Carbon dynamics of intensively managed forest along a full rotation

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Carbon dynamics of intensively managed forest along a full rotation: a juvenile versus adult stage approach

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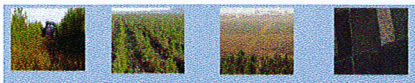
1. Introduction

- Almost all European forests are **transformed by management** [1] with varying intensities and silvicultural operations have profoundly modified the natural disturbance regime. Forest management exerts a **major influence** on the contribution of temperate forests to **global carbon sequestration** [2]. Meanwhile, it is well recognized that northern forests contain large amounts of carbon (C) in both biomass and soils and these reservoirs may be more vulnerable to future climate changes [1].
- Managed forests present **mosaic of stand ages** that are continuously being renewed through **natural** (drought, storm...) and **anthropogenic disturbances** (soil preparation, thinning, understorey control, harvest, shorter rotation...), which influence **forest growth** and the concomitant **energy, water** and **carbon exchanges** [3,4,5,6].
- They result ultimately in either positive or negative changes in the biomass and soil carbon pools but few, if any, datasets or modeling tools are available for quantifying these impacts.
- Accurate accounting of these large C stocks requires a sound scientific understanding of how **disturbances** and **climate variability** impact the emission and sequestration of carbon and how their respective effects might be factored out.

Objective: *For disentangling these impacts, we have collected a long term series of half-hourly latent, sensible heat and CO_2 fluxes from a managed pine forest and we analysed the effect of management operations, tree age and climate using these data.*



7. Discussion

- Anthropogenic disturbances are more likely to affect young stands and its carbon balance, especially during **site preparation**. Over 8 years, the young stand **released 807 gC m^{-2}** whereas the adult one **fixed 2658 gC m^{-2}**.
- Meanwhile, for the young stage, the total carbon stocks in the biomass and in the soil **decreased** by **880 gC m^{-2}** due to frequent soil disturbances, understorey control and early thinning. For the adult stage, carbon sequestration was **constant**.
- In the young stand, the change in carbon stock was **more dramatic in the biomass compartment.** In the soil, the mineralisation of carbon after ploughing was offset by the gain of carbon in the organic layer due to slash residues after ground removal.
- At the mature stage, the ecosystem remains a consistent **carbon sink** independent of silvicultural operation (thinning). It seems **more sensitive to climate** as observed in 2002, 2005 and 2006 characterized by severe soil droughts.
- Our data suggest that **management intensification** would have a negative impact on site carbon sequestration.
- Our data on carbon exchanges suggest the importance of dynamically including disturbances linked to forest management in **modeling approaches** (cf. poster n° B51B0492), especially in the early stage of tree growth, for a reliable estimation of the carbon budget.

2. Experiments

Bilos (juvenile stage)

Eddy flux measurements,
Biomass measurements,
Soil measurements,
Meteorological measurements

Le Bray (adult stage)

3. Silvicultural operations

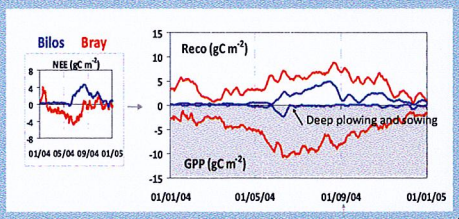
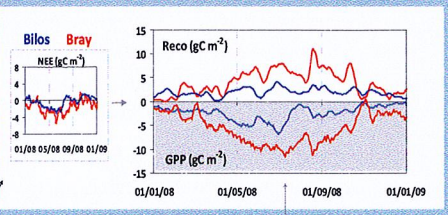


Figure 2. Evolution of the carbon fluxes for a characteristic meteorological year, in the young stand (blue lines) and in the adult one (red lines)

- Plowing and sowing operations increase the heterotrophic respiration through massive inputs of dead plant material: dead wood, organic humus layers and ground vegetation and the activation of the mineralization of soil organic matter.
- The succession of silvicultural operations during the site preparation made the ecosystem a net carbon source: 10 years after clearcutting, the cumulative balance is still positive, but 2 years after the sowing, the site rapidly becomes a sink of CO_2.
- The impact of thinning and vegetation removal (weeding) at the age of 5 years old brought the balance to almost neutral (2009).
- In the adult stage, no significant impact of silvicultural operation: strong carbon sequestration sensitive to climate

4. Age effects

Figure 3. Evolution of the carbon fluxes for a characteristic meteorological year, in the young stand (blue lines) and in the adult one (red lines)



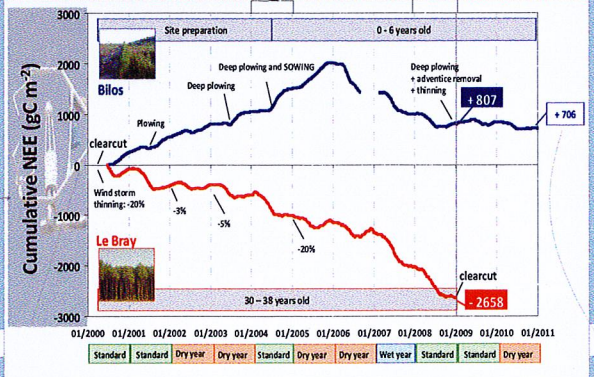
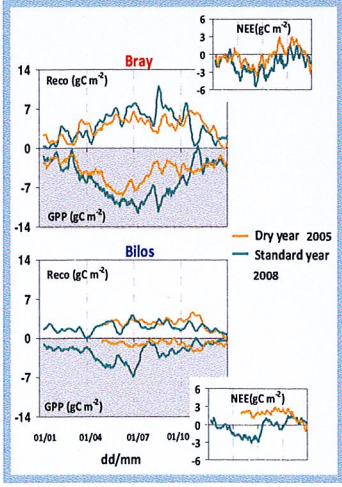


Figure 1. Cumulative net ecosystem exchange calculated over an 8-year period in the young stand (blue lines) and in the adult one (red lines)

- Under characteristic meteorological conditions, the magnitude of the carbon fluxes **increased with stand age**. Annual GPP reached **2087 gC m^{-2}** against **881 gC m^{-2}** for the young stand, and the onset of the growing season is earlier in the adult stand. These observations are explained by the difference in soil available water, stand LAI being similar for the two sites (3.5 m^2 m^{-2}).
- We noticed a **higher exposure to soil drought** in the young stand due to incomplete soil exploration by roots and thus lower soil water extractable.
- Understorey from the young stand is more sensitive to soil drought [6].

5. Climate effects



Our data show that the management operations masked the impact of soil water deficit at the juvenile stage.

- In both stands, a drastic decrease in GPP occurred during the summer dry year 2005 compared to the characteristic year 2008.
- In the adult stand, the drop in GPP occurred as SWC reached the wilting point (Bray, *Figure 4* orange lines).
- In the young stand, carbon fluxes in 2005 are mostly explained by the effect of the previous ploughing: ecosystem respiration dominates and GPP remained low most part of the year.
- Therefore, the site is a carbon source all along the 2005 year.

Figure 4. Evolution of the carbon fluxes for a characteristic meteorological year (Green lines) and a dry year (Orange lines), on both sites.

6. Carbon stocks

Bilos (juvenile)

Carbon stocks (gC m^{-2})	2000	2010	C stock variations
Aboveground biomass	1455 ± 92	2170 ± 66	+ 715
Belowground biomass	1843 ± 15	528 ± 21	- 1315
Organic soil	2875 ± 206	291 ± 75	- 2585
Mineral soil	9881 ± 1093	12187 ± 1010	+ 2305
Total (gC m^{-2})	16056 ± 1123	15176 ± 1171	- 880

Table 1. Carbon stocks measured in the biomass add soil compartments for several periods in the two stands

Carbon balance is consistent between stocks and fluxes

Bray (mature)

Carbon stocks (gC m^{-2})	2003 [7]	2004 [8]	2009 [9]
Organic soil	1410 ± 304	3063 ± 175	no significant changes
Mineral soil	10890 ± 1914	9917 ± 802	
Total (gC m^{-2})	12300 ± 2218	12980 ± 977	

References

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