Carbon sequestration and soil gas flux dynamics for multiple forest management and field preparation scenarios

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1 Research topic and objectives

In the context of climate change, it is of vital importance to sustain the viability of forest ecosystems as they represent a major sink of terrestrial organic carbon [1].

This project aims to quantify the total carbon sequestration capacity of multiple forestry practices, configurations of such practices and for a range of commercial species.

We hypothesize that field preparation, soil amendment and vegetation control are significant factors for optimizing carbon sequestration and that a better understanding of these dynamics will provide a robust framework for future forest management.

The results of this research should help inform stakeholders of the best practices involving carbon sequestration, guide forestry practices in a manner which help efforts for forest preservation and improve existing tools for carbon accounting.

2 Meta-analysis of the effect of forest management intensity on carbon sequestration and storage

Forest management practices for commercial species in forestry can impact carbon sequestration and storage in soils and biomass (vegetation, trees) [2]. In this study, we aim to test the effect of field preparation, soil amendment and competition control on aboveground (tree biomass) and underground (tree roots and soil) carbon storage.

Methodology : Data retrieval following the PRIMSA-EcoEvo guidelines and analyzed in R with the *metafor* package.

Keywords : reforestation, carbon stocks, soil carbon, tree biomass, field preparation, plantation type, soil amendment, competition control, chronosequence.

3 A closer look at a specific forest management scenario in southern Quebec

- In the pulp and paper industry, waste products are traditionally disposed of in landfills.

- An alternative is to redirect the waste or by-products (i.e. wood ash, biosolids) in commercial, intensive forest plantations as a soil amendment.

- Advantages : reduced GHG emissions from landfilling [3], increased carbon sequestration from tree growth [4]. and from organic matter (biosolids) incorporated to soils [5].

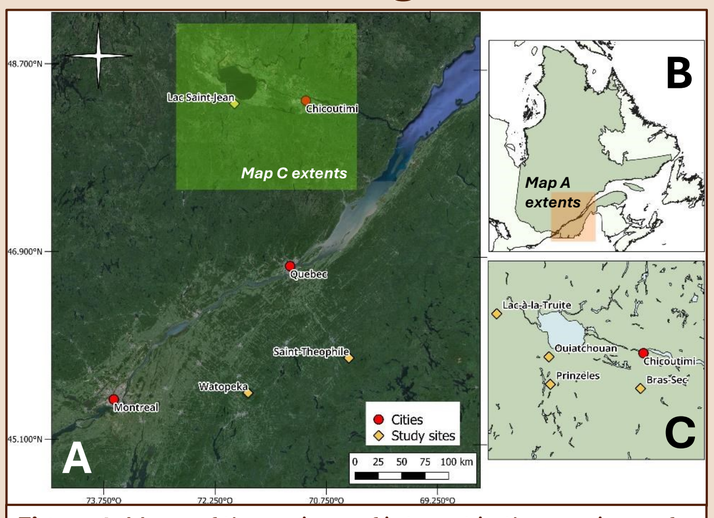


Figure 1. Maps of the regions of interest in the province of Quebec (A and B) and study sites in Lac Saint-Jean (C).

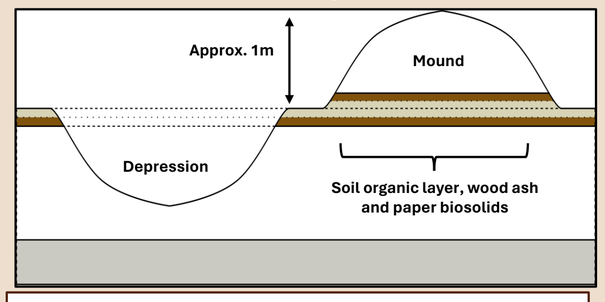


Figure 2. Mounding field preparation.

Main advantages :
Long lasting nutrient reserves for planted trees within the mounds, durable competition control maintained from differential ground height and durable way to dispose of paper biosolids.

Plantation preparation process
1) The wood ash and paper biosolids are first applied at the soil surface.
2) Machinery is used to construct the mounds as microsites for tree planting.
3) Hybrid poplars are planted the next summer on top of the mounds.
4) Tree growth and health are periodically monitored until commercial exploitation.

4 Effect of mounding and paper biosolids as a soil amendment on total carbon stocks of hybrid poplar and white spruce plantations

The goal of this study is to measure the effect of mounding and fertilization with pulp and paper mill sludge on total carbon stocks over the different development stages of various silvicultural scenarios.

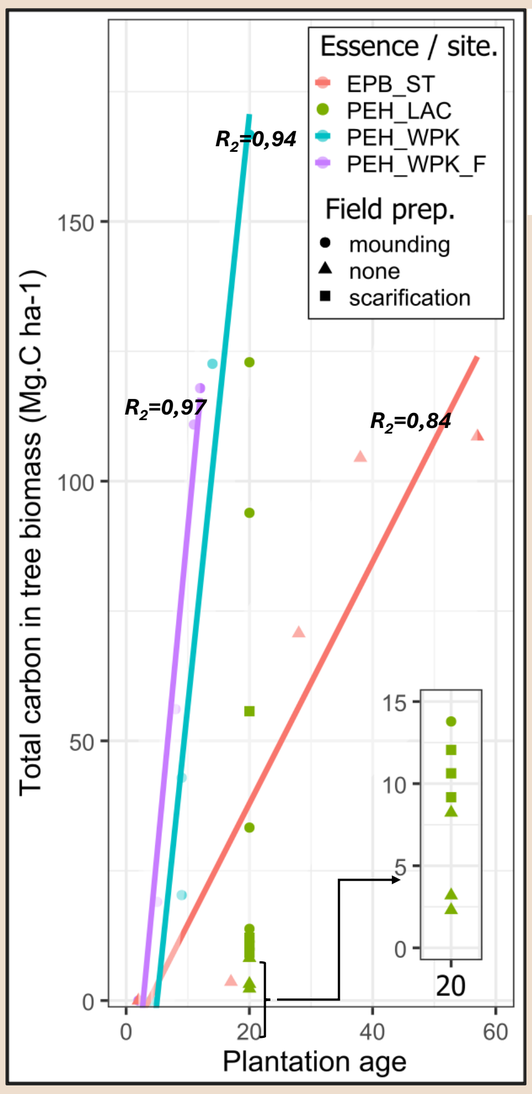


Figure 3. Total carbon accumulation in tree biomass (stem and roots) over time for the studied plantation scenarios in southern Quebec. Green data points indicate the carbon stocks for 20-year-old hybrid poplar with different field preparation in northern, less productive sites.

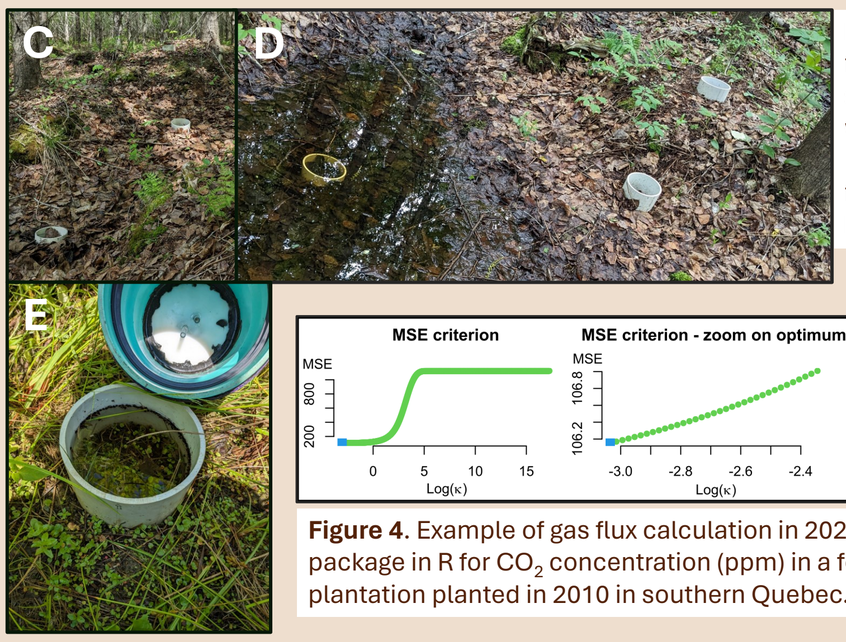
Images A and B. Hybrid poplar plantation in southern Quebec (9 years) and soil core sampling for subsequent density and carbon content analyses.

Preliminary results

- More carbon stored in hybrid poplar, intensive plantations.
- Significant effect of paper biosolids on tree growth and carbon storage (23% more at 20-years; 166 vs 216 Mg C ha^{-1}).
- Significant effect of site quality on productivity and carbon stocks.

5 Effect of mounding and paper biosolids on soil gas fluxes of hybrid poplar plantations

The goal of this study is to measure the effect of mounding and soil amendment with paper biosolids on CO_2, CH_4 and N_2O fluxes over the different development stages (i.e. age increments) of hybrid poplar plantations.



Images C, D and E. Gaz flux sampling transect showing well drained and waterlogged soils (C and D respectively) and a gas flux chamber, aerated before sampling (E).

Figure 4. Example of gas flux calculation in 2023 using the *HMR* package in R for CO_2 concentration (ppm) in a fertilized hybrid poplar plantation planted in 2010 in southern Quebec.

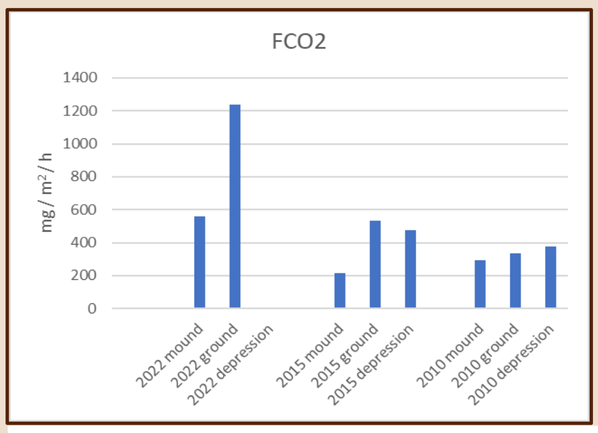


Figure 5. Preliminary soil CO_2 flux sampling in July 2023 in hybrid poplar plantations (Watopeka).

Methodology
Gaz flux chambers are used to measure gas accumulation. The samples (20ml) are collected manually with a syringe, stored in vacuumed vials and brought back and analyzed in the laboratory.

CO_2/CH_4 : Picarro G2201-i
N_2O : Shimadzu GC-2014

6 References & acknowledgements

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