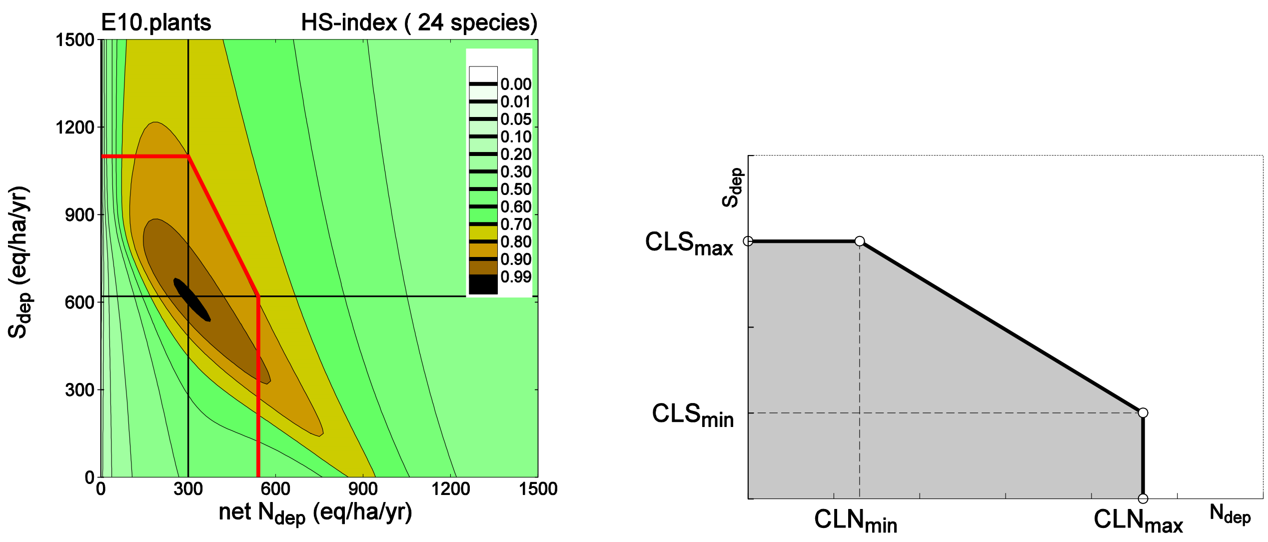

Figure 4: Left: N-S critical load function (CLF) derived from the chosen HS-index limit value (red line). Right: General shape of N-S CLF defined by the 4 quantities CLN_{min}, CLS_{max}, CLN_{max} and CLS_{min}.

The above methodology has been applied to a newly created European data base, obtained from combining the existing 'European background data base' with a European habitat map from the Bioscore project (see D15.4). Fig.5 shows maps of percentiles of a critical load quantity (CLN_{max}, see Fig.4) within the grid cells covering Europe, derived from about 1,300,000 habitat sites.

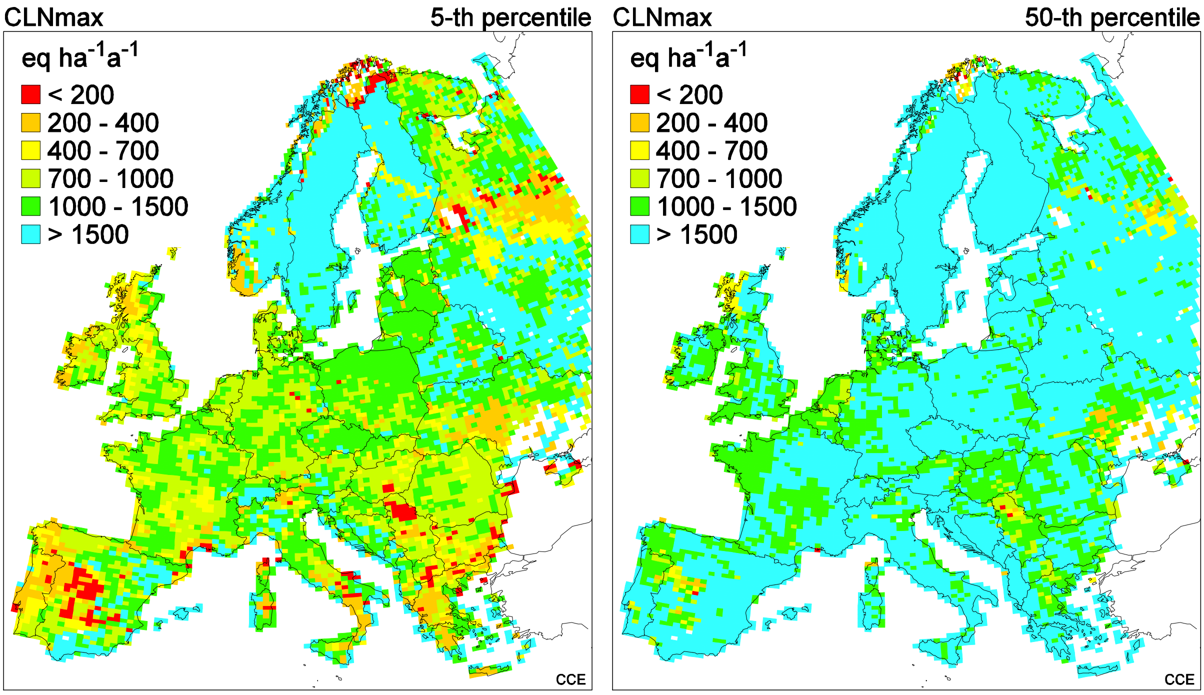

Figure 5: 5-th and 50-th percentile of critical loads of CLN_{max} in every grid cell, derived from the HS-index computed with the PROPS model and steady-state soil model.

In Fig.6 the cumulative distribution functions (CDFs) of the 4 quantities defining the CLFs are shown for the about 1,300,000 habitats covering Europe.

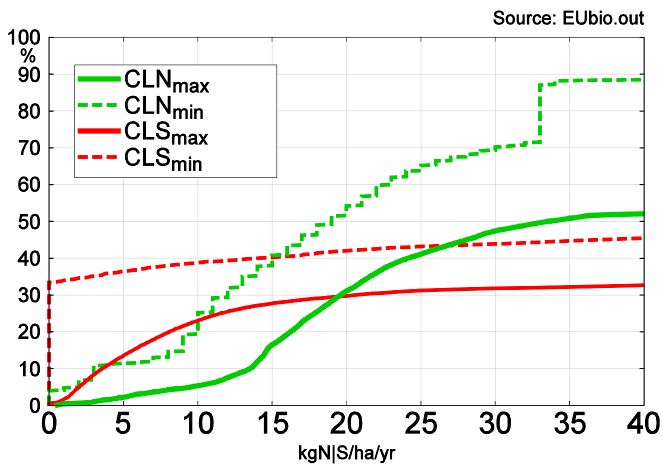

Figure 6: Cumulative distribution functions (CDFs) of the 4 critical load parameters (see Fig.4) computed from the European data base (about 1,300,000 habitats).

Exceedances of critical loads of N and S

For any given N and S deposition scenario, the exceedance of those biodiversity CLs can now be routinely computed. Exceedance for a collection of habitats in a grid cell is expressed as the 'average accumulated exceedance' (AAE), essentially an area-weighted exceedance of the individual CLs – a measure routinely used in European assessments since more than 15 years. In Fig.7 exceedances (AAEs) of the newly derived biodiversity critical load are shown for the years 2010 and 2050.

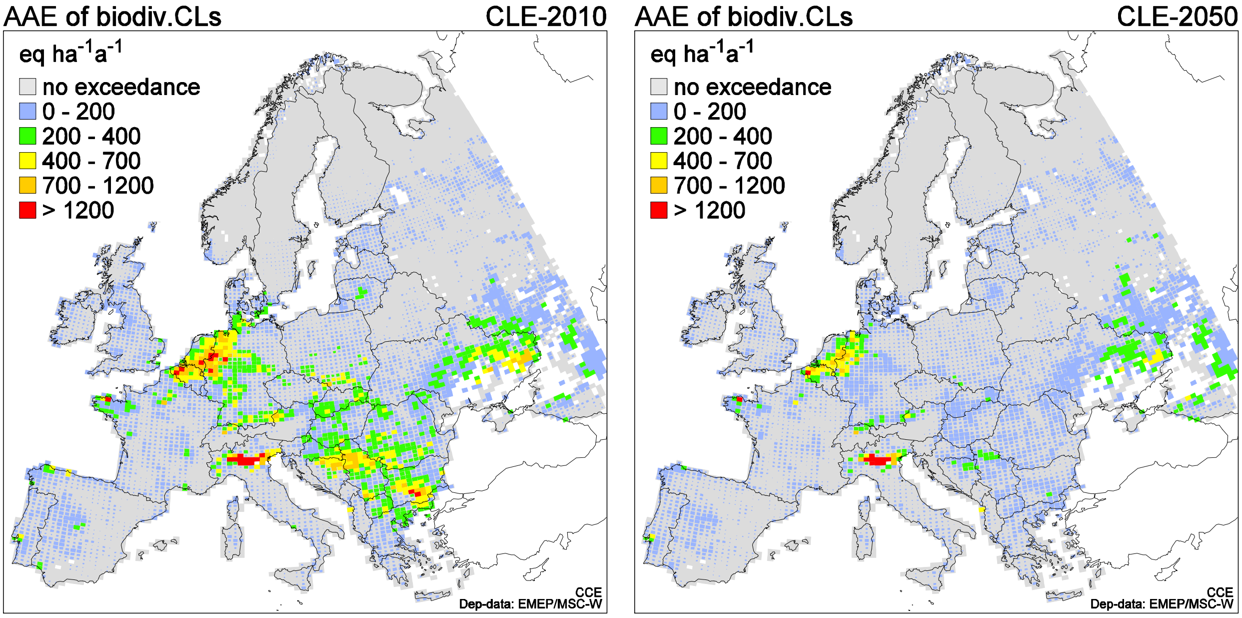

Figure 7: Exceedance of N-S CLs for biodiversity under 2010 (left) and 2050 (right) N and S deposition.

The newly derived European N-S CLs for biodiversity, as well as parameters derived from them that are needed in optimisation, have been provided for work with the GAINS integrated assessment model, to be carried out under Component 5.

4. Milestones achieved:

This deliverable is linked to milestone MS70 ('Analysis of exceedances of critical thresholds for N-compounds …').

5. Deviations and reasons:

The delay of 3.7 months allowed incorporating discussions/findings from a C4-C5 meeting at IIASA 29-30 June 2015.

6. Publications:

Slootweg J, Posch M, Hettelingh J-P, Mathijssen L (eds), 2015. Modelling and mapping of atmospherically-induced plant diversity impacts in Europe: CCE Status Report 2014. RIVM, Bilthoven, Netherlands

Posch M, Reinds GJ, Mol-Dijkstra JP, Wamelink GWW, De Vries W, 2015: Critical nitrogen loads and their exceedances at European scale based on protection of plant species diversity (in prep).

7. Meetings:

- Numerous meetings between WP16 and WP15 (at Alterra, Wageningen) to link the PROPS model to the European database.
- ECLAIRE General Assembly in Budapest (29.09-02.10.2014);
- CCE Workshop and ICP Modelling & Mapping Task Force (LRTAP Convention) meeting in Zagreb (20-23 April 2015)
- C4-C5 Technical Meeting at IIASA (29-30 June 2015).

8. List of Documents/Annexes:

None