Energy, water and carbon exchanges in young coniferous stands in South West of France

Effect of the presence of a layer of gorse

Virginie Moreaux (1), E. Lamaud, J.M. Bonnefond, A. Bosc, D.Loustau

(1) INRA, UR1263 EPHYSE, F-33140, Villenave d’Ornon, France
Contact: virginie.moreaux@bordeaux.inra.fr
Introduction
### Environmental round table, 2007

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>2006</th>
<th>2020</th>
<th>2006/2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat</strong></td>
<td>9.7</td>
<td>19.7</td>
<td>+10.1</td>
</tr>
<tr>
<td><strong>Biomass</strong></td>
<td>8.8</td>
<td>15.0</td>
<td>+6.2</td>
</tr>
<tr>
<td>Geothermal energy</td>
<td>0.4</td>
<td>2.3</td>
<td>+1.9</td>
</tr>
<tr>
<td>Solar energy</td>
<td>0.00</td>
<td>0.9</td>
<td>+0.9</td>
</tr>
<tr>
<td>Waste</td>
<td>0.4</td>
<td>0.9</td>
<td>+0.5</td>
</tr>
<tr>
<td>Biogaz</td>
<td>0.00</td>
<td>0.6</td>
<td>+0.5</td>
</tr>
<tr>
<td><strong>Electricity</strong></td>
<td>5.6</td>
<td>12.9</td>
<td>+7.2</td>
</tr>
<tr>
<td>Hydraulic energy</td>
<td>5.2</td>
<td>5.8</td>
<td>+0.6</td>
</tr>
<tr>
<td>Land Wind energy</td>
<td>0.2</td>
<td>3.6</td>
<td>+3.4</td>
</tr>
<tr>
<td>Sea Wind energy</td>
<td>0.0</td>
<td>1.4</td>
<td>+1.4</td>
</tr>
<tr>
<td><strong>Biomass</strong></td>
<td>0.2</td>
<td>1.4</td>
<td>+1.2</td>
</tr>
<tr>
<td>Photovoltaic energy</td>
<td>0.0</td>
<td>0.5</td>
<td>+0.5</td>
</tr>
<tr>
<td>Other (geothermal energy, marine energy...)</td>
<td>0.0</td>
<td>0.1</td>
<td>+0.1</td>
</tr>
</tbody>
</table>

+ 12 Mm³ in 2012 (ie. 30%)

+ 20 Mm³ in 2020 (ie. 1 Mm³/yr)
Background around the Landes forest (France).

- The process of cultivation and growth follows a production cycle that extends over a period of 45-50 years (*Lesgourgues et al. 1997*).
Intensification of the forest practices

Sustainability of the forest ecosystem towards the soil fertility, and water resources?

Early stage: presence of species as natural N-fixing shrubs

In the Landes forest: gorses and brooms

\textit{Ulex Europeaus, Ulex Minor and Cytisus scoparius}

Main objective

- analyse the effects of the first silvicultural practice on the energy, water and carbon fluxes from two young maritime pine stands: JUNE 2009 – MAY 2010
Material & Method
Material & method

Paired measurements in the two sites

<table>
<thead>
<tr>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree species</td>
</tr>
<tr>
<td>Age (July 2009)</td>
</tr>
<tr>
<td>Forest practices</td>
</tr>
<tr>
<td>Stocking (tree.ha$^{-1}$)</td>
</tr>
<tr>
<td>Mean LAI (m$^2$.m$^{-2}$)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONTROL (C)</th>
<th>WEEDED (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinus pinaster, Ait</td>
<td></td>
</tr>
<tr>
<td>4 years</td>
<td></td>
</tr>
<tr>
<td>14400</td>
<td></td>
</tr>
<tr>
<td>2.62</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>1803</td>
<td></td>
</tr>
<tr>
<td>0.79</td>
<td></td>
</tr>
</tbody>
</table>

1st weeded and depressing in November 2008
2nd weeded in November 2009

JUNE 2009 – MAY 2010
Results

Energy balance
Water exchanges
Carbon exchanges
Energy balance closure (EBC)

- EBC is better closed on the CONTROL with a slope of 0.78 compared to a slope of 0.85 on WEEDED.

- Literature:
  - Wilson et al 2002: slope: 0.79 ± 0.01, intercept: 3.7 ± 2.0
  - Berbigier et al 2001: slope: 0.86, intercept: 0.007
Results

Energy balance

- **Annually**
  - Rn (W) < Rn (C)
  - Difference of ~4%

- **Seasonally**
  - High differences from April to July
  - Reversed in winter
Results

\[ Rn = Rg - aRg + LW\downarrow - LW\uparrow \]

Effect of albedo is compensated by the effect of LW $\uparrow$
Results

Partitioning of the energy fluxes

growth

CONTROL

WEEDED

drought

winter

\[ \beta_w = 1.58 \]
\[ \beta_c = 0.50 \]

\[ \beta_w = 2.18 \]
\[ \beta_c = 2.23 \]

\[ \beta_w = 0.86 \]
\[ \beta_c = 0.92 \]
Results

Water balance

Partitioning between evapotranspiration (ET) and transpiration (Tr)

- Total ET comparison:
  
  Growing season: \( \text{ET (C)} = 1.5 \times \text{ET (W)} \)
  
  Drought: \( \text{ET (C)} = \text{ET (W)} \)

- Pine Tr comparison:
  
  Growing season: \( \text{Tr (C)} = 1.5 \times \text{Tr (W)} \)
  
  Drought: \( \text{Tr (C)} = 1.5 \times \text{Tr (W)} \)

- \((\text{ET} – \text{Tr})\) comparison:
  
  Growing season: Higher on the control plot
  
  Drought: Similar

Vegetation layer is more sensitive to drought.
Soil water content (0-80cm)

SWC higher in the weeded plot due to:

- lesser ET
  - weaker rainfall interception
  - lesser transpiration
Simultaneous water stress

- **CONTROL**
- **WEEDED**

Parallel dynamic of secondary growth

Identical effect of drought
Results

Soil Moisture Deficit

$g_c$ (mm\cdot s$^{-1}$)

Field capacity

Wilting point

Holding capacity

Higher $g_c$ on the control plot at low VPD

Abrupt response of $g_c$ to an increase of VPD

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field capacity</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>Wilting point</td>
<td>25</td>
<td>55</td>
</tr>
<tr>
<td>Holding capacity</td>
<td>110</td>
<td>80</td>
</tr>
</tbody>
</table>
Results

Carbon fluxes

- Temporal evolution of NEE (filtered data)

Dynamic of the fluxes more pronounced on the control plot, with higher values

**Dry and warm events**: high reduction of the fluxes on the control plot

**Dry and cold events**: high reduction of the fluxes, for both released and fixed carbon
Results

Partitioning between GPP and Re

\[
NEE = \frac{a_1 PAR}{a_2 + PAR} + R_{ref} \cdot Q_{10}^{T_{SURF}-15}
\]

- WEEDED
- CONTROL

JUNE

- Higher respiration
- Higher carbon assimilation
- Higher LUE

SEPTEMBER

- Same respiration
- Same carbon assimilation
- Same LUE
Partitionning between GPP and Re

GPP and Re higher in the control plot, with a earlier decreasing in GPP

Is this earlier decrease in GPP during the drought linked to the layer vegetation?
Conclusion and prospects
Effects of weeding and thinning

- on radiative balance:
  - Slight decreasing of the available energy (4%)
  - Reducing of latent heat flux but few change in sensible heat

- on hydrological processes and carbon fluxes:
  - No attenuation of the summer drought since effects on transpiration on tree growth look identical.
  - Dynamic of the ET and GPP on the control plot is more important and react faster to dry conditions: attributed to the dynamic a the gorse layer

- Next step:
Thanks for your attention

Acknowledgment: Denis Loustau and Eric Lamaud
Michel Sartore, Didier Garrigou, Pierre Trichet, Frédéric Bernier, Jean-Luc Denou, Jean Michel Beau, Salles commune
Temporal evolution of the fluxes (filtered data)
## Annual ecosystem fluxes

<table>
<thead>
<tr>
<th>Annual exchange</th>
<th>Bilos (age = 0)</th>
<th>Bray (age = 28)</th>
<th>Bray (age = 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEE carbon (gC m(^{-2}))</td>
<td>290</td>
<td>-575</td>
<td>-498</td>
</tr>
<tr>
<td>GPP (gCm(^{-2}))</td>
<td>727</td>
<td>2255</td>
<td>2025</td>
</tr>
<tr>
<td>TER (gCm(^{-2}))</td>
<td>996</td>
<td>1680*</td>
<td>1527</td>
</tr>
<tr>
<td>PPFD (mol m(^{-2}))</td>
<td>9227</td>
<td>9296</td>
<td>9308</td>
</tr>
<tr>
<td>(R_n) (MJ m(^{-2}))</td>
<td>1956</td>
<td>3006</td>
<td>2746</td>
</tr>
<tr>
<td>(T_{air}) (°C)</td>
<td>13.2</td>
<td>15.0*</td>
<td>13.4</td>
</tr>
<tr>
<td>(H) (MJ m(^{-2}))</td>
<td>928</td>
<td>620</td>
<td>515</td>
</tr>
<tr>
<td>(LE) (MJm(^{-2}))</td>
<td>895</td>
<td>1592</td>
<td>1491</td>
</tr>
<tr>
<td>Evaporation (mm)</td>
<td>358</td>
<td>666</td>
<td>624</td>
</tr>
<tr>
<td>Precipitation (mm)</td>
<td>875</td>
<td>930</td>
<td>515(^{†})</td>
</tr>
</tbody>
</table>

Kowalski et al. 2003
Meteorological characteristics: June 2009 - May 2010

- **Annually:**
  - Mean annual $T = 12.4 \, ^\circ\, C$
  - Annual $P = 936 \, mm$

- **Particular events:**
  - **Drought**
    - $P = 7 \, mm$ (10/08 - 16/09)
    - SWC < 50 mm (0-80 cm)
  - **Storms**
    - $P = 222 \, mm$ (November)