Evaluation of mitigation effect from climate-change adapted forests
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Evaluation of mitigation effect from climate-change adapted forests

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Adapted to ... what?

The future of the forests environment (atmosphere, soil, hydrology) is not determined. Forest management may rely upon:

- (i) versatility: optimal combination of forest alternatives
- (ii) diversity: species and provenances mixture, ...
- (iii) resilience: plasticity,
Criteria for biogeochemical and climatic sustainability

✓ Negative or neutral radiative forcing

- Radiative balance
- Convective heat fluxes
- Greenhouse effect

« biophysical forcing »

✓ Negative (C) or neutral (N, P etc.) mass balance

- Carbon
- Water
- Nutrients

✓ Of the whole forest – wood products chain
Concerting management alternatives
(projects: FOREVER, MACCAC, Evafora, Forêts-21)

1. Managers, stakeholders

Climate scenarios
Other data (soil, inventories)

Management alternatives

Calcul
Simulations 8x8 km
2000-2100

2. Web services and model chain

GO+ Biljou CAT GALES FWI

3. Users

Web Server

INRA
SCIENCE & IMPACT

Task 38 – Workshop, 7 Nov. 2017, Angers, France
Forest management alternatives for biomass production

Species selection
- Coniferous: *Pinus p.*, *Pseudotsuga m.*, *Pinus s. Pinus n.*
- Broadleaved: *Fagus, Quercus*,
Predictive tool: process model of Forest WP chain Go+CAT

Forcings

Radiative & energy balances
Photosynthesis
Respiration
Allocation

Management: soil, vegetation, trees

Radiation
LW
H₂O
CO₂

Soil water
Plant water (ψ_leaf)
Deep runoff
Groundwater

Foliage
Branches
Stem
Tap root
Coarse roots
Small roots
Fine roots

Harvest Mortality
Soil C input
DPM, RPM
BIO
HUM

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Go+ model in short

Vegetation
- Hourly time step / ha spatial unit,
- 2 layers: Sun–Shade / Farquhar’ – Jarvis’ – Hydraulics –
- Phenology, Allocation, Growth, Mortality

Soil
- Roth-C,
- 3 Soil layers,
- Bucket model + Groundwater

Management
- Soil preparation,
- Vegetation management,
- Tree stand management
Management alternatives – 1. European Beech Standards.

Intensive
("Biomass and Energy")

Target D = 60 cm
Revolution = 10 y
Competition Index = 0.35

D = 80 cm
R = 15 y
C = 0.35

Self Thinning
("theoretical reference")

Age = 150y
R = 3 y
C = 1.0

Historical climate
Management Alternatives – 2. Coniferous Standards.

Intensive
(« Biomass and Energy »)

Standard
(« Timber »)

(Historical climate)
Results 1. 2000-2100 radiative forcing of management alternatives at regional level

- Aquitaine French Region (1Mha)

**Impacts:**

- Albedo (8x8 km) (SW $\downarrow$ RCP, $\alpha$ predicted by GO+, monthly $\tau_{atm}$ from NASA)
- Biogenic carbon sequestration
  - in situ: soil, tree and vegetation biomass (GO+ model)
  - C stored in 8 wood products categories (CAT model)

- Fossil carbon
  - Forest operations (Gonzalez Garcia et al. 2014)
  - Products transformations (CAT model)

- Fossil carbon substitution (Sathre et O’Connor, 2010)
  - $f$ from 0.5 (energy) to 3.0 (timber)

- Attenuation of atmospheric variations by Earth model (Forster et al. 2007)

- Radiative forcing of CO$_2$ = $f$ (concentration en CO$_2$) (Boucher et al. 2007)
1. Carbon stocks *in situ* and in wood products

RCP 2.6

- Soil and biomass stocks depleted in intensive alternatives
2. Radiative forcing is negative only if substitution is accounted for.
3. The overall radiative forcing of standard management is cooler in colder scenarios.
4. Dynamics of nutrients stocks in soil and biomass for different management alternatives predicted by Go+ (V. 26.51).

- Experiments at stand scale
- *Pinus, Fagus, Pseudotsuga*
- 4 to 8 management schemes tested
5. Biomass harvested and nutrients export over a 95 year period:

Intensification has a cost!
Few lessons from recent and ongoing R&D projects with ANR, ADEME, CNRS

- The best management scheme is the one that can be implemented by managers
- Intensification has environmental costs (climate, water, nutrients)
- Climate-management interaction is substantial

Thank you for attention
Acknowledgements

Recent projects having supported the Go+ model development:
- **ORACLE** (French ANR, N. De Noblet, CNRS, coord.)
- **MACCAC** (French ANR, O. Roupsard, CIRAD, coord.)
- **Forever** (CNRS, A. Dufour, coord.)
- **Evafora** (Ademe, O. Picard coord.)
- **PROFOUND** Cost action (COST, C. Reyer coord.)
Evaluation (1/4). Fluxes and stocks of energy, C and water.

COLLELONGO SITE

LE BRAY SITE

$R_n$, $\lambda E$

$NEE$

Basal area

LAI

Soil water

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Evaluation (2/4)

Daily fluxes at FLUXNET Sites. Statistics:

- $R^2$, RMSE
- Systematic & Unsystematic errors

### Table 1: Rn, $\lambda E$, and NEE Statistics

<table>
<thead>
<tr>
<th>Site</th>
<th>$R^2$</th>
<th>RMSE</th>
<th>$R^2$</th>
<th>RMSE</th>
<th>$R^2$</th>
<th>RMSE</th>
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</thead>
<tbody>
<tr>
<td>BC Campbell 49</td>
<td>0.97</td>
<td>13.1</td>
<td>0.76</td>
<td>13.5</td>
<td>0.67</td>
<td>1.7</td>
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<tr>
<td>BC Campbell 88</td>
<td>0.95</td>
<td>15.6</td>
<td>0.69</td>
<td>13.3</td>
<td>0.26</td>
<td>1.8</td>
</tr>
<tr>
<td>Collelongo</td>
<td>0.60</td>
<td>54.8</td>
<td>0.41</td>
<td>41.7</td>
<td>0.30</td>
<td>5.5</td>
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<tr>
<td>Hesse</td>
<td>0.75</td>
<td>41.4</td>
<td>0.70</td>
<td>28.2</td>
<td>0.2</td>
<td>3.0</td>
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<tr>
<td>Soroe</td>
<td>0.59</td>
<td>58.0</td>
<td>0.65</td>
<td>56.8</td>
<td>0.51</td>
<td>4.0</td>
</tr>
<tr>
<td>Le Bray</td>
<td>0.61</td>
<td>44.3</td>
<td>0.26</td>
<td>23.0</td>
<td>0.22</td>
<td>2.9</td>
</tr>
</tbody>
</table>

### Table 2: Systematic and Unsystematic Errors

<table>
<thead>
<tr>
<th>Site</th>
<th>$Rn$ (Watts.m$^{-2}$)</th>
<th>$\lambda E$ (Watts.m$^{-2}$)</th>
<th>NEE (gC.d$^{-1}$m$^{-2}$)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>s: systematic error</td>
<td>u: unsystematic error</td>
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</tr>
<tr>
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<td>3.8</td>
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<tr>
<td>Le Bray</td>
<td>18.0</td>
<td>41.0</td>
<td>23.0</td>
</tr>
</tbody>
</table>

s: systematic error; u: unsystematic error;
Evaluation (3/4)

Growth, production and soil groundwater trajectories.

1. Coniferous
Evaluation (4/4)

Growth and production trajectories.

2. Broadleaved
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- **PROFOUND** Cost action (COST, C. Reyer coord.)

Data used for calibration or evaluation:

- **European carbon** data cluster (L3 and L4 data from FR-Hes, FR-LBr, IT-Col, DK-Sor)
- **Fluxnet** (Vancouver Douglas fir chronosequence, A.T. Black)
- **ISIMIP** database (Solling, Collelongo, Soroe, Le Bray sites)
- **GIS Coop de données (Pompogne site, D. Merzeau)**
- **INRA** long-term forest inventory data (**Vielle** site, C. Meredieu et al.)
- **Forest Soil** database (V. Badeau, INRA Nancy)
- **Historical series of meteorological data** (Météo-France)