4. The European Background Database

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4.1 Introduction

A main task of the Coordination Center for Effects (CCE) is to collect and collate national data on critical loads and dynamic modelling, and to provide European maps and other databases to the relevant bodies under the LRTAP Convention, especially for the purpose of integrated assessment. Ideally, all those data are based on national data submissions, provided by National Focal Centres (NFCs) upon a call for data. However, if a country does not contribute national data, values from a European background database (EU-DB), which is held and updated by the CCE, can be used for those areas.

The previous version of the European background database has been described in the 2003 CCE Status Report (Posch et al., 2003). Over the last years new databases have become available, and thus the EU-DB has been updated. As before, only forests (forest soils) are considered in the European background database. Individual tree species are not identified, but a distinction is made between coniferous, broad-leaved (deciduous) and mixed forests. In deriving variables for the EU-DB which are not directly available in existing databases, the recommendations and transfer functions in the Mapping Manual (UBA, 2004) are followed as closely as possible.

In the following sections the data sources and procedures used for deriving the variables in the European background database are described. EU-DB contains the same data as were asked from NFCs in the last call for data (see Chapter 2). Some of the variables are displayed in map or graphical format.

4.2 Map Overlays

Input data for critical load calculations and dynamic modelling include parameters describing climatic variables, base cation deposition and weathering, nutrient uptake, N transformations and cation exchange. A combined map with the information to derive the required input data was constructed by combining the following maps/databases:

(a) The harmonised land cover map produced by the CCE and SEI by combining the Corine land cover map with the SEI land cover map (see Chapter 3).

(b) A soil map at scale 1:1,000,000 for all European countries (Eurosoil, 1999); except for Russia, Belarus, Ukraine and Moldova, for which the FAO 1:5,000,000 soil map (FAO, 1981) was used.

(c) Average forest growth derived from a updated data base of the European Forest Institute (EFI), which contains growth data a variety of species and age classes in about 250 regions in Europe (Schelhaas et al., 1999).

(d) A global map of detailed elevation data (on a 30”×30” grid) from NOAA/NGDC (Hastings and Dunbar, 1998).

(e) A map with EMEP grid cells of 50×50 km², in which S and N deposition data are provided.

Overlaying these maps and data bases, merging polygons within every EMEP50 grid cell differing only in altitude and discarding units smaller than 1 km² results in about 90,000 different forest-soil combinations.

The soil maps are composed of so-called soil associations, each polygon on the map representing one association. Every association, in turn, consists of several soil typological units (soil types) that each covers a known percentage of the soil association. The soil typological units on the maps are classified into more than 200 soil types (Eurosoil, 1999).

For each soil typological unit information is available, of which soil texture and drainage classes are used here to derive other input data. Six texture classes are defined from clay and sand content and listed in Table 5.12 in the
Mapping Manual. The drainage classes, which are used to estimate the denitrification fraction, are derived from the dominant annual soil water regime (Eurosoil, 1999; FAO, 1981).

Table 4-1 shows the distribution of forest over soil types in Europe for the 10 most common forest-soil types derived from the overlay of the soil- and forest map. Most forests are located on Podzols (about 25%), especially in the Nordic countries, and to a lesser extent on Podzoluvisols (about 15%), Cambisols (about 16%), Luvisols (about 9%) and Lithosols (about 4%). Forest soils occur mainly on coarse (texture class 1) and medium textures (class 2). Forests on the fine textures (classes 3-5) are relatively rare. About 9% of European forests are located on peat soils (histosols).

Table 4-1. Area of the 10 most common forest-soil combinations in Europe.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Area (km²)</th>
<th>% Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Podzols (P)</td>
<td>698246</td>
<td>25.2</td>
</tr>
<tr>
<td>Cambisols (B)</td>
<td>430280</td>
<td>15.6</td>
</tr>
<tr>
<td>Podzoluvisols (D)</td>
<td>421249</td>
<td>15.2</td>
</tr>
<tr>
<td>Histosols (O)</td>
<td>255690</td>
<td>9.2</td>
</tr>
<tr>
<td>Luvisols (L)</td>
<td>248140</td>
<td>9.0</td>
</tr>
<tr>
<td>Gleysols (G)</td>
<td>156363</td>
<td>5.7</td>
</tr>
<tr>
<td>Lithosols (I)</td>
<td>115961</td>
<td>4.2</td>
</tr>
<tr>
<td>Regosols (R)</td>
<td>103512</td>
<td>3.7</td>
</tr>
<tr>
<td>Arenosols (Q)</td>
<td>79445</td>
<td>2.9</td>
</tr>
<tr>
<td>Rendzinas (E)</td>
<td>69388</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Some inaccuracy in these estimates exists, because the soil map consists of soil associations. The map overlay thus gives a forested area for each association, not for each soil type. Forests have been assigned evenly to all soil types within the association, which in reality will not always be the case.

4.3 Input data for critical loads and dynamic modelling

All calculations were done by assuming a soil depth (rooting zone) of 0.5 m.

Precipitation surplus and soil water content

To compute the concentration and leaching of compounds in the soil, the annual water flux through the soil has to be known. To this end meteorological data are needed. Long-term (1961-1990) average monthly temperature, precipitation and cloudiness were derived from a high resolution European data base (Mitchell et al., 2004) that contains monthly values for the years 1901-2001 for land-based grid-cells of 10°×10° (approximately 15×18 km in central Europe). For sites east of 32° a 0.5°×0.5° global database from the same authors was used.

Actual evapotranspiration was calculated according to a model used in the IMAGE global change model (Leemans and Van den Born, 1994) following the approach by Prentice et al. (1993). Potential evapotranspiration was computed from temperature, sunshine and latitude. Actual evapotranspiration was then computed using a reduction function for potential evapotranspiration based on the available water content in the soil, described by Federer (1982). Soil water content is in turn estimated using a simple bucket-like model that uses water holding capacity (derived from the available soil texture data) and precipitation data. A complete description of the model can be found in Annex 4 of Reinds et al. (2001).

These computations also yield the annual average soil water content $\theta$.

The available water content (AWC) was estimated as a function of soil type and texture class according to Batjes (1996) who provides texture class dependent AWC values for FAO soil types based on an extensive literature review.

Base cation and chloride deposition

The total depositions of Ca, Mg, K and Na onto forests have recently been modelled by EMEP/MSC-W on the EMEP50 grid (Van Loon et al., 2005). Chloride deposition was assumed equal to the Na deposition.
Base cation weathering

Weathering of base cations, $BC_w$, was computed as a function of parent material class and texture class and corrected for temperature, as described in the Mapping Manual (UBA, 2004).

Weathering rates of Ca, Mg, K and Na as fractions of $BC_w$ were estimated as a function of clay and silt content (in %) for texture classes 2 to 5 (Van der Salm, 1999) and as fixed fractions of total weathering for texture class 1 (De Vries, 1994).

Nutrient uptake

Net uptake of base cations and nitrogen was computed by multiplying the estimated annual average growth of stems and branches with the element contents of base cations and N in these compartments. Wood densities of 450 kg/m$^3$ and 650 kg/m$^3$ as well as branch-to-stem ratios of 0.15 and 0.20 for coniferous and deciduous trees, respectively, have been used. For mixed forests the average of these values were applied.

Forest growth was derived from the EFI database mentioned above (Schelhaas et al., 1999). Growth was assessed by taking from the database the average growth over all age classes for the combination of region and tree species group.

Contents of N, Ca, Mg and K in stems and branches of coniferous and deciduous forests are derived from Table 5.8 in the Mapping Manual UBA (2004), which is based on data from a literature study by Jacobsen et al. (2002). The average values of spruce and pine were assigned to conifers and the average of oak and beech to deciduous forests. Again, an average of these was used for mixed forests.

Denitrification and N immobilisation

The denitrification fraction, $f_{de}$, was computed as a function of drainage status, which is known for each soil type and is given in Table 5.9 of the Mapping Manual (UBA, 2004).

N immobilisation consists of a constant (time-independent) part, which is the same as used in critical load calculations (1 kg N ha$^{-1}$ a$^{-1}$) and a time-dependent part, which is computed as a function of the prevailing C:N ratio of the top soil. This C:N ratio is estimated from a transfer function by Klap et al. (2002) which can also be found in the Mapping Manual (UBA, 2004). This transfer function computes the C:N ratio as a function of soil texture, forest type, climate variables and the N deposition of the relevant year (1995). The speed of change of the C:N ratio depends on the size of the C pool in the topsoil. This C pool for the top 20 cm is estimated from the organic carbon content (available for every soil type) and bulk density.

The bulk density $\rho$ of the soil was computed from a transfer function using clay and organic carbon content, derived from data by Hoekstra and Poelman (1982) and Van Wallenburg (1988; see also UBA, 2004). Clay content is an attribute to the soil map, carbon content for each soil type was derived from a European database on forest soils (Vannmechelen et al., 1997).

Al-H relationship and organic acids

The Al concentration is computed from a gibbsite equilibrium (i.e. $\alpha=3$) and the equilibrium constant is estimated from simultaneous measurements of [Al] and pH at about 150 forest monitoring plots as a function of soil texture class (De Vries et al., 2003).

Dissociation of organic acids was modelled by assuming them as mono-protic with a dissociation constant of $pK=4.5$ (see eq.5.46 in UBA, 2004). The DOC concentration was estimated from a linear regression with soil pH and texture using data from European Intensive Forest Monitoring plots. A charge density $m=0.023$ mol/molC was used throughout.

Cation exchange capacity and base saturation

Cation exchange capacity (CEC) was computed as a function of clay content, organic carbon content and soil pH according to a transfer function by Helling et al. (1964; see also UBA, 2004).

Base saturation for the reference year (1995) was estimated from a transfer function derived by Klap et al. (2002; see also UBA, 2004). This transfer function computes the base saturation as a function of soil texture, forest type
as well as the S, N and base cation deposition. The base saturation values were used to calibrate the exchange constants of the H-Al-Bc exchange.

4.4 Results

The EU-DB obtained from the databases and transfer functions described above can be used to compute critical loads of S and N acidity and nutrient N. Critical loads have been computed with the Simple Mass Balance (SMB) model, using a critical Al:Be ratio of 1 mol mol\(^{-1}\) for all forests and soils, except for peat soils (Histosols), for which a critical molar Be:H ratio is used (1 for conifers, 1/3 for deciduous forests and an average value of 2/3 for mixed forests). Several of the input variables as well as critical loads are displayed as cumulative distribution functions in Chapter 2, where they are compared to data from countries which have submitted national data in response to the recent call.

In Figure 4-1 the 5\(^{th}\) percentiles of the maximum critical load of S acidity, \(CL_{\text{max}}(S)\), and the critical load for nutrient N, \(CL_{\text{nut}}(N)\), are displayed on the EMEP50 grid. The maps clearly show that in most grid cells (the 5\(^{th}\) percentile of) the critical load for nutrient N is smaller than that of \(CL_{\text{max}}(S)\).

The exceedance of the acidity and nutrient N critical loads for the year 2010 is shown in Figure 4-2. In this scenario the implementation of the current legislation (the Gothenburg Protocol and the EU NEC Directive) is assumed. The forest-specific deposition has been provided by the EMEP/MSC-W (Tarrasón et al., 2004). As can be seen, acidification is a substantial problem only in some parts of central Europe, whereas eutrophication is a much more wide-spread and severe problem. These maps should be compared with the exceedance maps in Chapter 1.
Figure 4-2. The average accumulated exceedance (AAE) of the acidity critical loads (left) and the critical loads of nutrient nitrogen (right), using the deposition to forests in 2010, assuming the implementation of current legislation (Gothenburg Protocol and EU NEC Directive).

Not only critical loads can be calculated with the European background database, also simulations with the dynamic soil acidification model VSD (Posch and Reinds, 2005), which has been used by many European countries (see Part II), have been carried out. Figure 4-3 shows the temporal development of two major soil variables, pH and base saturation between 1990 and 2100 after running the VSD model on each of the circa 90,000 forest sites with S and N deposition constant after 2010 at ‘Gothenburg level’ (as used in Figure 4-2). The figure shows the temporal development of some percentiles (‘percentile traces’) of the distribution of those variables over the 110 years of simulation. As can be seen, the temporal development is rather unspectacular, which is not surprising for the pH, since for a constant deposition the soil solution concentrations will soon be in equilibrium with the deposited ions. Rather more surprising are the very minor changes occurring in the European distribution of base saturation, which is a slowly reacting soil variable. However, small changes in the distribution do not necessarily mean small changes at individual sites, decreases in some regions could be compensated by increases in others.

Figure 4-3. Temporal development (1990-2100) of some percentiles of pH (left) and base saturation (right) of the about 90,000 forest sites of the European background DB, when the VSD model is run with the ‘Gothenburg deposition’ after 2010.

Not only the variables themselves and their distributions are of interest, but also the relationship between them. Two key variables in any dynamic acidification model are the pH of the soil solution and the base saturation of the cation exchange complex. In Figure 4-4 the correlation between these two variables is shown for the year 2100, i.e. the last year of the simulation shown in Figure 4-3. The about 90,000 data points are shown in three colours, depending on the magnitude of the Gapon exchange constant for the Al-Bc exchange, $K_{\text{AlBc}}$. Since this is generally unknown, it is calibrated so that at every site a prescribed base saturation is obtained in 1995. The red dots in Figure 4-4 show sites for which $\log_{10}K_{\text{AlBc}}<0$, the blue dots sites for which $\log_{10}K_{\text{AlBc}}>2$, and the green ones with values between those two limits. Especially for sites with values of $K_{\text{AlBc}}$ in the range between 0 and 2, the relationship between pH and base saturation shows an S-shaped pattern which has also been observed and/or modelled by Reuss (1983), Bloom and Grigal (1985) and De Vries et al. (1989).
Figure 4-4. Correlation between base saturation and soil solution pH in 2100 for about 90,000 sites of the EU-DB. Red: sites with $\log_{10} K_{AlBc} < 0$, green: $0 \leq \log_{10} K_{AlBc} \leq 2$, blue: $\log_{10} K_{AlBc} > 2$, where $K_{AlBc}$ is the Al-Bc Gapon exchange constant.

In Figure 4-5 shows the correlation between two more pairs of variables at the end of the simulation of the about 90,000 European sites in 2100. The left panel illustrates, as expected, that high [Al]:[Bc] ratios are more likely to occur in soils with low base saturation; and the right panel confirms that the leaching of N is generally higher in soils with a low C:N ratio, i.e. soils which approach N saturation.

Figure 4-5. Correlation between base saturation and molar Al:Bc ratio (left) and between total N concentration in soil solution and the C:N ratio in the top soil layer (right) in 2100 for about 90,000 sites of the EU-DB.
The European background database has not only been used to compute critical loads and simulate the time development of the soils, but also to compute target loads and delay times. For acidification target loads are characterised not by a single number but by a function – very much like acidity critical loads. In Figure 4-6 the 5th percentile of the $TL_{\text{max}}(S)$ – the quantity of a target load function corresponding to $CL_{\text{max}}(S)$ in the critical load function – is displayed for the target years 2030 and 2050. By definition, a target load cannot be greater than a critical load, and for ecosystems for which no target load has to be calculated (e.g. an ecosystem which never experienced exceedance) the critical load function is, by definition, used a target load function. Thus the number of ecosystems in every grid cell is the same for critical load and target load statistics. The black-shaded grid cells in Figure 4-6 indicate cells in which for at least 5% of the ecosystem area no target loads can be calculated, i.e. even a reduction of the acidifying deposition to zero does not lead to a recovery of the ecosystem in the target year. Figure 4-6 should be compared to Figure 4-1 (left) to get an impression of the stringency of the target load as compared to the critical load.

**Figure 4-6.** The 5th percentile of target loads $TL_{\text{max}}(S)$ for the years 2030 (left) and 2050 (right) on the EMEP50 grid, computed from the European background database.

### 4.5 Concluding remarks

The European background database (EU-DB) has been updated for use by the CCE to fill in gaps left by countries which do not deliver data as well as for possible studies on a European scale. The EU-DB includes the latest available data on a European scale for the calculation of critical loads and for running simple dynamic models. The database, however, is not a final product; it will be checked and updated, whenever inconsistencies in the existing data are found or new data become available.

### References

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