Projected changes in mineral soil carbon of European forests, 1990-2100

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Not this ATEAM:
But this ATEAM:
RothC

\[ \text{CO}_2 \]

- RESIDUE
- soil surface

- DPM \( k=10 \text{ y}^{-1} \)
- RPM \( k=0.3 \text{ y}^{-1} \)
- BIO \( k=0.66 \text{ y}^{-1} \)
- HUM \( k=0.02 \text{ y}^{-1} \)
- IOM
Data

- Climate data
  - 20th Century – measured (temperature and precipitation) data interpolated to ATEAM grid (Mitchell et al., 2004)
  - 21st Century – downscaled output from 4 GCMs to ATEAM grid (Mitchell et al., 2004) for 4 IPCC SRES scenarios (see next slide)
  - PET calculated using LPJ-DGVM for ATEAM grid for 1900-2100
Scenarios for future climate

Economically oriented

A1 – “World Markets”
- very rapid economic growth
- low population growth
- rapid introduction of technology
- personal wealth above environment

B1 – “Global Sustainability”
- rapid change in economic structures
- "dematerialization"
- introduction of clean technologies
- emphasis is on global solutions

A2 – “Provincial Enterprise”
- strengthening regional cultural identities
- emphasis on family values and local traditions
- high population growth
- less concern for rapid economic development

B2 – “Local Stewardship”
- emphasis is on local solutions
- less rapid, and more diverse technological change
- strong emphasis on community initiative
- local, rather than global solutions

Climate data: 2080-1990 temperature

Note: 2080 and 1990 are 30 year averages of 2051-2080 and 1961-1990 respectively
Climate data: 2080-1990 water balance

Note: 2080 and 1990 are 30 year averages of 2051-2080 and 1961-1990 respectively
Data

• Soils data
  – new soils database of ESB (JRC-Ispra) aggregated from 1km$^2$ to ATEAM grid
  – SOC (t C ha$^{-1}$) to 30cm depth calculated as weighted mean for each cell from %C and bulk density
  – Clay% - weighted mean for each cell
Soils data – SOC
Data

• NPP data
  - NPP calculated using LPJ-DGVM for ATEAM grid (g C m\(^{-2}\)) and used in the EFISCEN model to calculate litter inputs to the soil
NPP change data: 2080-1990 NPP

Note: 2080 and 1990 are 30 year averages of 2051-2080 and 1961-1990 respectively
Data

• Litter data
  – EFISCEN calculated litter input
  – including effects of changing NPP (using LPJ outputs) and effects of changing age-class structure (projected with EFISCEN from national forest inventories)
Change in litter inputs 1990-2080

% change from 2000 forest litter input

Year

2001 2007 2013 2019 2025 2031 2037 2043 2049 2055 2061 2067 2073 2079 2085 2091 2097

Age class effect only A2 A1FI B1 B2
Data

• Land-use change
  – ATEAM land-use change scenarios of Rounsevell et al. (2004)
  – 1990 baseline land-use / land-cover from Corine data bases
  – change in proportions of forest, grassland and cropland, as well as proportions of land under liquid-, non-woody- and woody-bioenergy crops, urban and surplus land for 2020, 2050 and 2080 calculated per ATEAM grid cell
Land-use change

Forest area in 2080 under the four SRES scenarios
Land-use change

Forest area in 1990, 2020, 2050 and 2080 under the B2 scenario
Simulation procedure

• RothC run to equilibrium using average met. data 1900-1930
• Inputs of C necessary to obtain target starting soil C value (from soils data base) calculated analytically from target value and RothC output:
\[ P = P_i \times \frac{C_{meas} - IOM}{C_{sim} - IOM} \]
• IOM set according to Falloon et al. (1998):
\[ IOM = 0.049 \times C_{meas}^{1.139} \]
• model run to equilibrium using these C inputs to give soil C values at equilibrium in 1900 that match soil map values
• model run forward from 1900-2100 using data previously described
Litter input change - implementation

• Changes in litter input due to NPP changes and changes in forestry age-class structure as simulated by the EFISCEN model were used to adjust the plant additions between 1900 and 2100 as follows:

\[ P_t = P_{t-1} \times \frac{L_t}{L_{t-1}} \]
Land-use change - implementation

• Land-use change data for 30-year time-slices, 1990, 2020, 2050 & 2080
• Model calculates land-use change matrix each 30 years and initiates new runs from each of forestry, cropland and grassland:

\[
\Delta LU_{(ARA \rightarrow FOR)} = I_{FOR} \times \frac{D_{ARA}}{D_{ARA} + D_{GRA}} \\
\Delta LU_{(GRA \rightarrow FOR)} = I_{FOR} \times \frac{D_{GRA}}{D_{ARA} + D_{GRA}} \\
\Delta LU_{(FOR \rightarrow GRA)} = I_{GRA} \times \frac{D_{FOR}}{D_{ARA} + D_{FOR}} \\
\Delta LU_{(FOR \rightarrow ARA)} = I_{ARA} \times \frac{D_{FOR}}{D_{GRA} + D_{FOR}}
\]

• Outputs are linearly interpolated each year
• Per-ha stock apportioned according to history of the land category and summed by area within the cell of that land-use type
Results
Results
Climate only
Climate-only impact on SOC

(effect of different GCMs)
Climate-only impact on SOC
(effect of different climate scenarios)

Forest SOC stock (t C ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Year</th>
<th>A1FI</th>
<th>B1</th>
<th>B2</th>
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Change in forest SOC – climate only

A2 scenario HADCM3
Change in forest SOC in tC/ha (climate only)

- >15
- 16 - 10
- 10 - 6
- 5 - 0.1
- 0
- 0.1 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 50
- 50 <
Climate data: 2080-1990 temperature

Note: 2080 and 1990 are 30 year averages of 2051-2080 and 1961-1990 respectively
Climate data: 2080-1990 water balance

Note: 2080 and 1990 are 30 year averages of 2051-2080 and 1961-1990 respectively
Results

Adding the effects of litter
Comparing climate-only with climate & litter effects (HadCM3-A2)
Climate & litter impact on SOC

(effect of different climate scenarios)
Change in litter inputs 1990-2080

![Graph showing the change in litter inputs from 2000 forest litter input over years from 2001 to 2097. The graph includes lines for different age class effects and projections for A2, A1FI, B1, and B2 scenarios.]
Change in forest SOC – climate & litter

A2 scenario HADCM3
Change in forest SOC in tC/ha
(climate only)
Change in forest SOC – climate & litter

A2 scenario HADCM3
Change in forest SOC in tC/ha
(climate, NPP and litter)
Results

Adding the effects of land-use change
Impact on total forest SOC

Including land-use change
Impact on total forest SOC

No land-use change

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<tr>
<th>Year</th>
<th>Total SOC (Pg)</th>
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Overall effect (for EU15)

- Considering all of land-use change, change in age-class structure, climate and CO$_2$ driven NPP increase, and direct climate impacts on the soil:

  - B1 – increase by 3.3 Pg (19%)
  - B2 – increase by 4.6 Pg (27%)
  - A1FI – increase by 0.1 Pg (1%)
  - A2 – decrease by 0.3 Pg (2%)
Conclusions - 1

• Climate change speeds decomposition and will tend to decrease forest SOC

• Increases in NPP and changing age-class structure in European forestry will counteract this decline – in some cases leading to a small per-area increase (3-4 t C ha\(^{-1}\)) in SOC over the next century (B1 and B2), in others resulting in a small per-area decrease (2-4 t C ha\(^{-1}\); A1FI and A2) over the next century

• Increasing litter inputs cause increases in SOC until about 2050 when they level / decline and when the climate-mediated speeding of decomposition becomes dominant
Conclusions - 2

• Increasing forest area enhances the European forest SOC sink

• B1 and B2 show sustained forest area increases – largest SOC gains

• A2 – increase in forest area until 2050 after which it rapidly declines – paralleled in total SOC stock

• Gains including all effects:
  – B1 – increase by 3.3 Pg (19%)
  – B2 – increase by 4.6 Pg (27%)
  – A1FI – increase by 0.1 Pg (1%)
  – A2 – decrease by 0.3 Pg (2%)
Policy implications

• Already captured public imagination
• Foo Fighters - forest planted to replace CO₂ emitted in production and distribution of their latest CD
• Planted by FutureForests (www.futureforests.com)
• Also: Coldplay, David Gray, Massive Attack, Mel C, Atomic Kitten
Policy implications

• Increases in forest SOC due to changing age class structure – *not eligible as a sink as much of the effect due to planting before 1990?*

• Increases in forest SOC due to increased NPP – *not eligible as a sink as not direct human-induced effect?*

• Increases in forest SOC due to increased forest area – *eligible as sinks in the Kyoto process under article 3.3 as afforestation / reforestation / deforestation (ARD) activities?*

• Increases in forest SOC due to forest management – *eligible if after 1990?*
Thank you for your attention