

Critical loads for eutrophication and acidification for European terrestrial ecosystems;

A project that supplied the UBA CCE with a flexible and well documented background data base for critical loads

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Aim of the project

- Construct a database and software in R to compute critical loads for eutrophication (by Nitrogen) and acidification (by Nitrogen and Sulphur) for terrestrial ecosystems in Europe.
- Reporting of the background data used (maps, tables), the computational rules implemented to derive some of the data (e.g. transfer functions between soil type and soil characteristics) and of the procedures that compute the critical loads.
- 'Validate' this database and its results

Workpackages

- WP 1: Data compilation and assessment
- WP 2: Calculation of steady state critical load for eutrophication and acidification
- WP 3: Evaluation of the results
- WP 4: Final report and presentation

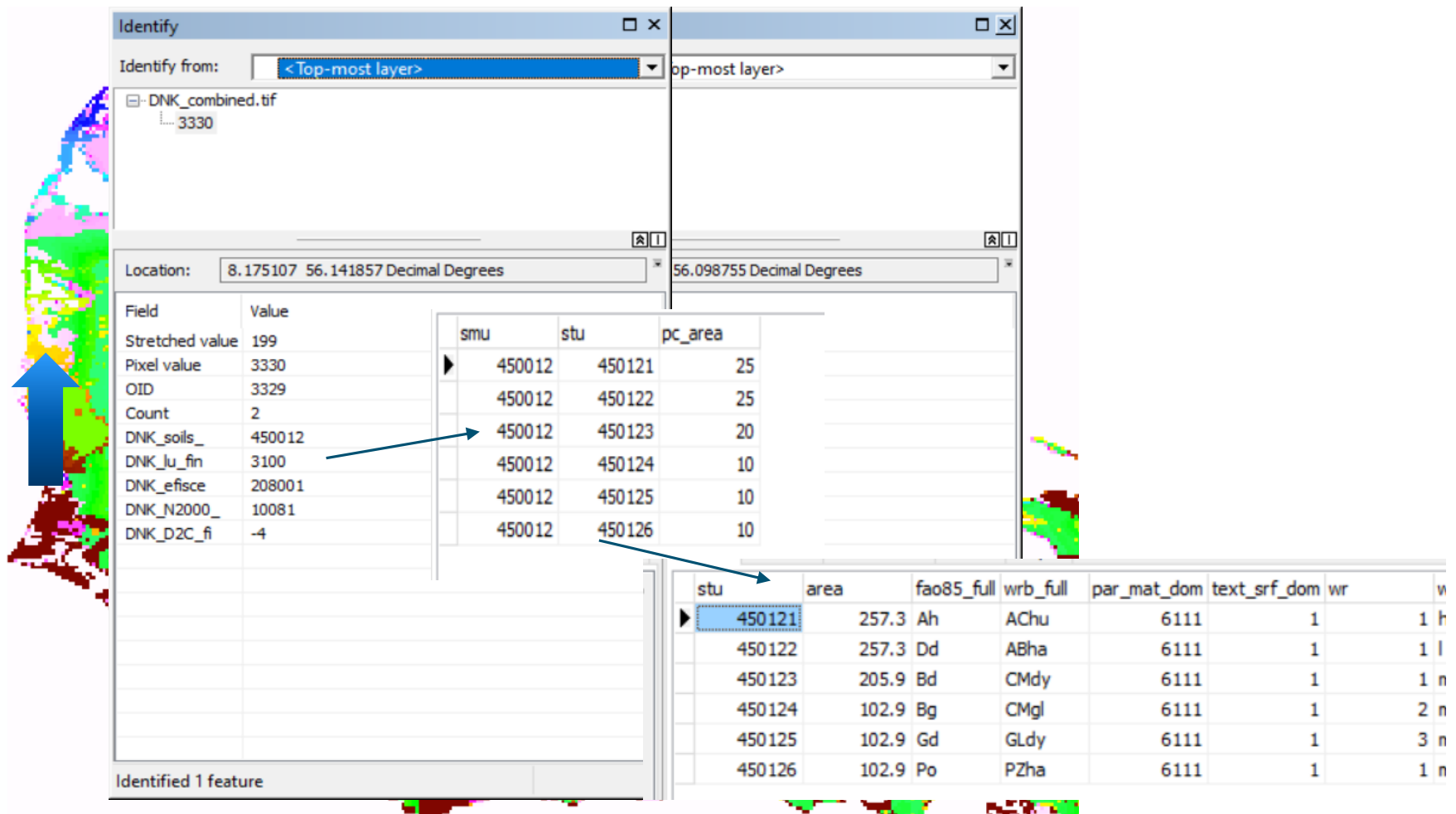
WP1: Compilation of data; geographical data

An ArcGIS-pro script in Python was made to combine maps of:

- *Land cover*: The harmonised LRTAP land cover map
- *Soils*: The latest version of the European Soil Database v2 map at a scale 1:1 M.
- *Forest growth regions*: Forest growth regions for Europe associated to the EFI database. For the parts of Russia mapped, 74 administrative regions.
- *Distance to coast*: The distance to coast from a NASA dataset
- *Nature 2000 areas*: The European Union's the latest delineation of Natura 2000 (N2k)
- Delineation of countries

Data are stored in georeferenced tiff files per country at 0.01×0.01 grid cells yielding 8.6 million unique receptors

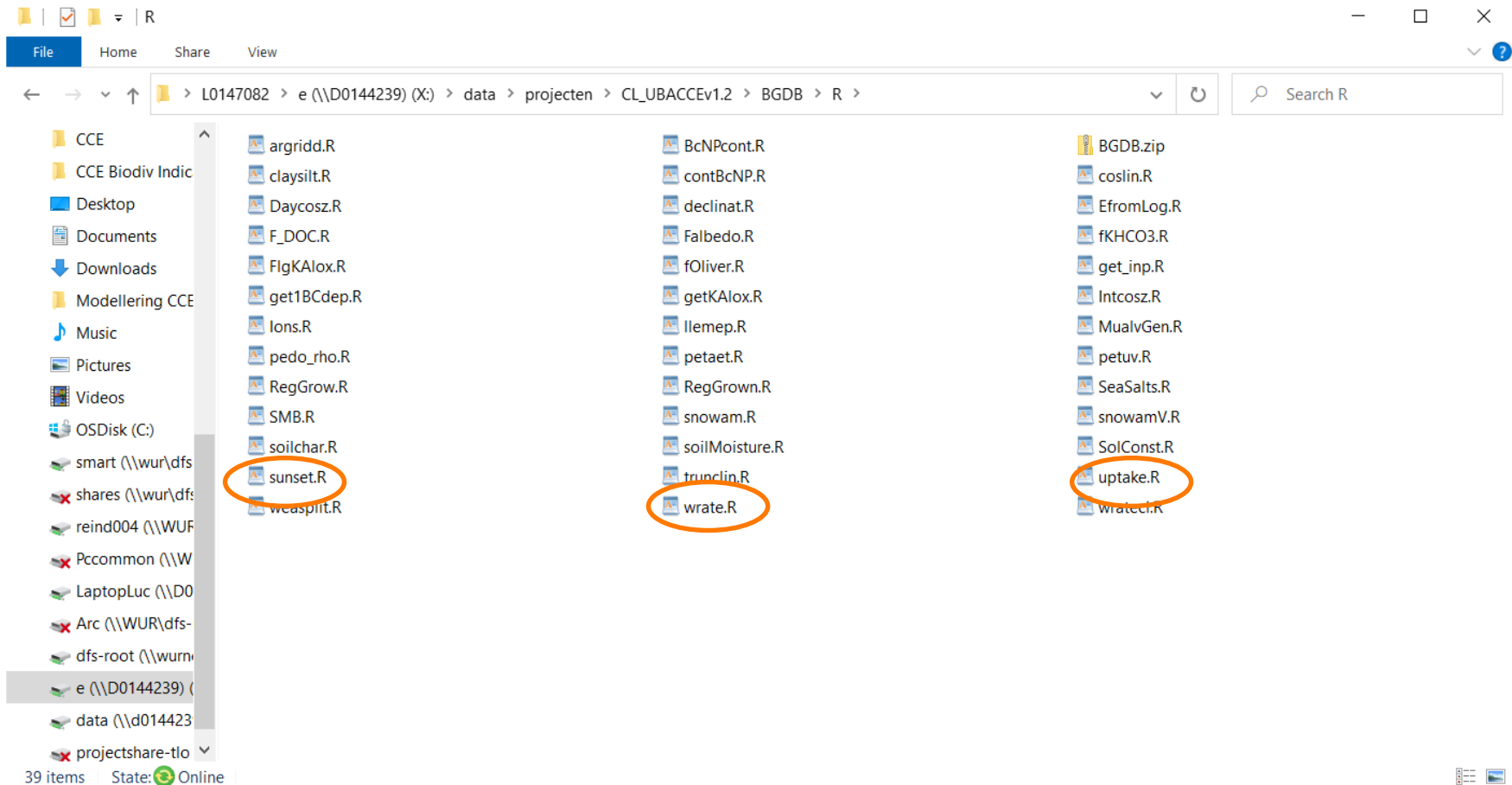
Results of the map overlays



Computing critical loads; setup

- A package (BGDB) was developed in R containing basic routines for e.g. computing weathering rates, nutrient uptake, sunset as a function of day in the year and latitude, etc.
- A number of scripts (BGRUN) was made for more elaborate computations, such as preparing meteorological data for use in MetHyd, reading the map overlay data, MetHyd computations of leaching etc.
- A main script was made (MainLoop.R) that carries out all tasks from initialisation, reading in data, running MetHyd, running SMB to writing out results

Basic routines are stored in a R package



Example: compute the bicarbonate equilibrium constant as a function of temperature

1.1	Contents of this report
2.1	Land cover
2.2	Soils
2.3	Forest growth regions
2.4	Distance to coast
2.5	Nature 2000 areas
2.6	Base cation deposition:
2.7	Meteorological data and hydrology
2.8	Overlay procedure
2.8.1	General procedure
2.8.2	Details of the ArcGIS procedures
3.1	Simple Mass Balance (SMB) equations
3.2	Parameters for computing ANC
3.2.1	Aluminium
3.2.2	Bicarbonate
3.2.3	Organic acids
3.3	Soil parameters
3.3.1	Thickness of the rooting zone
3.3.2	Denitrification fraction
3.3.3	Weathering rates of base cations
3.3.4	Nitrogen immobilization:
3.4	Uptake of nitrogen and base cations

3.2.2 Bicarbonate

The concentration of bicarbonate is computed according to:

```
#' @title fKHCO3
# (3.6) 
$$[HCO_3] = \frac{K_1 \cdot K_H \cdot p_{CO_2}}{[H]}$$

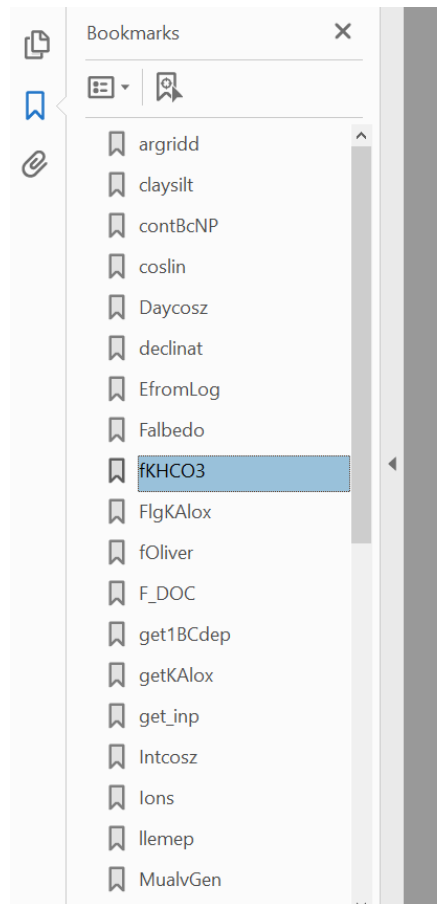
# (3.6)
#' @author M. Posch, ported to R by jaap slootweg
#' @description Returns the bicarbonate equilibrium constant in
# (mol/m3)^2/atm
#' @param temp Temperature (oC)
#' @details
# (3.7a) 
$$p_{CO_2} = 10^{-1.8 - 0.0158 \cdot T_{abs} - 14.018}$$

# (3.7b) 
$$K_H = 10^{-1.8 - 0.0158 \cdot T_{abs} - 14.018}$$

# (3.7b) 
$$K_1 = 10^{-3404/T_{abs} - 0.0328 \cdot T_{abs} + 14.844}$$

#' Ref: Harned and Davis (1943), quoted in Cosby et al. (1985).
#' @return KHCO3
#' @export
fKHCO3 <- function(temp) {
  Tabs = 273+temp
  lgKH = 2386/Tabs+0.0153*Tabs-14.018
  lgK1 = -3404/Tabs-0.0328*Tabs+14.844
  10^(6+lgKH+lgK1)
}
```


Documentation of the package generated as a (bookmarked) PDF



fKHCO3

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fKHCO3

fKHCO3

Description

Returns the bicarbonate equilibrium constant in (mol/m3)²/atm

Usage

`fKHCO3 (temp)`

Arguments

`temp` Temperature (oC)

Details

$[HCO_3] = pCO_2 * KHCO_3 / [H]$, as a function of temperature (in oC), where $KHCO_3 = KH * K_1$... Henry's law constant * first dissociation constant [= $10^{-1.8} = 0.0158489$ (mol/m3)²/atm at 25oC]
Ref: Harned and Davis (1943), quoted in Cosby et al. (1985).

Value

`KHCO3`

Author(s)

M. Posch, ported to R by jaap slootweg

R procedures for more elaborate tasks: BGRUN

Some examples of R scripts of BGRUN

- Prepare the meteorological data by reading in Eobs data set and CRU data sets and replace missing values by (advanced) interpolation of available data (MakeMetSlice8.R)
- Read the results from the map overlays, remove units with e.g. bare rock or water bodies, assign soil characteristics to soil units such as organic matter content and soil water contents at different pressure heads etc. (GetSoilMap.R)

What is done in MainLoop

- (1) Set criteria for the critical loads
- (2) Specify whether meteorology must be prepared and/or MetHyd must be run
- (3) Basic settings are made in EUCLpar.R on, e.g., soil depth and the wood density of trees.
- (4) Get_Inp.R defines all other model parameters such as aluminium dissolution constant and the dissociation constant for organic acids.
- (5) Growth and base cation (BC) deposition are read from files.
- (6) Countries for which the model(s) need to be run are defined by their ISO-3166 2-letter code
- (7) Read the soil map information
- (8) Read the file __SoilChar.Tab that contains data for pH, organic carbon and nitrogen and CaCO₃ content per soil type
- (9) Determine the clay, sand and silt content of the soil based on the STU's texture class
- (10) Read the meteorological data previously prepared with MkCrudeMet.R
- (11) Get the rasters (.tif files) from the overlay procedures that belong to the countries that have been selected
- (12) Start the master loop over the stripes of 0.5 degrees. Run MetHyd if needed
- (13) Get from the already read-in data the base cation deposition for this latitude stripe
- (14) Compute the weathering rates for all soils in the latitude stripe
- (15) Compute the uptake of nutrients for each receptor in the latitude
- (16) For critical loads based on base saturation ($iA_{ci} = 3$), set the exchange model to Gapon and set the exchange constants to standard values.
- (17) Run the SMB model
- (18) Make a dataframe (AllData) to store the results from SMB
- (19) After all latitude stripes have been processed, write out the list of dataframes to an ASCII-file

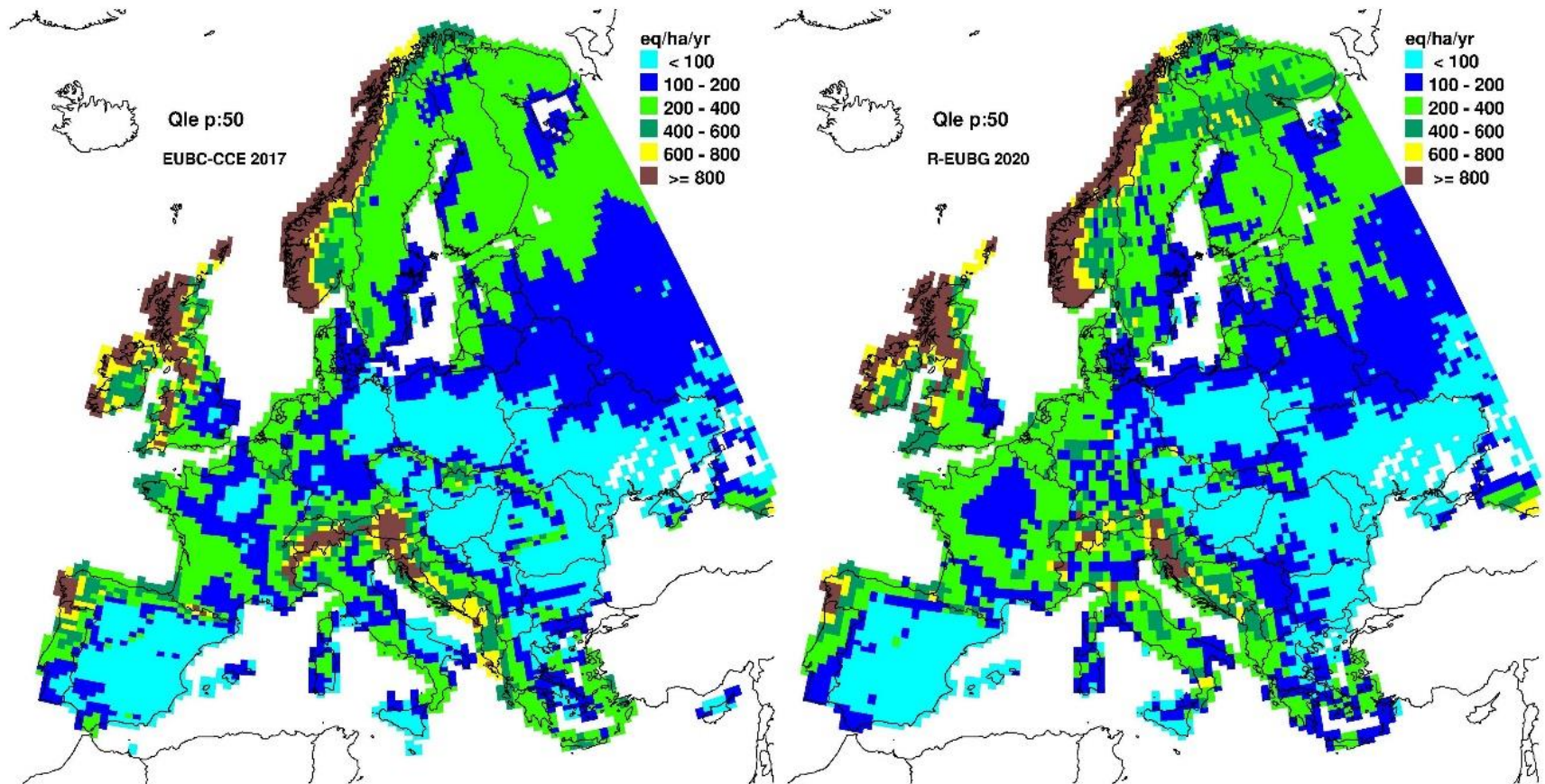
Performance

- A full run for the whole of Europe (8.6 million receptors) with running MetHyd (using 20 years of daily meteo) takes about 5 days
- A full run with an available MetHyd results run takes about 10 minutes!

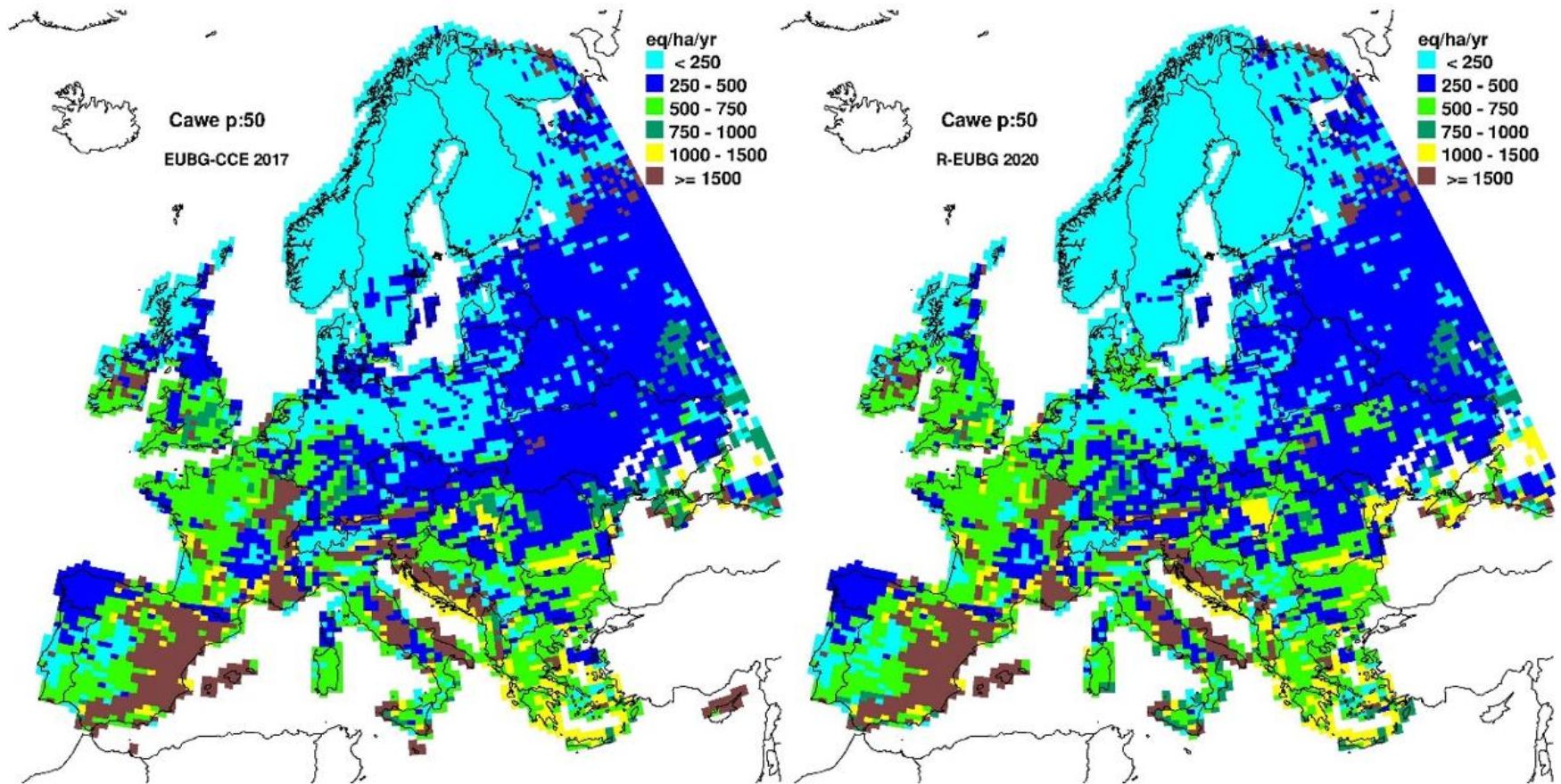
WP 3 Verification

- Results were compared to runs with the background DB of 2017.
- Slight differences may occur because of the update of meteorological data and changes in the setup of MetHyd, and because of updated forest growth data (=changes in nutrient uptake)
- Results were compared to NFC results from Ireland and Germany

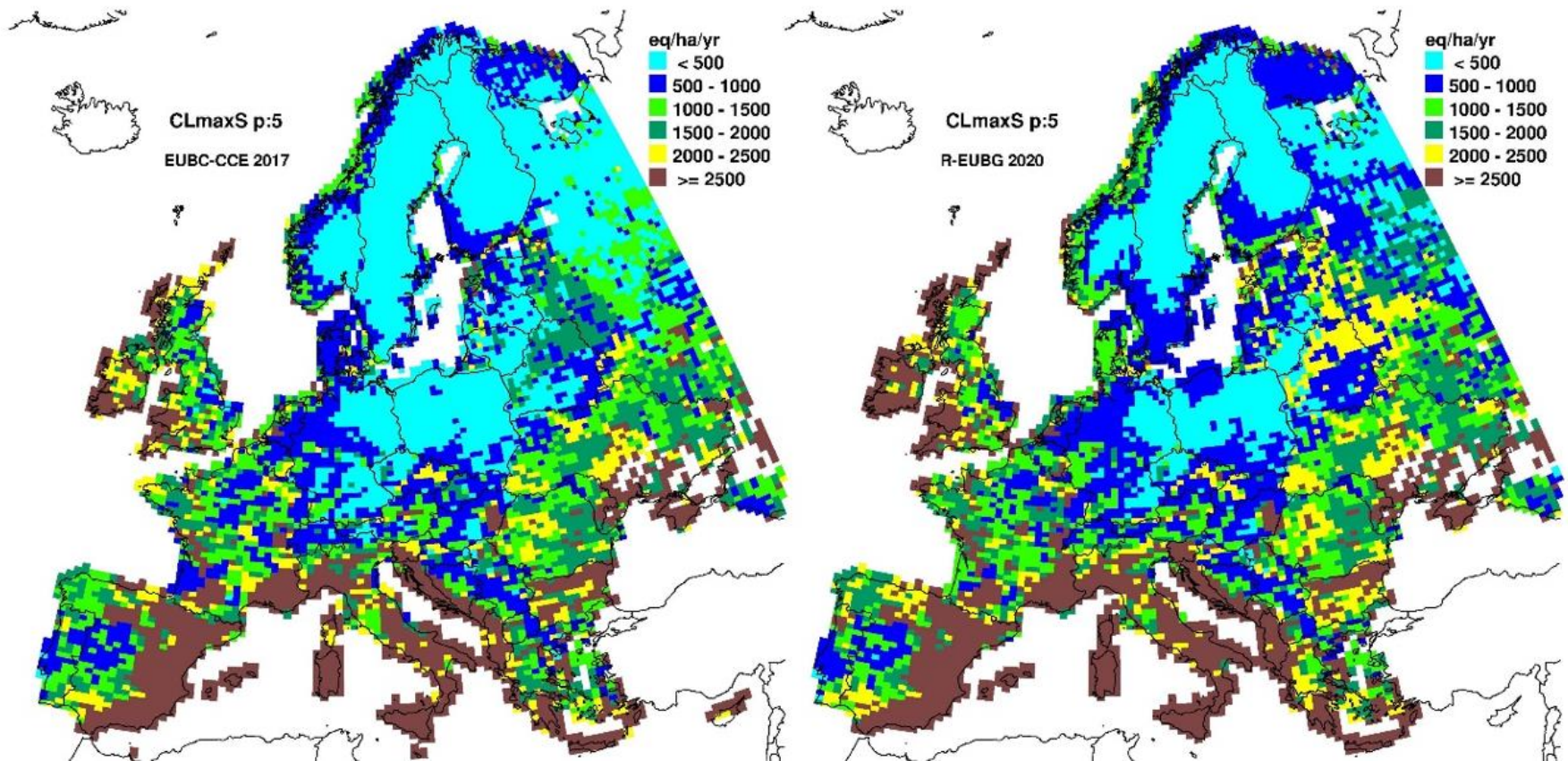
Comparing results with 2017: Leaching



Comparing results with 2017: Ca weathering

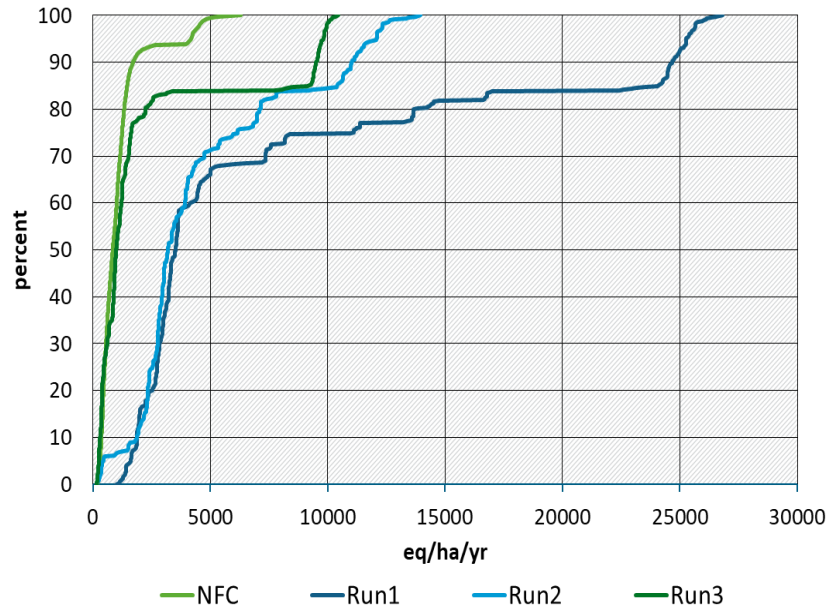


Comparing results with 2017: CLmaxS

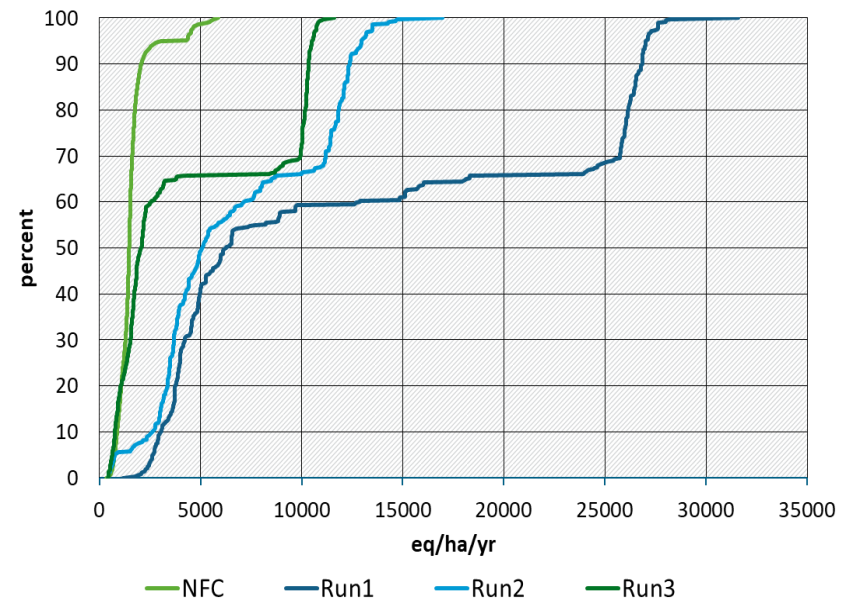


Comparison with CL's from the Irish NFC

CLmaxS
Forests



CLmaxS
Non-Forests



Run1: Standard run with $Al/Bc = 1$, all BC ions separate, fixed $IgKAl_{ox}$ (8.7 for mineral soils, 6.7 for peat)

Run2: Run with critical pH = 4.2 and BC merged in Ca, Mg deposition considered as sea-salt, fixed $IgKAl_{ox}$ (8.7 for mineral soils, 6.7 for peat)

Run3: Run with critical pH = 4.2 and BC merged in Ca, Mg deposition considered as sea-salt and $IgKAl_{ox}$ as a function of soil type

Conclusions

- A fully operational system to compute critical loads with SMB was delivered to UBA. Map overlays are made using ArcGIS, computations in R
- By also making an R version of MetHyd, there is no more need for UBA to use any of the RIVM CCE FORTRAN based software
- Computational speed is very good given the fact that MetHyd needs to be run only once (unless meteorological data are updated)
- Result compare very well with the RIVM CCE background data base critical loads of 2017

Conclusions (2)

- Comparison of results to national data is hampered by the fact that NFC's use different criteria, different underlying maps and different methods that cannot be reproduced (e.g. Germany uses > 20 different critical pH values depending on soil types on the German soil map)
- The project was fun to do, but costed more time than envisaged; especially testing and adapting the R procedure to make it reproduce the 2017 results was time consuming
- Cooperation with UBA was constructive and pleasant
- There will be an UBA report available on the work, hopefully this summer. Accessible to all.

Thank you for
your attention!

To explore
the potential
of nature to
improve the
quality of life

Python procedure

CL_CCEUBA_final_v1

Soils input file (.shp)
C:\data\d_cceuba\Deliverables\geodata\soil\sgdbe4_0_geo.shp

SMU-STU relationship file (.csv file)
C:\data\d_cceuba\Deliverables\geodata\soil\smu_stu.csv

GADM36_0
C:\data\d_cceuba\Deliverables\geodata\GADM36_0.gdb

Location of ascii files (for landuse)
C:\data\d_cceuba\Deliverables\geodata\LandUse\ascii_out_AL_NO_PL_YU_fromemepdetailed_100m

ZDEUNIS excel file (landuse)
C:\data\d_cceuba\Deliverables\geodata\LandUse\ZDEUNIS.xlsx\ZDEUNIS\$

Efiscen input file (raster file)
C:\data\d_cceuba\Deliverables\geodata\gefiadmnew

N2000 input file (shape)
C:\data\d_cceuba\Deliverables\geodata\N2K\Natura2000_end2018.shp

Distance to Coast input file (.tif)
C:\data\d_cceuba\Deliverables\geodata\Dist2Coast\GMT_intermediate_coast_distance_01d\GMT_intermediate_coast_distance_01d.tif

Output folder location
C:\data\d_cceuba\Deliverables\geodata\output

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