Eclaire C4: Ecological responses at European and regional scale

Wim de Vries

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SEVENTH FRAMEWORK PROGRAMME

Contents

- Aims/tasks of component 4
- Models included: DGVMs and DSVMs
- Model linkages and specific tasks in WP14-WP17
- Discussion issues

Main tasks Component 4

- Further develop and apply verified (in WP13) dynamic global vegetation models (DGVMs) and dynamic soil vegetation growth models (DSVMs) to predict
  - Carbon sequestration (WP14)
  - Plant species diversity (WP15)
  - in response to ECLAIRE scenarios of future emissions and climate change, incorporating management changes.

- Apply verified models to map novel thresholds for N deposition and O_3 exposure and exceedances at European scale (WP16).

- Assess impacts of model resolution on threshold exceedances by comparison of high and low resolution model results at landscape scale (WP17).

Interactions studied in C4

- Air quality effects and interactions
  - Ozone exposure.
  - Changes in diffuse radiation, caused by changes in PM.
  - CO_2 fertilization.
  - N and S deposition.
  - Nutrient (phosphate and base cations) availability/limitation.
  - Soil acidity.
- Climate change
  - Water availability
  - Temperature

Systems to be modelled and reference productivity data

- Systems to be modelled
  - Intensively managed grasslands
  - Croplands
  - Semi natural vegetation (heathlands, grasslands)
  - Forests
  - Wetlands

- Reference data for yield:
  - Grassland: census data grassland productivity, MODIS data
  - Croplands: FAO crop yields
  - Forests: EFISCEN database

Role of DGVMs and DSVMs

- Focus DGVMs
  - Predict productivity/carbon sequestration in response to changes in climate, CO_2 exposure, N deposition, *diffuse radiation* and ozone exposure.

- Focus DSVMs
  - Predict productivity/carbon sequestration in response to changes in N and *S deposition, soil acidity, nutrient (phosphate and base cations) availability* , climate, CO_2 and ozone exposure.

Role of DGVMs and SGVMs

- Other roles of SVGMs (link to UNECE work on CL)
  - Predict plant species diversity in response to changes in N and S deposition, soil acidity, nutrient (phosphate and base cations) availability and climate (role ozone exposure, CO_2 fertilization?)
  - Derive critical loads for N (and S) deposition on the basis of an inverse modelling approach (from required abiotic conditions).

Model choice

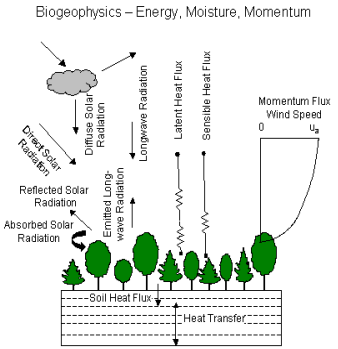
Limited number of models, all engaged in major European wide infrastructure activities

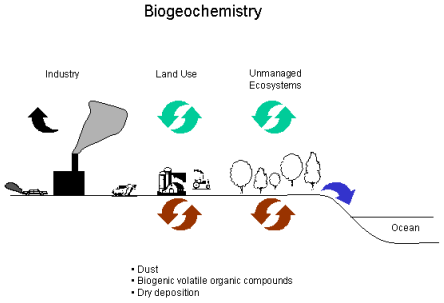
- DGVMs: CLM, LPJ Guess, Jules, O-CN
- DSVMs with a strong role in ICP M and M/critical loads community
  - VSD^{+}-FORSPACE; VSD-MADOC: soil chemistry-growth models
  - GBMOVE-EUMOVE: plant species diversity models

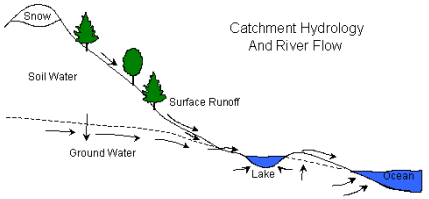
MODEL: CLM 4.0

- Community Land Model CLM4.0 (http://www.cgd.ucar.edu/tss/clm/)
- CLM is the land scheme of the Community Earth System Model (CESM)
- CLM formalizes concepts of ecological climatology to understand how natural and human changes affect climate
- It includes physical, chemical, and biological processes by which terrestrial ecosystems affect and are affected by climate across a variety of spatial and temporal scales.

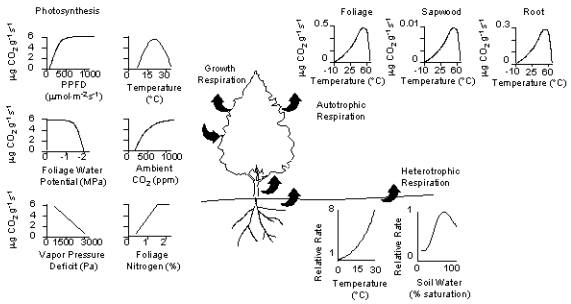
Biogeophysics | **Biogeochemistry** | **Hydrologic cycle** | **Dynamic Vegetation**







Copyright Bonan, G.B. (2002) Ecological Climatology: Concepts and Applications. Cambridge University Press, Cambridg



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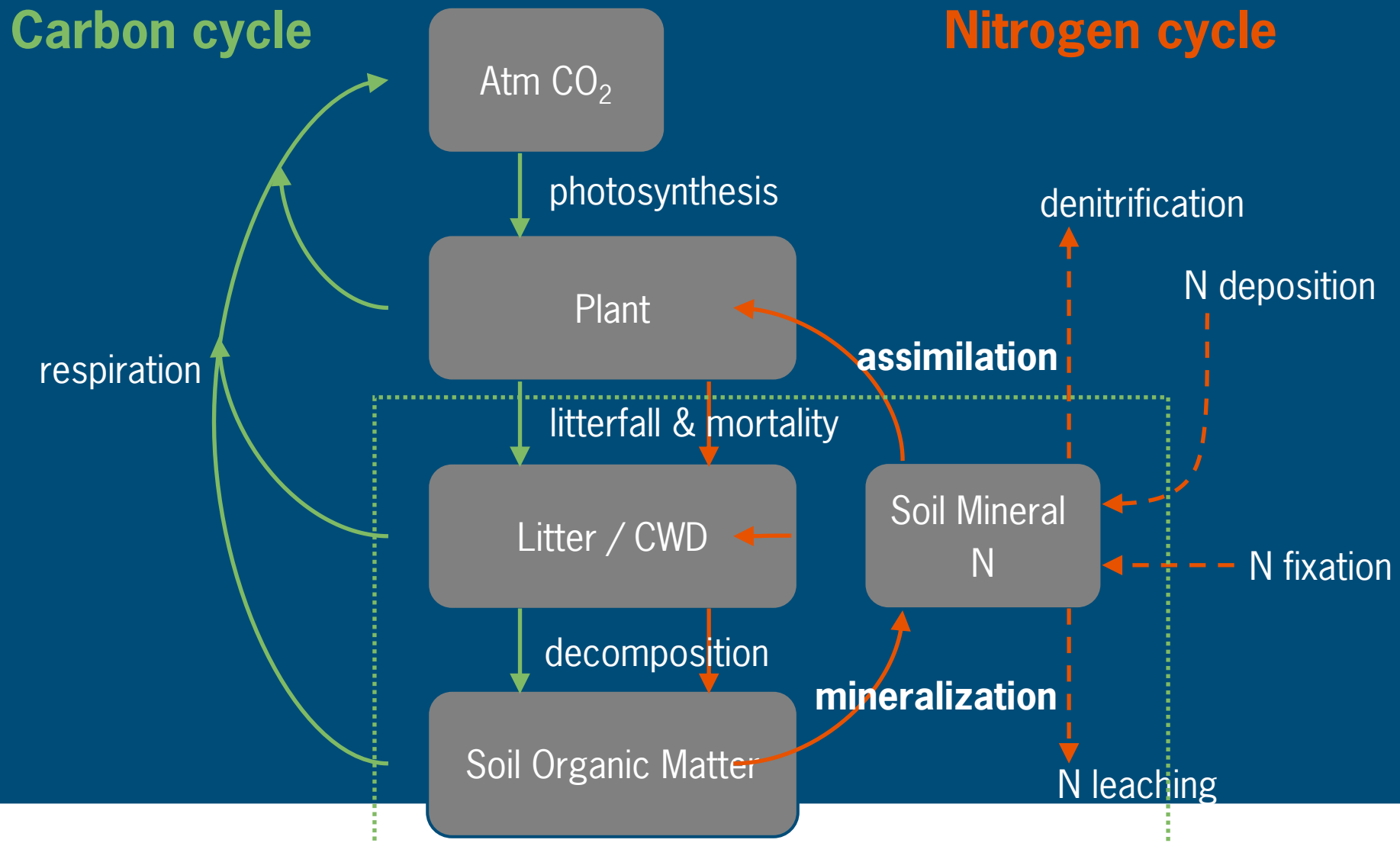
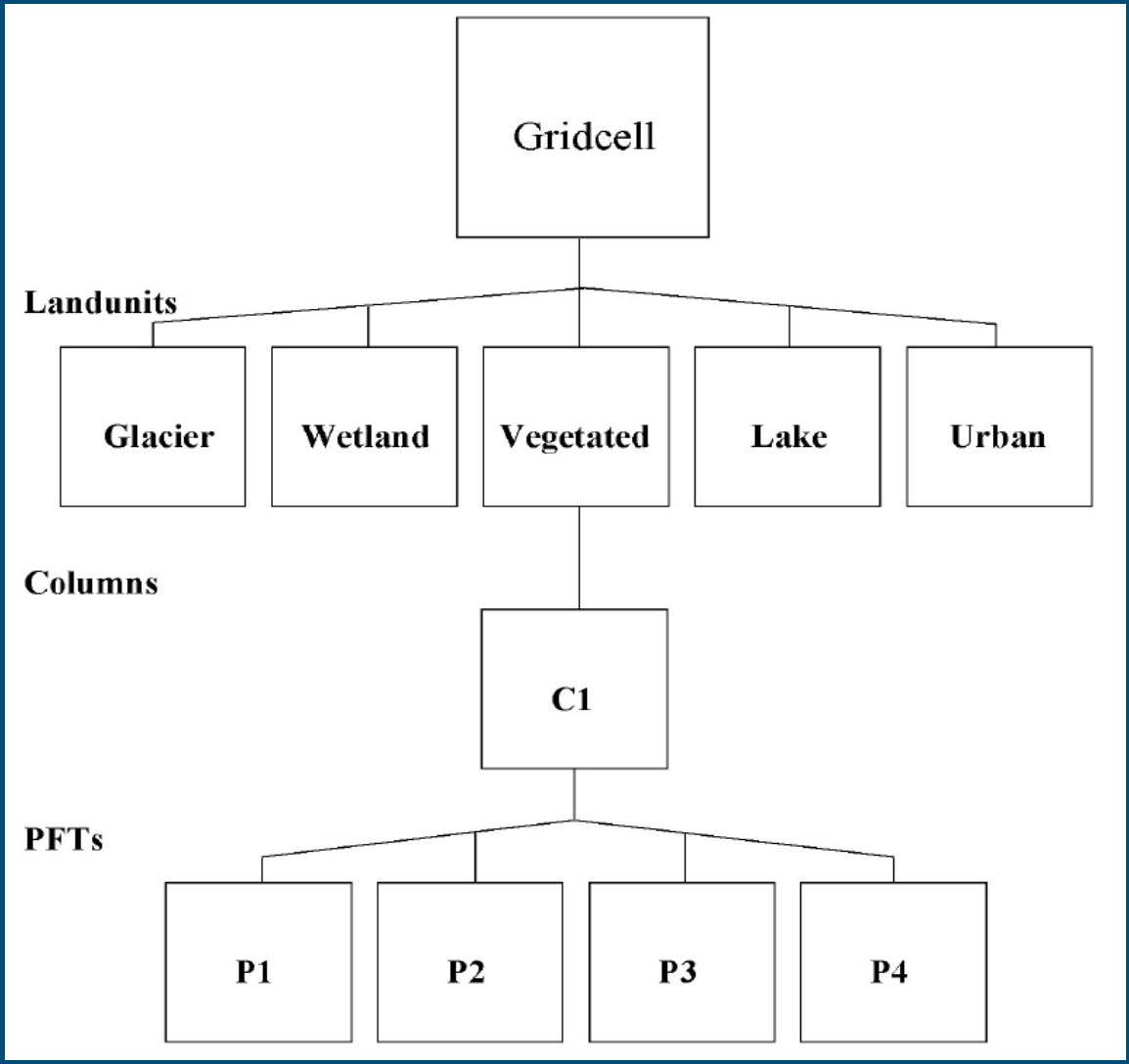
Representation of the C/N interaction in CLM



CLM-CN Model structure

Nested hierarchical representation of the land surface



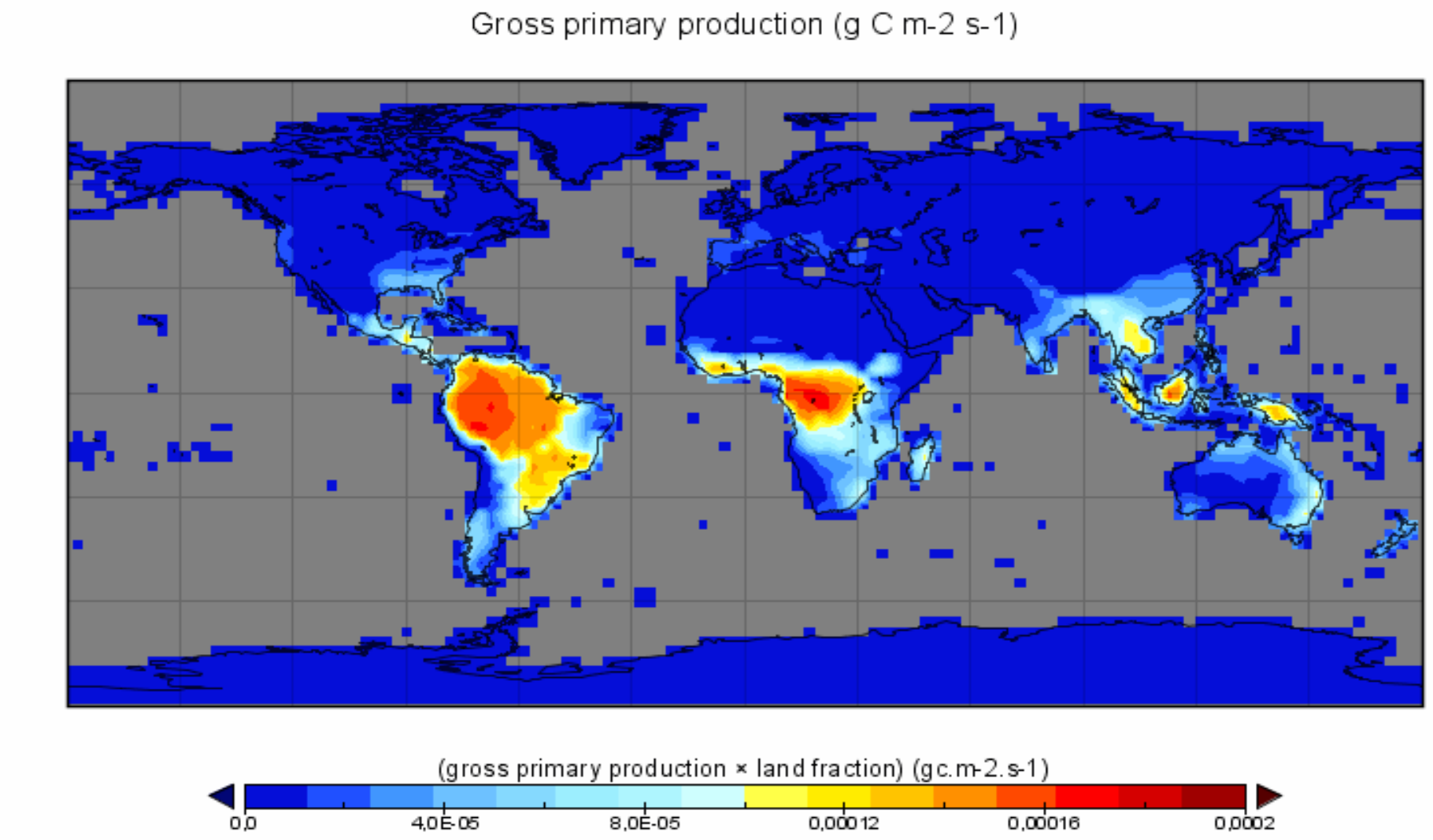
GRIDCELL – pixel of the CGM or RCM

LANDUNITS - Fraction of Gridcell with uniform soil properties

COLUMNS - Fraction of Landunit with uniform soil status (water, temperature)

PFTs - Fraction of Column with uniform Plant Functional Type

Modelling GPP at global scale with CLM

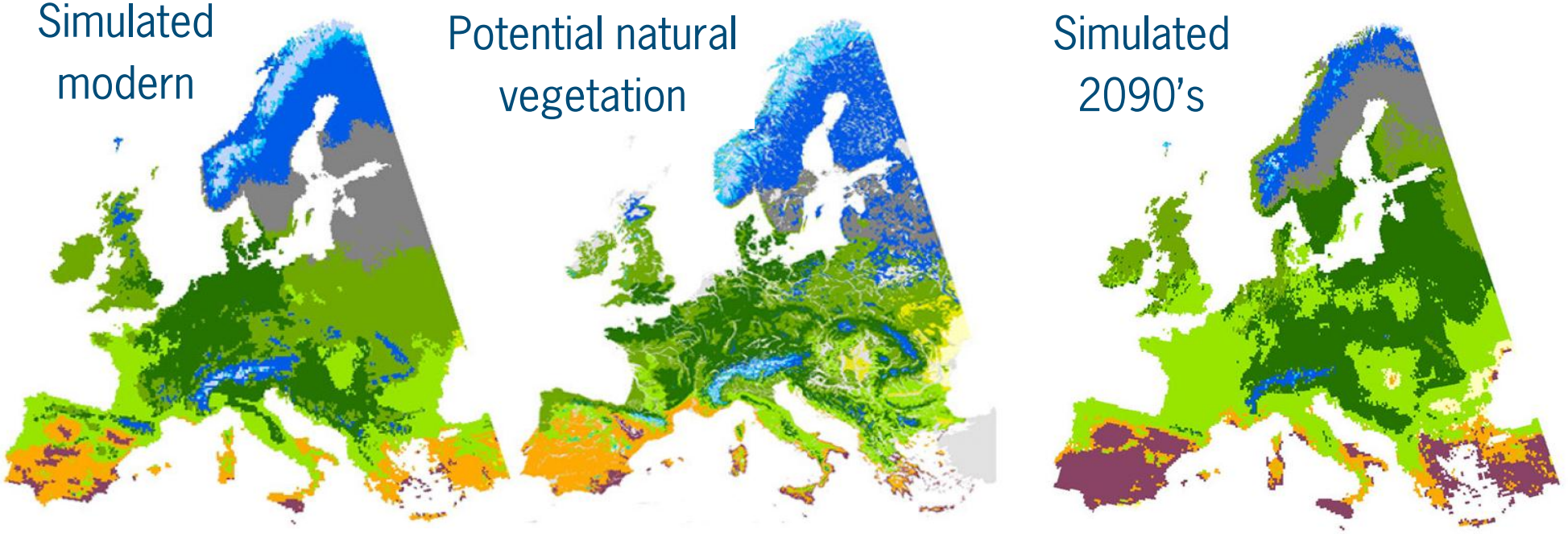


Modelling vegetation zones in Europe with LPJ-Guess

Simulated modern

Potential natural vegetation

Simulated 2090's



- Arctic/alpine desert
- Arctic/alpine tundra
- Boreal/alpine mixed woodland
- Boreal/alpine conifer forest
- Hemiboreal mixed forest
- Temperate beech and mixed beech forest
- Temperate mixed broad-leaved forest
- Thermophilous mixed broad-leaved forest
- Mediterranean sclerophyllous forest/woodland
- Mediterranean sclerophyllous shrubland
- Steppe woodland
- Steppe

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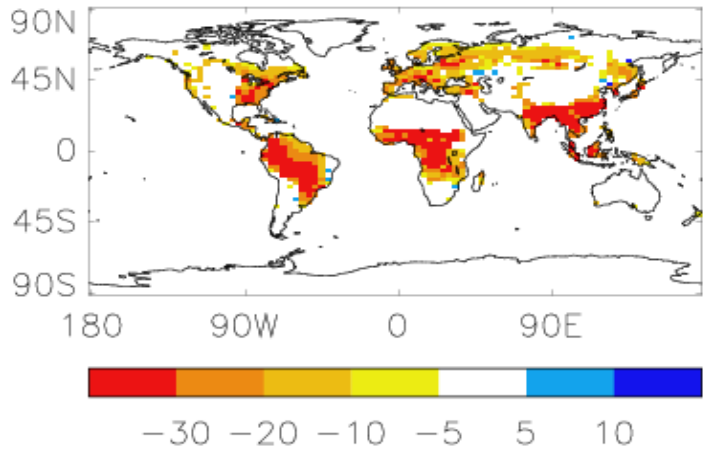
Hickler et al. in press.

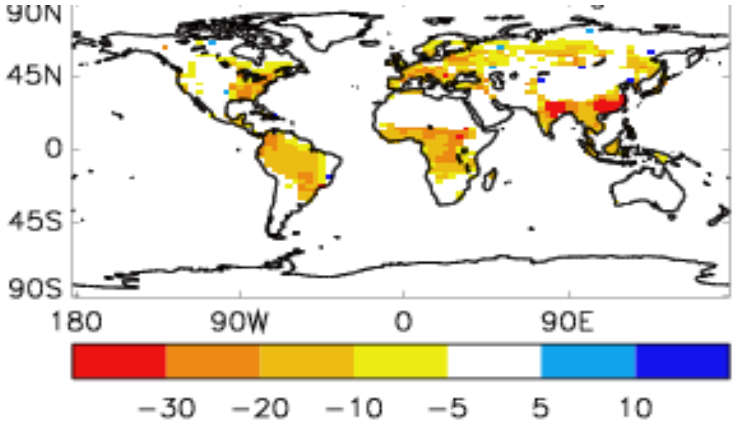
JULES application: Ozone effects on GPP, 1901-2100

% Δ GPP due to O_3-effect

High sensitivity parameterisation



Low sensitivity parameterisation

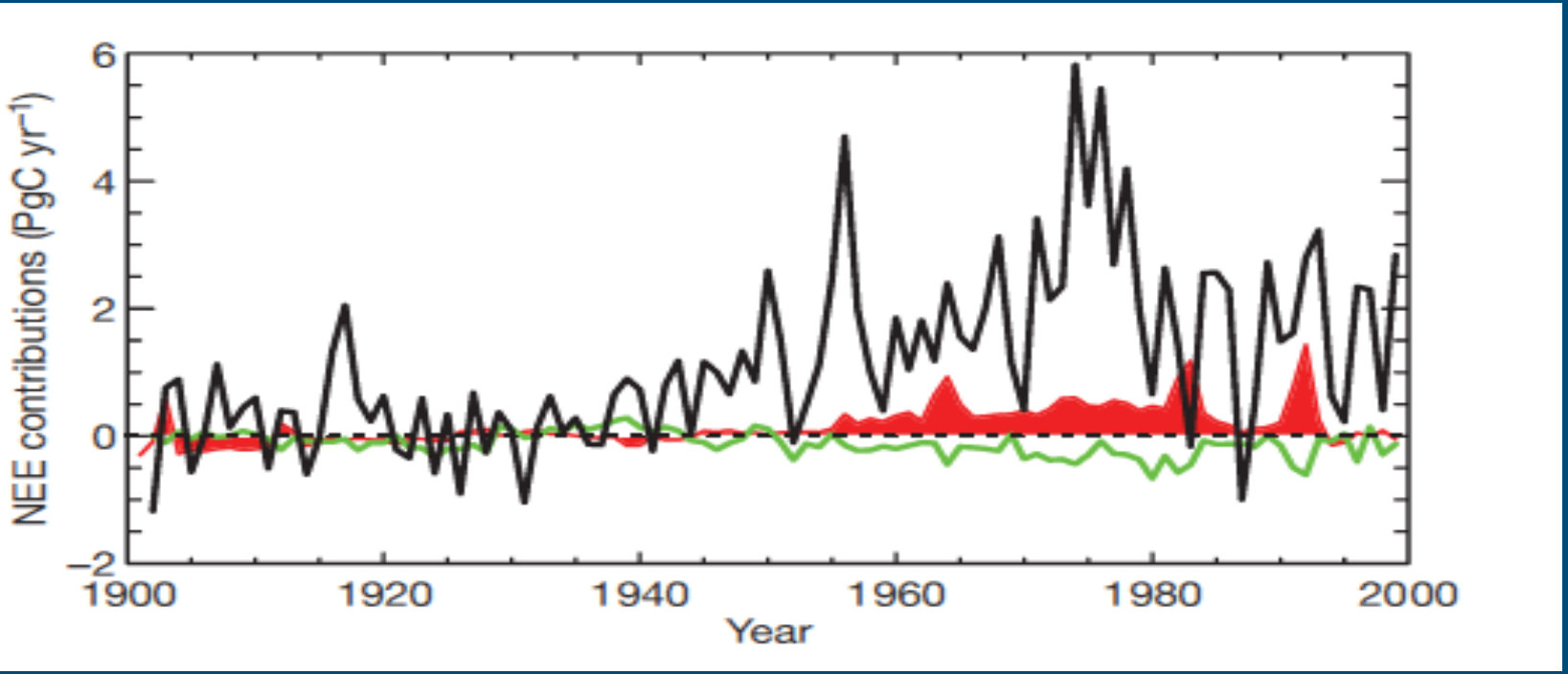


- Large reductions in productivity and land carbon storage over temperate and tropical regions
- Elevated future [O_3] reduces land ecosystem carbon sequestration
- Large indirect radiative forcing due to additional CO_2 in the atmosphere
- Chemistry more important driver of climate change than hitherto expected

Sitch et al. 2007, Nature

JULES application: Aerosol effects on C uptake 1901-2100

Enhancement of plant C uptake due to increased diffuse radiation

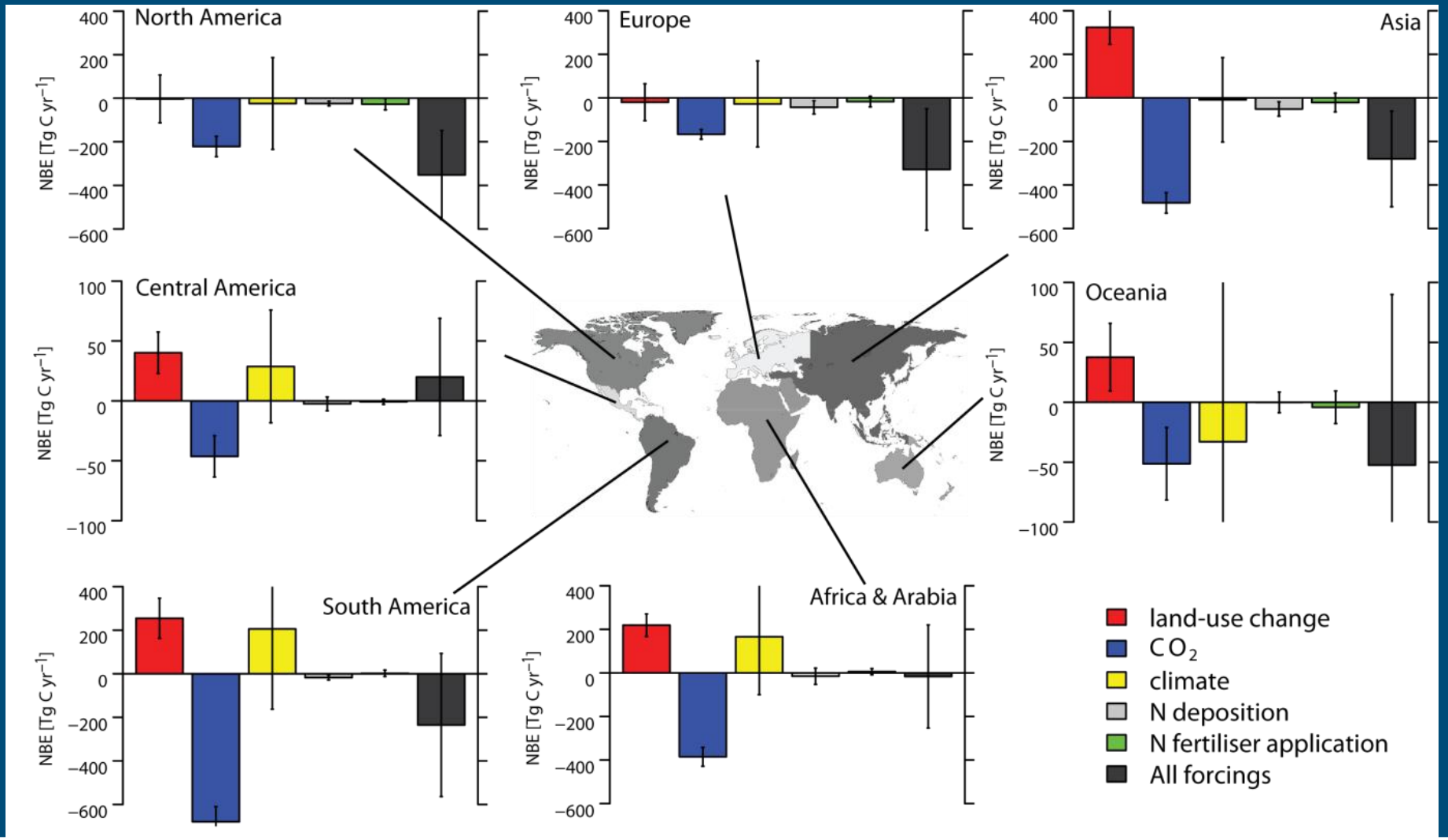


During 1960-2000 (dimming & brightening periods)

Diffuse radiation fertilization effect	+23.7%
Reductions in total PAR	-14.4%

Source: Mercado et al. 2009, Nature

O-CN application impact of drivers on global C sequestration



Source: Zaehle et al. (2011)

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VSD+-FORSPACE/EUMOVE model chain

Initial biomass
Management
Structure

Deposition
Soil chemistry
Hydrology

EUMOVE → **Plant diversity**

FORSPACE
- plant biomass → **C-sequestration**

VSD+
- Soil processes → **C-sequestration**

-pH
-nutrient availability

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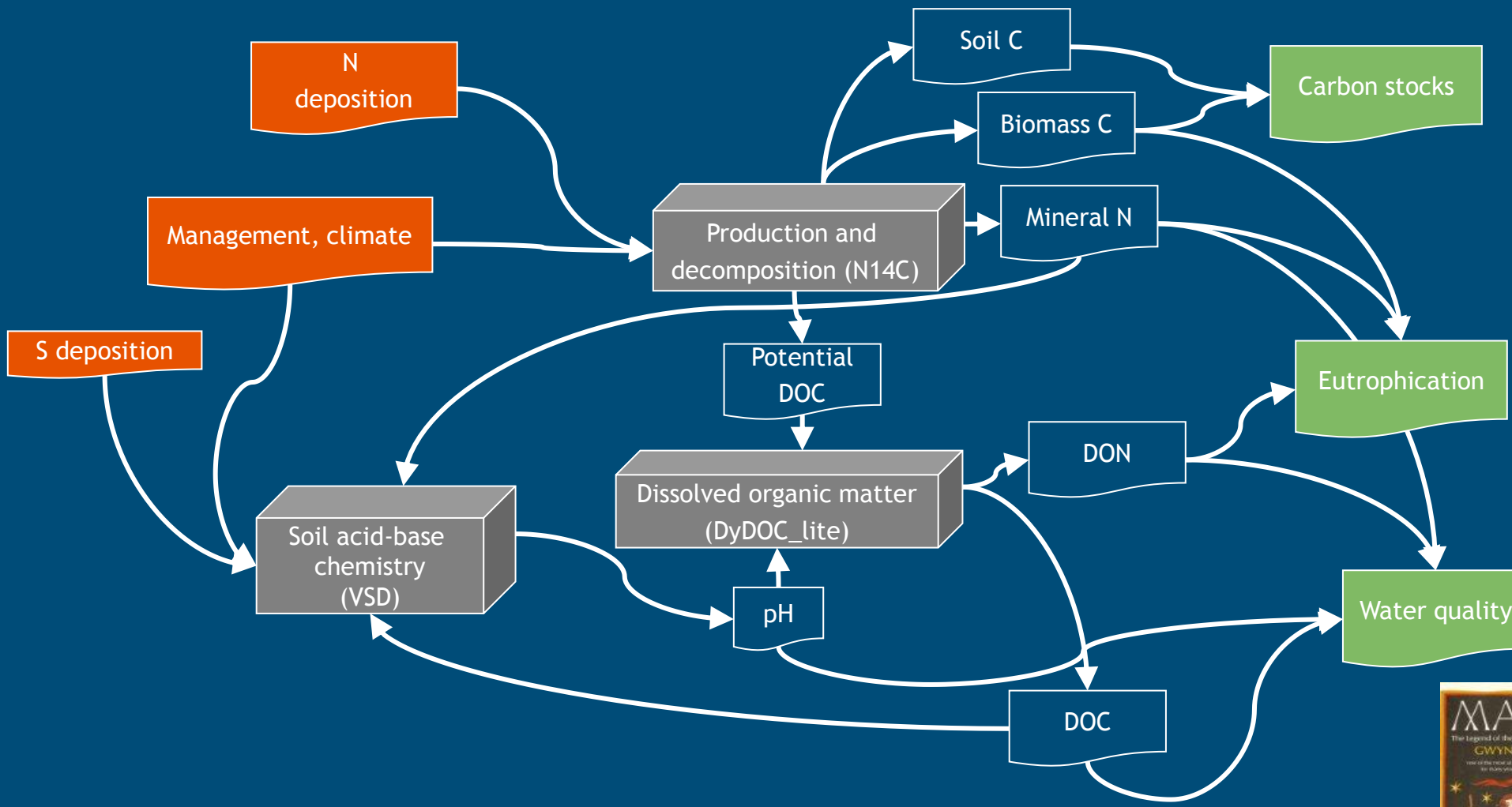
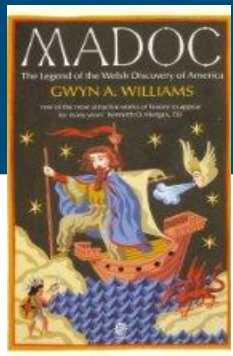
MADOC Model chain





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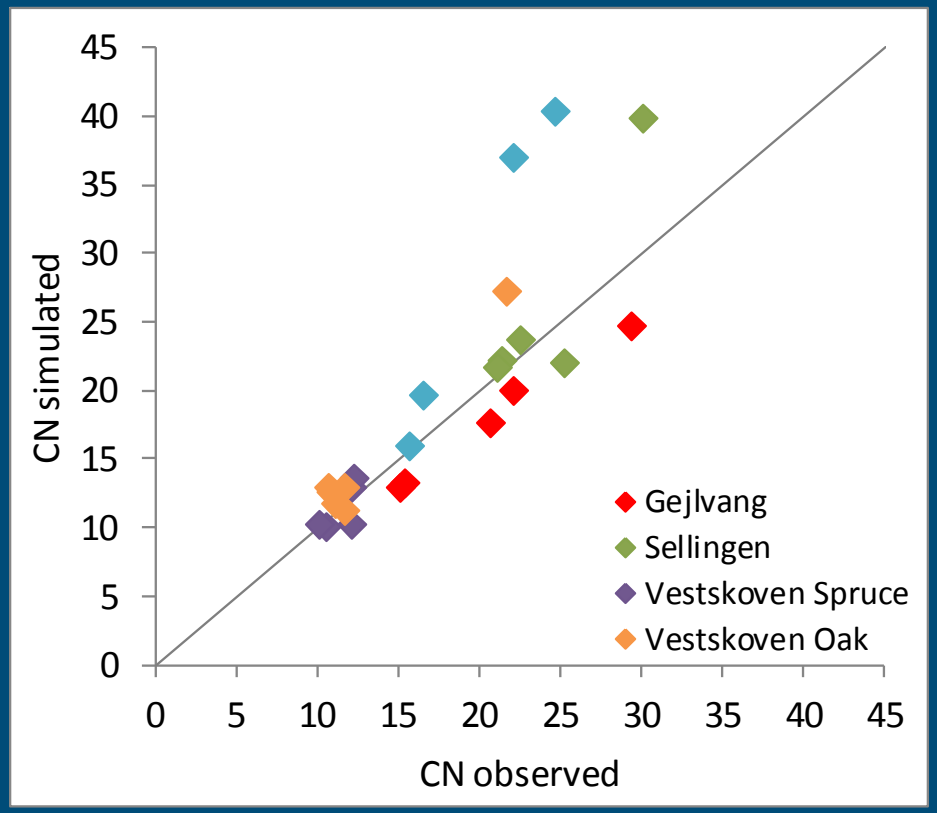
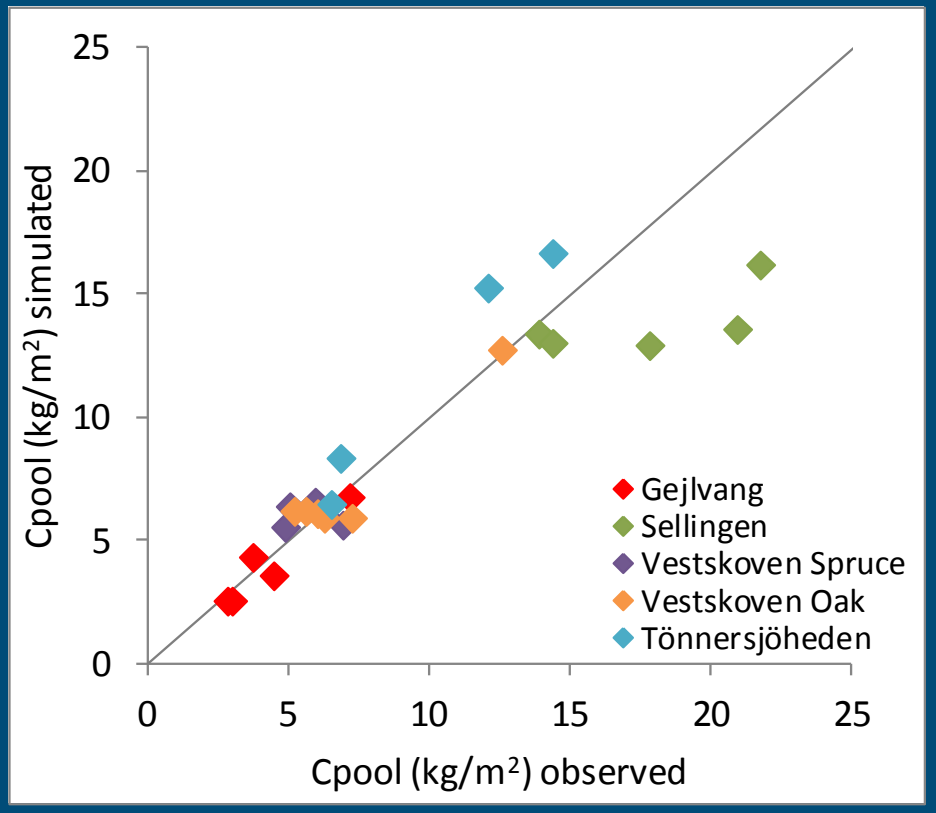
Validation C-N interactions at chronosequences





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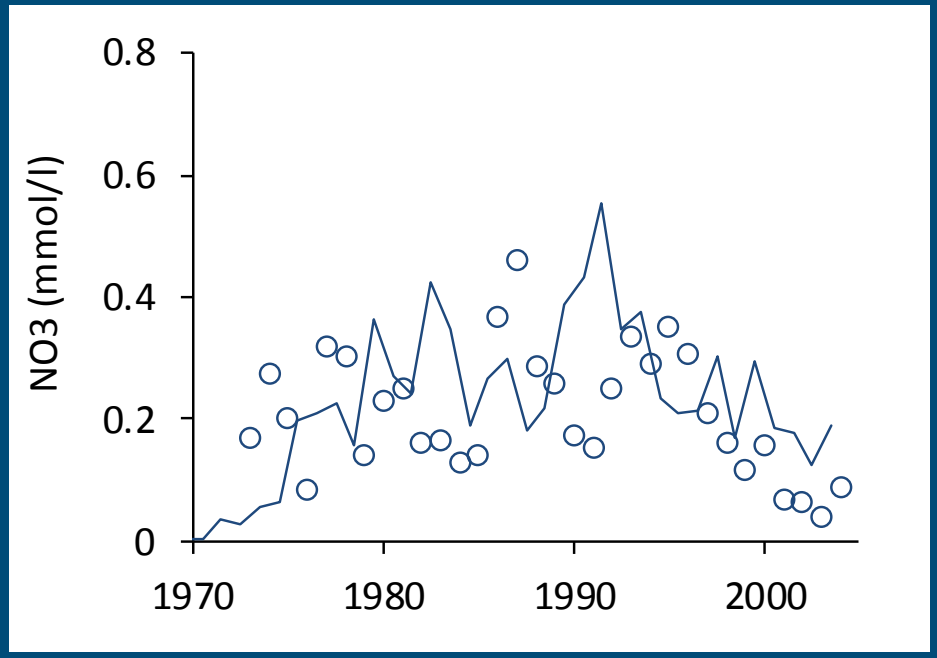
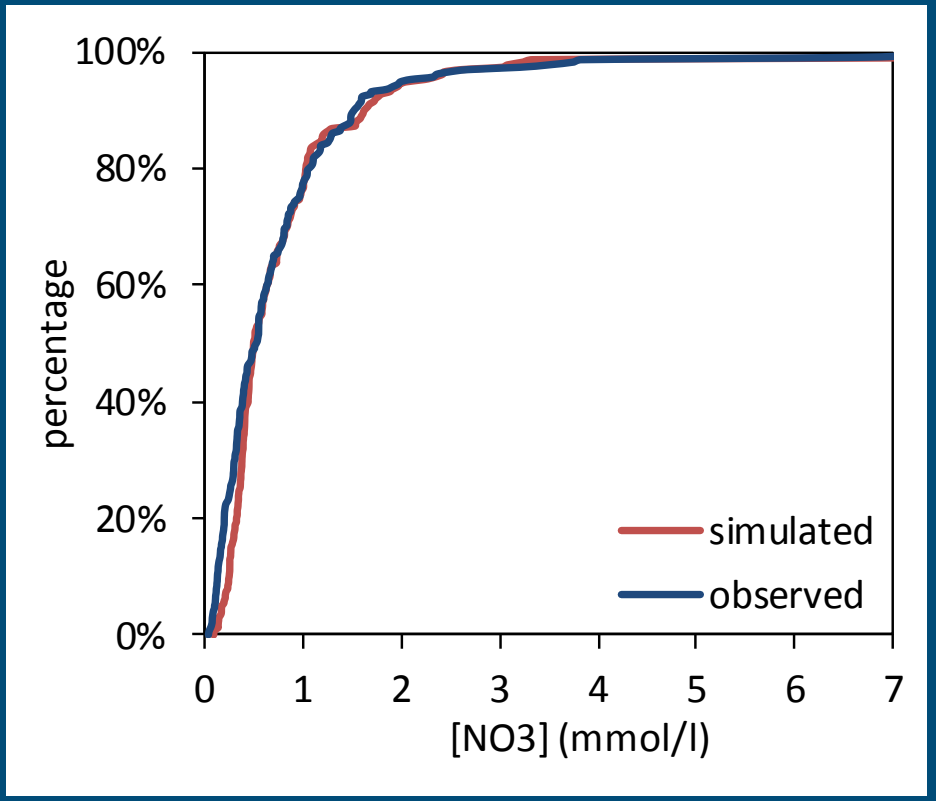
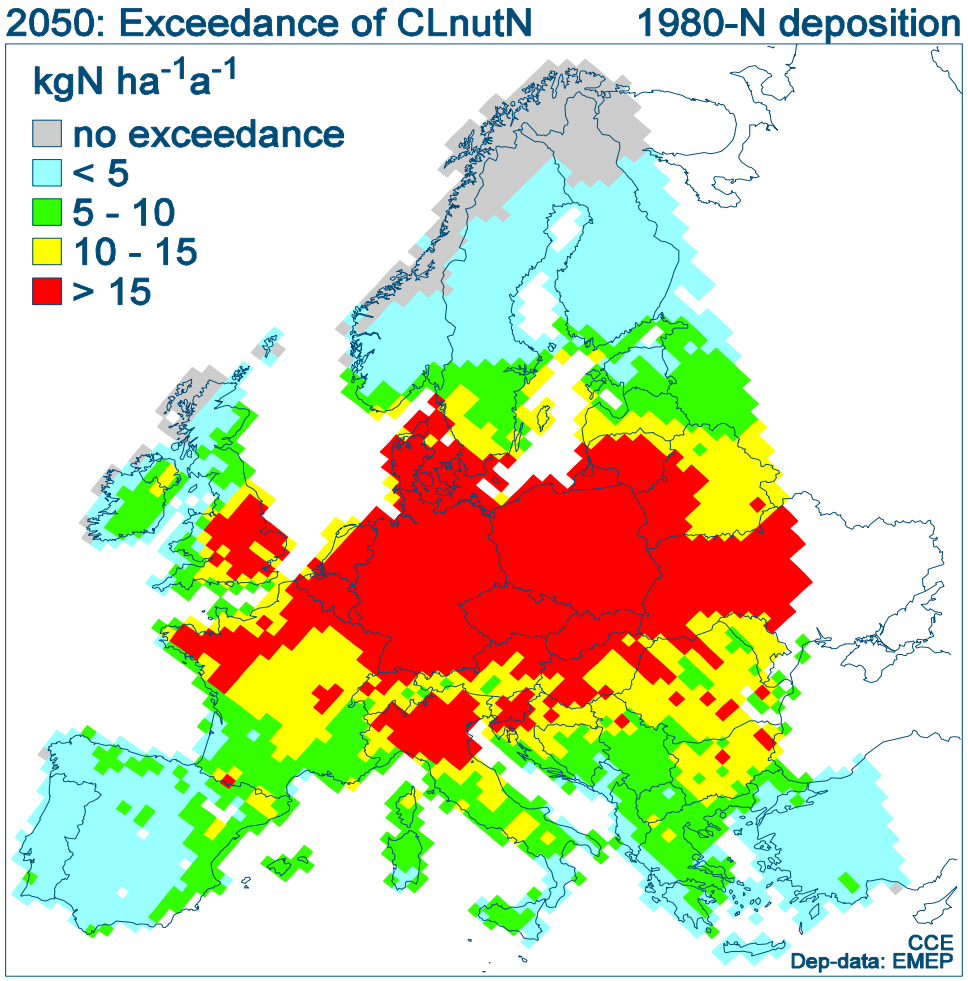
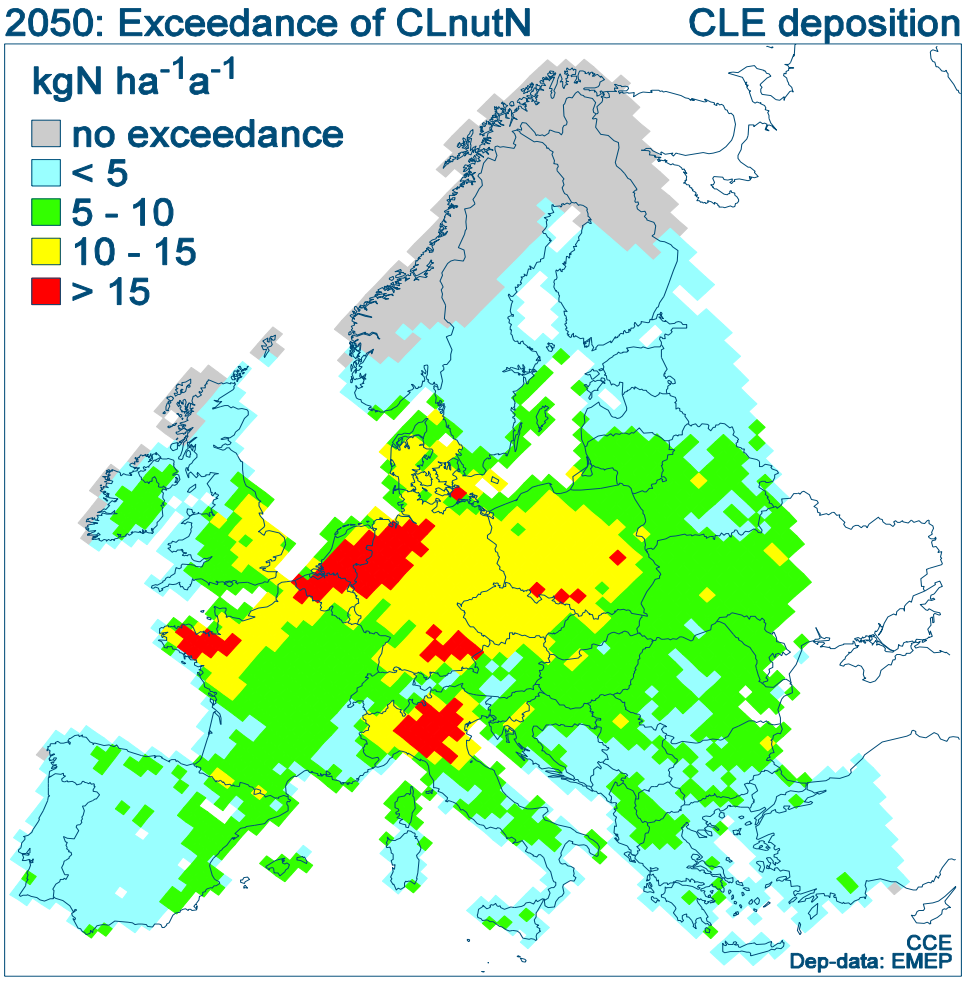
Validation NO3 behaviour at long term monitoring plots





VSD+ application: Critical N load exceedances





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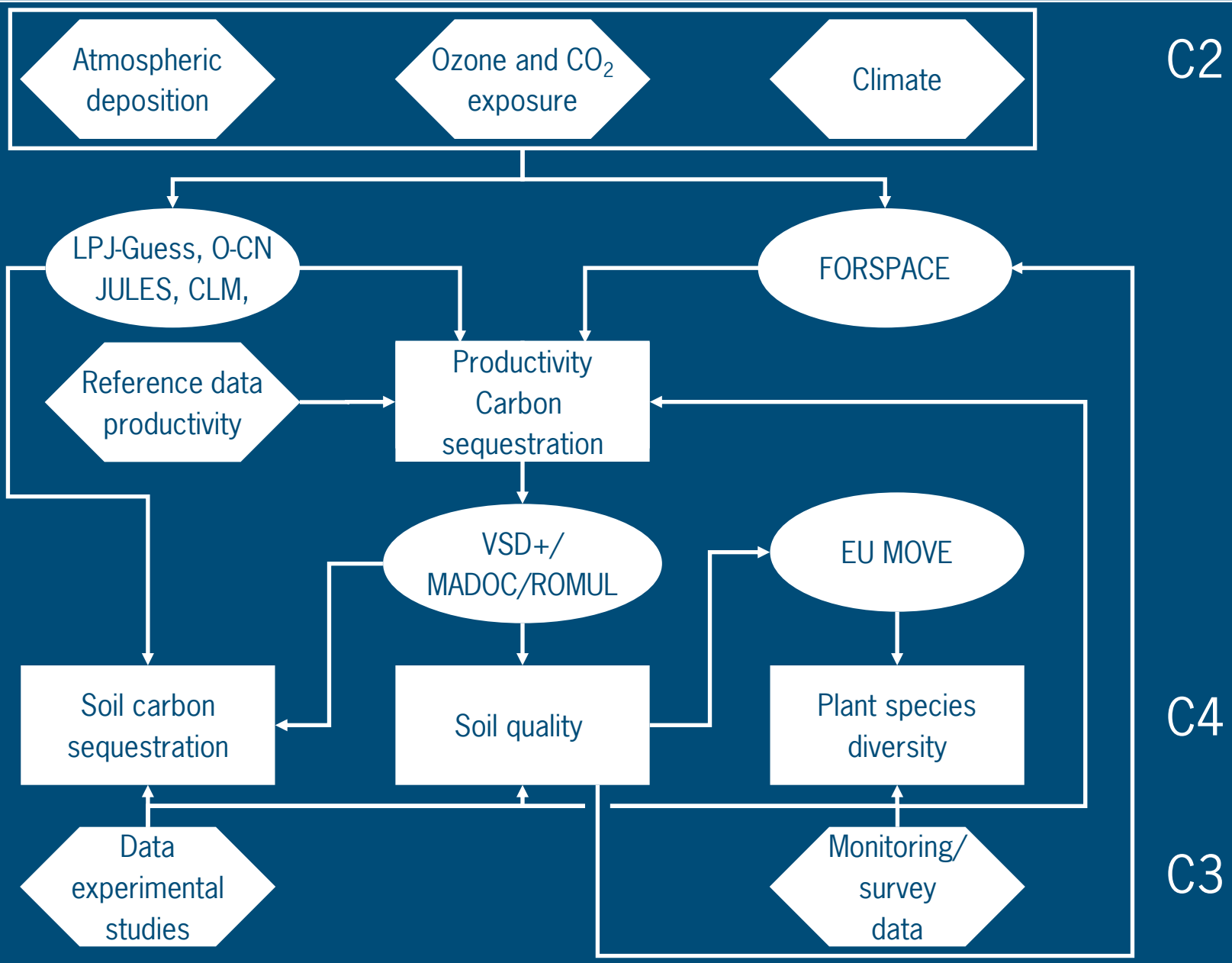
Static plant diversity models: MOVE, GBMOVE, EUMOVE

- Multiple logistic regression of vegetation indices (Ellenberg indicator values) for moisture, acidity and N availability versus species presence in tens of thousands of relévés from NL (MOVE) and UK (GBMOVE) plant communities (static approach)
- Build calibration equations between mean Ellenberg values and abiotic data
- Multiple logistic regression for measurements of moisture, acidity and N versus species presence in tens of thousands of relévés from EU (EUMOVE)

Eclaire modeling approaches in C4 and links to C3 and C2



WP14 Air pollution-climate impacts on European carbon stocks and green house gas emissions

- Improvement DGVMs
  - LPJ-Guess: improved process description of O_3 uptake and phytotoxic effects including protective role of BVOCs.
  - JULES: improving existing leaf level O3 uptake model and linking with existing soil and vegetation N uptake models.
  - CLM and O-CN: inclusion of deposition model estimating total/stomatal O_3 flux.

WP14 Air pollution-climate impacts on European carbon stocks and green house gas emissions

- Improvement DSVMs
  - Linking Forspace model to VSD+: include availability of base cations, impact of soil pH and the effects of O_3 uptake on plant and soil carbon sequestration.
  - Linking updated JULES to MADOC: JULES provides NPP as input for simulations of soil carbon sequestration and plant species diversity.

WP14 Air pollution-climate impacts on European carbon stocks and green house gas emissions

- An ensemble model applications of long-term impacts of
  - various scenarios of climate change, air quality change (exposure to O_3, PM and CO2) and deposition of nutrients (N, S, P, base cations)
  - on plant production/ carbon sink strength
  - of forests, semi-natural systems, grassland and croplands using the integrated DGVMs and DSVMs

WP15 Interactive air pollution-climate impacts on biodiversity and soil quality

Model interlinkage of

- updated FORSPACE-VSD^{+} with multi-plant species model EUMOVE
- updated JULES-MADOC with EUMOVE.

Model application by VSD+- EUMOVE and JULES-MADOC -EUMOVE.

- Parameterizing VSD^{+} and MADOC by radiocarbon (^{14}C) data to constrain soil carbon turnover rates.
- Assessing long term impacts of combined air pollution and climate impacts on plant species diversity and soil quality

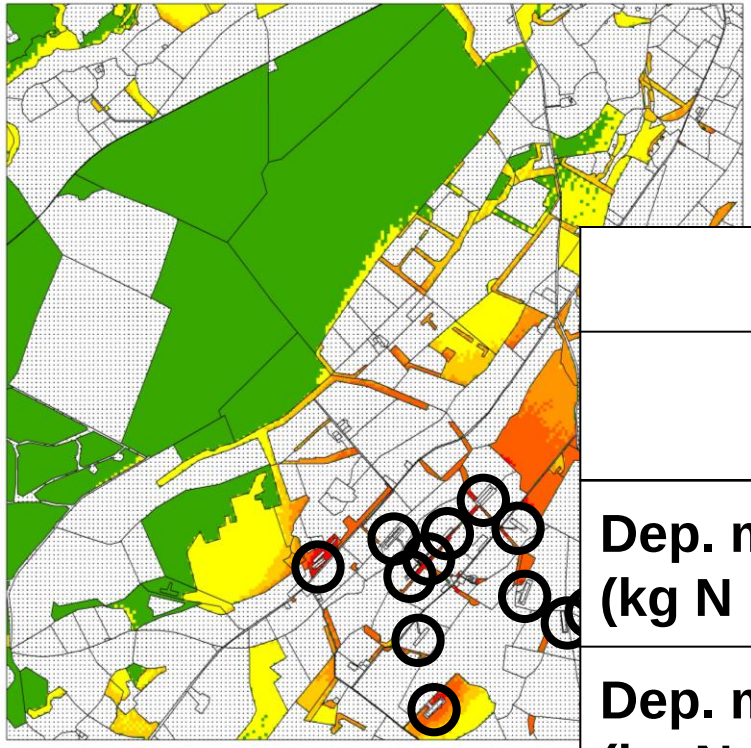
WP16 Mapping novel critical loads and exceedances

- Nitrogen
  - Apply VSD+-EUMOVE in an inverse way, to assess climate dependent critical N loads.
  - Attempt to map critical thresholds for NH_3 versus NO_x.
  - Mapping exceedances of critical nitrogen loads.
- Ozone
  - Mapping of critical ozone uptake thresholds, based on a spatial explicit assessment of tree species and crop types.
  - Mapping ozone uptake by EMEP DO_3SE and related exceedances of critical ozone uptake thresholds.

WP17 Local variation in threshold exceedance

- Assessment of critical N thresholds and their exceedances for 2010 in:
  - 2 study regions (central Scotland and the Netherlands)
  - 2 landscapes (Burnsmuir and Noordelijke Friese Wouden),
- with:
  - EMEP unified model (50 km x 50 km)
  - EMEP4UK at 5 x 5 km; EMEP4UK zoom at 1 x 1 km for central Scotland and the Netherlands;
  - NitroScape model at 50 x 50 m for landscape scale assessment

Example: Exceedance of N dep. critical load (10 kg N ha^{-1} yr^{-1})



Poultry farm

Study area in southern Scotland (6 x 6 km)

	Model (Resolution)		
	EMEP (50 x 50 km)	**FRAME (1 x 1 km)**	**LADD (25 x 25 m)**
Dep. mean (kg N ha^{-1} yr^{-1})	7.3	3.2	17.6
Dep. max (kg N ha^{-1} yr^{-1})	7.3	10.8	1200
% habitat area exceeded	0%	51%	34%

Vogt *et al.*, Spatial variability of atmospheric ammonia at the landscape scale: A case study (in prep.)

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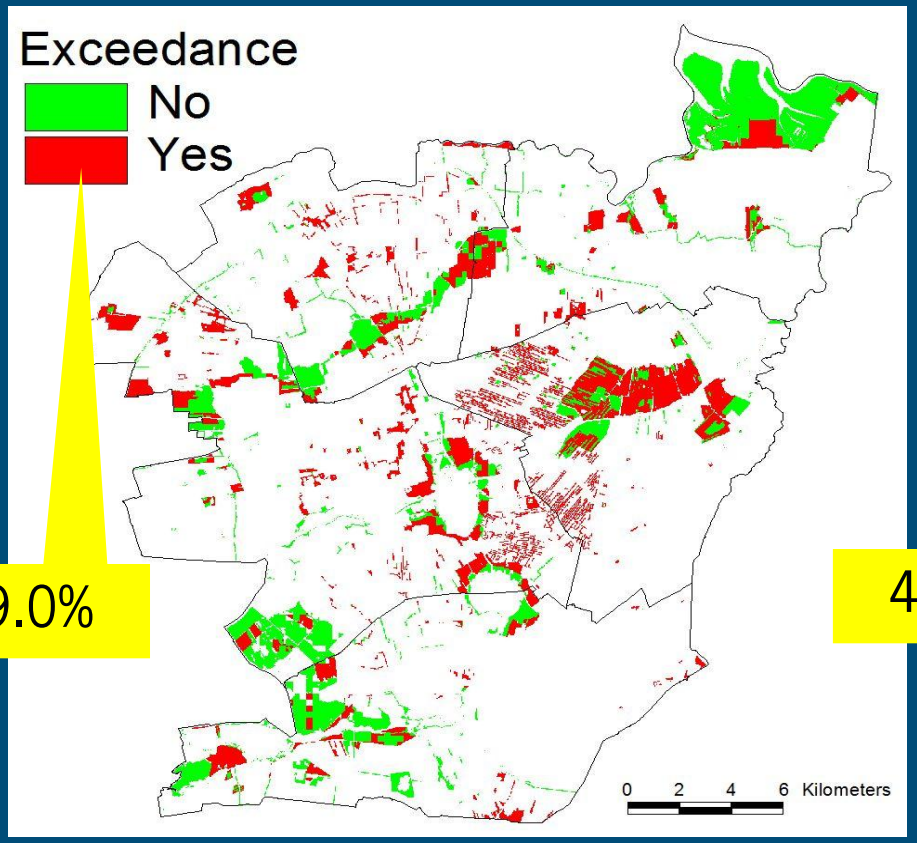
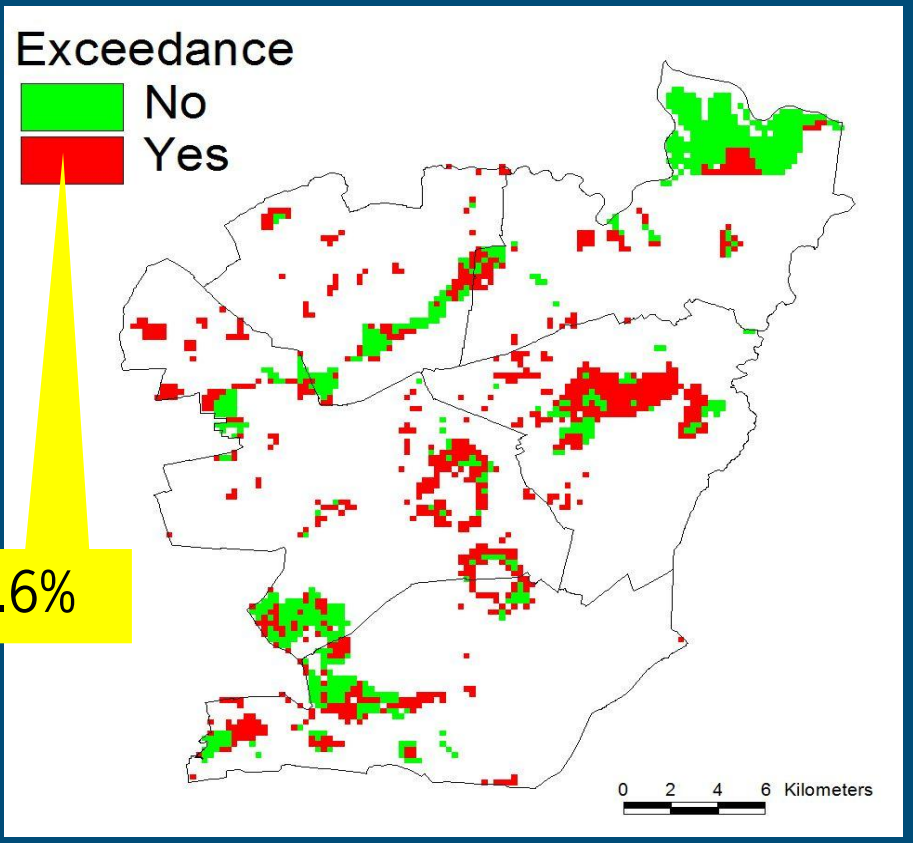
Example: Exceedance of N dep. critical load NFW



49.0%

25m



48.6%

250m

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Domains, grid resolutions and input data sources for zooming.

Decreasing domain size, increasing resolution

Domain	Grid resolution	Source of concentration and deposition data
EU27	50 x 50 km	**EMEP model (A2.4)**
NW Europe (including UK and the Netherlands)	5 x 5 km	**EMEP4UK model (A2.4)**
NW Europe (including central Scotland and NFW)	1 x 1 km	**EMEP4UK model (A2.4)**
Landscape (Burnsmuir and Noordelijke Friese Wouden)	**50 m or less**	**NitroScape model[1] (A2.4)**

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Discussion issues

- Common C4 meeting
  - Role of different DGVMs in C4.1
  - Interlinkages C4.1-C4.4
  - Use of common data/ scenarios for period 1900-2100 on land cover, soil, climate etc

- Combined C4 meetings with C2, C3 and C5
  - Required spatial and temporal resolution of input data (C2/C4).
  - Model improvement and validation at local/regional scale (C3/C5)
  - Use of C4 models or C4 model results in GAINS (C4/C5).

Questions?

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Aims Component 4

- Assess combined impact of air quality change and climate change at European scale on: (i) plant productivity/carbon sequestration (WP14) and (ii) plant species diversity (WP15).
- Map novel thresholds for N (NH_3, NO_x) deposition and O_3 exposure at European wide scale and their exceedances (WP16).
- Assess uncertainty of European scale predictions, considering the required upscaling: effects of model resolution (WP17).

Deliverables in first 2 years

- WP14
  - **D4.1.1:** Synthesis of applicable data on impacts of ozone on photosynthesis, stomatal conductance and plant functioning (**Month 6**)
  - **D4.1.2:** Updated versions of DGVMs and DSVMs that include ozone uptake model and N deposition on carbon uptake (**Month 18**).
  - **D4.1.3:** Validated and evaluated version of models (DGVMs and DSVMs) using databases on plant productivity (**Month 24**).
- WP15
  - **D4.2.1**: The model EUMOVE (**Month 24**)
  - **D4.2.2**: Collated dataset of European soil 14C data as a function of soil/vegetation type, for model parameterisation (**Month 24**)

Deliverables in first 2 years

- WP16
  - **D4.3.1:** Indicators for geo-chemical and biological endpoints **(Month 12).**
  - **D4.3.2:** Map of critical ozone uptake thresholds at European scale **(Month 24).**

- WP17
  - **D4.4.1:** Database of soil and vegetation data for the regional (5 x 5 km and 1 x 1 km) and landscape (~ 50 x 50 m) domains **(Month 12)**
  - **D4.4.2:** Database of ammonia concentration and nitrogen deposition data (from A2.4) for the regional (5 x 5 km and 1 x 1 km) and landscape (~ 50 x 50 m) domains, where available **(Month 18)**