Carbon, Water, and Energy Dynamics of a Pine Forest during the First Decade Since Plantation on Former Cropland

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Introduction

- The majority of North American **temperate conifer forests** are secondary growth **plantation stands**, a consequence of large-scale deforestation in the 19th and 20th centuries.
- **Enhancing carbon (C) sequestration by increasing forested land area** (e.g. plantation forests) is one of the most **cost-effective** options to **mitigate elevated atmospheric CO_2 levels** and hence contribute towards the **prevention of global warming** [1].
- The **quantification of C exchange** and productivity rates of new plantations are therefore of major interest to **forest industries** and **government policy makers**.
- However, the **C sequestration trajectory** of new forests planted on lands that historically have not contained forests is **still poorly understood**.
- To date, only a few **decadal-scale CO_2 flux studies** have been published.

Turkey Point Flux Station

- Planted in 2002 on 10 ha abandoned agricultural land.
- Eastern white pine (*Pinus strobus* L.), a preferred plantation species.
- Well-drained, sandy soils with **low residual soil organic matter**.

Figure 1. Location of the flux tower site.

Objectives

1. Examine how **energy**, **carbon**, and **water** fluxes vary during the first decade (2003-2013) of land-use change, when an abandoned cropland is **afforested**.

Net Ecosystem Productivity = Photosynthesis - Respiration
NEP **GEP** **ER**

NEP > 0: Ecosystem gains CO_2 from atmosphere = **sink**

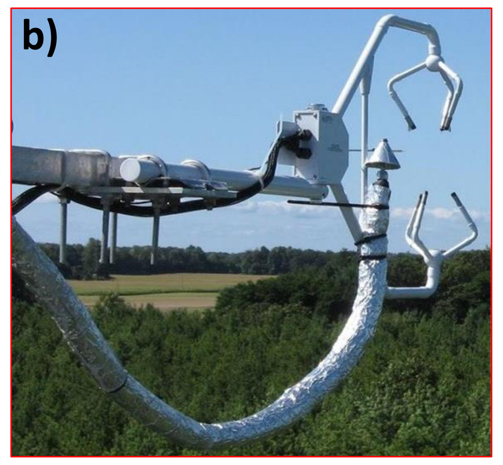
NEP < 0: Ecosystem loses CO_2 to the atmosphere = **source**

Characterize the **length of time** it takes for new white pine plantations to become a **sink of carbon**.

2. Investigate key **climatic** and **structural controls** that drive carbon fluxes and how their impacts change in the first decade of afforested stand development.

Methods

- A tower based **Closed Path Eddy Covariance** (CPEC) system continuously collects **½ hourly energy, CO_2, and H_2O fluxes** between the forest and the atmosphere.
- Weather instruments provide **site scale meteorology**. Ancillary measurements of **soil moisture** and **soil temperature** taken from sensors at various depths.



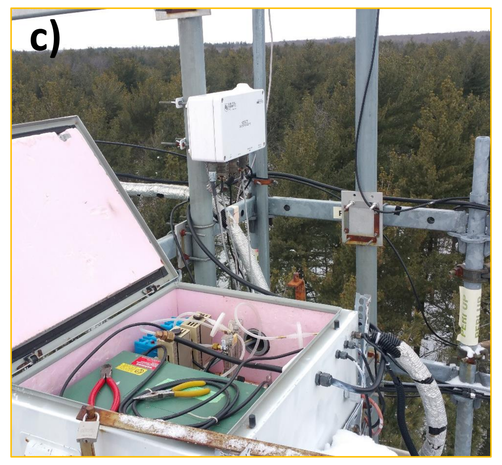
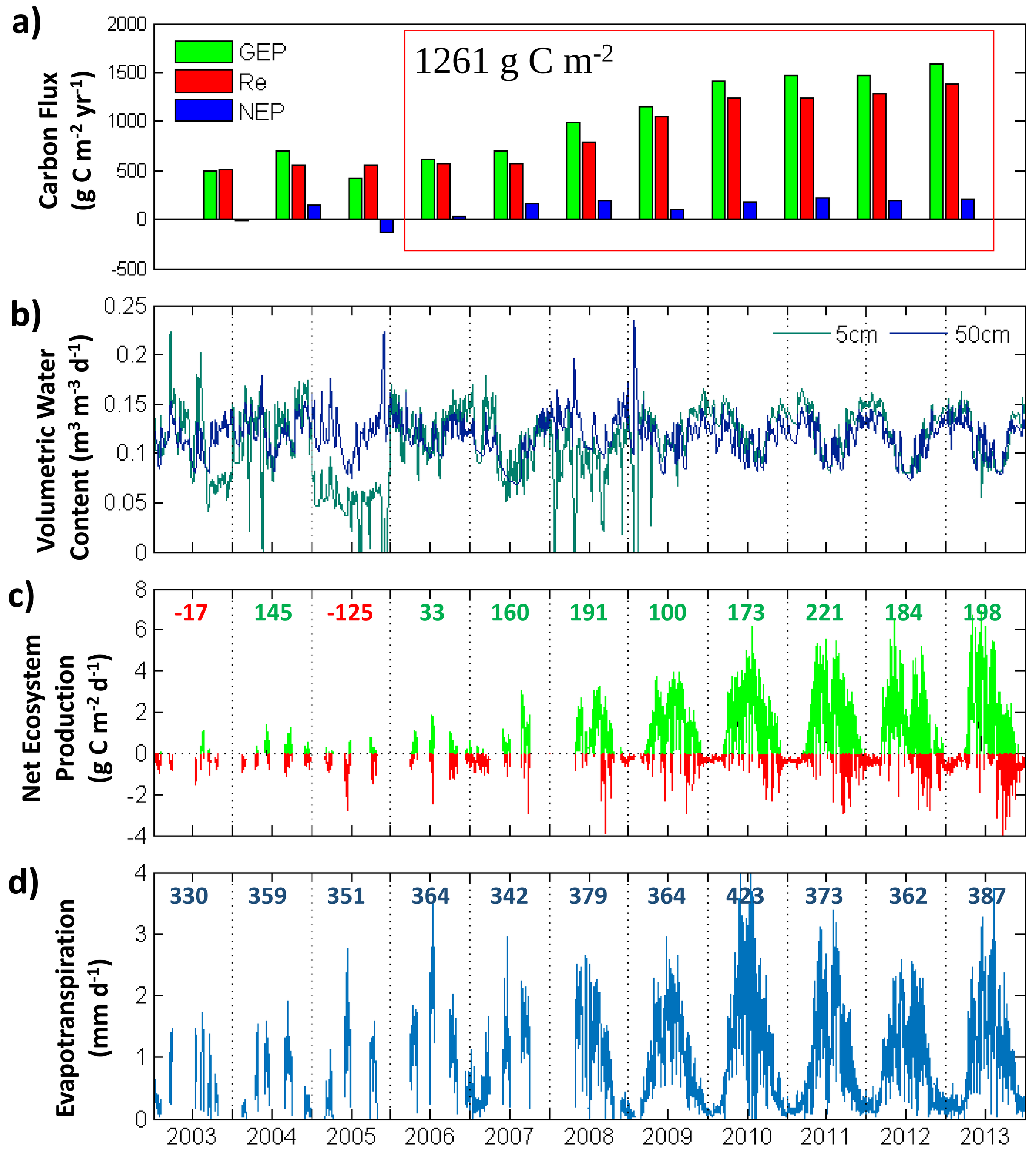


Figure 2. a) Eddy covariance tower extending above the canopy, b) 3-D sonic anemometer (CSAT), and c) Infrared gas analyzer (IRGA).

Results and Discussion



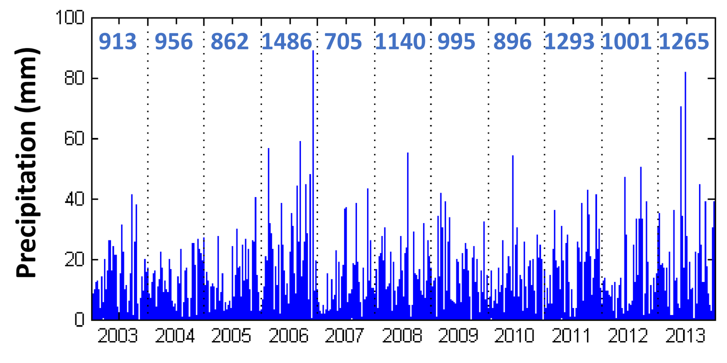
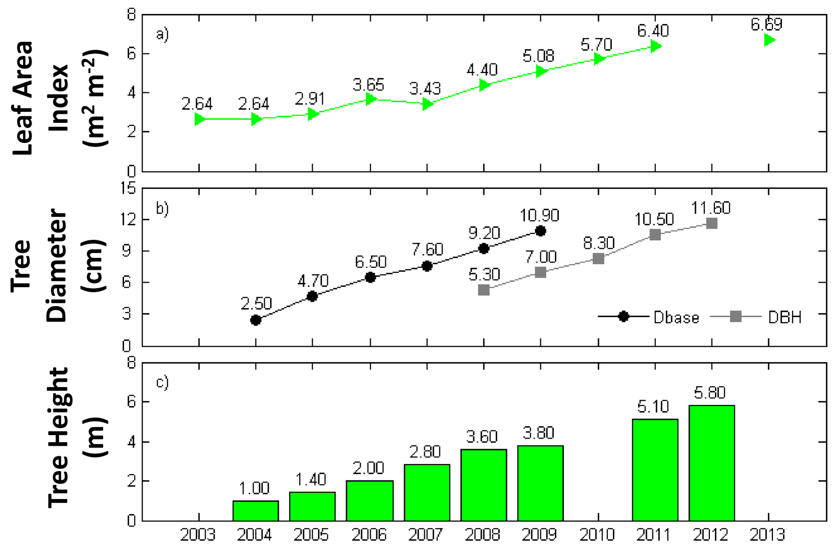


Figure 4. Daily total precipitation (P). Annual P is displayed above.

- Consistent sink of carbon after 4 years.
- NEP experiences a reduction in late summer, due to low P and/or VWC limitations (especially 2007 and 2012).
- Impact of seasonal drought was much more pronounced if it was combined with heat events (i.e. 2005).
- From 2006 onwards differences in VWC_{5cm} and VWC_{50cm} gradually diminish, reflecting the expanding root system and increased canopy shading.
- ET values increased slightly, with a low inter-annual variability; also affected by VWC limitations.

Figure 3. Annual carbon flux (a), daily mean volumetric water content (b), daily total net ecosystem production (c), and daily total evapotranspiration (d). The annual totals of NEP and ET are displayed above.

Results and Discussion



- After 5 years, LAI increases steadily and overtakes herbaceous growth.
- By 2013, the canopy was dense and closed, consisting of white pines which shaded out all understory vegetation.

Figure 5. (a) Leaf area index (LAI) from Landsat 5 and Landsat 7 at the 30m resolution. (b) Mean annual tree height. (c) Mean tree diameter at tree base (Dbase) and diameter at breast height (DBH) measurements.

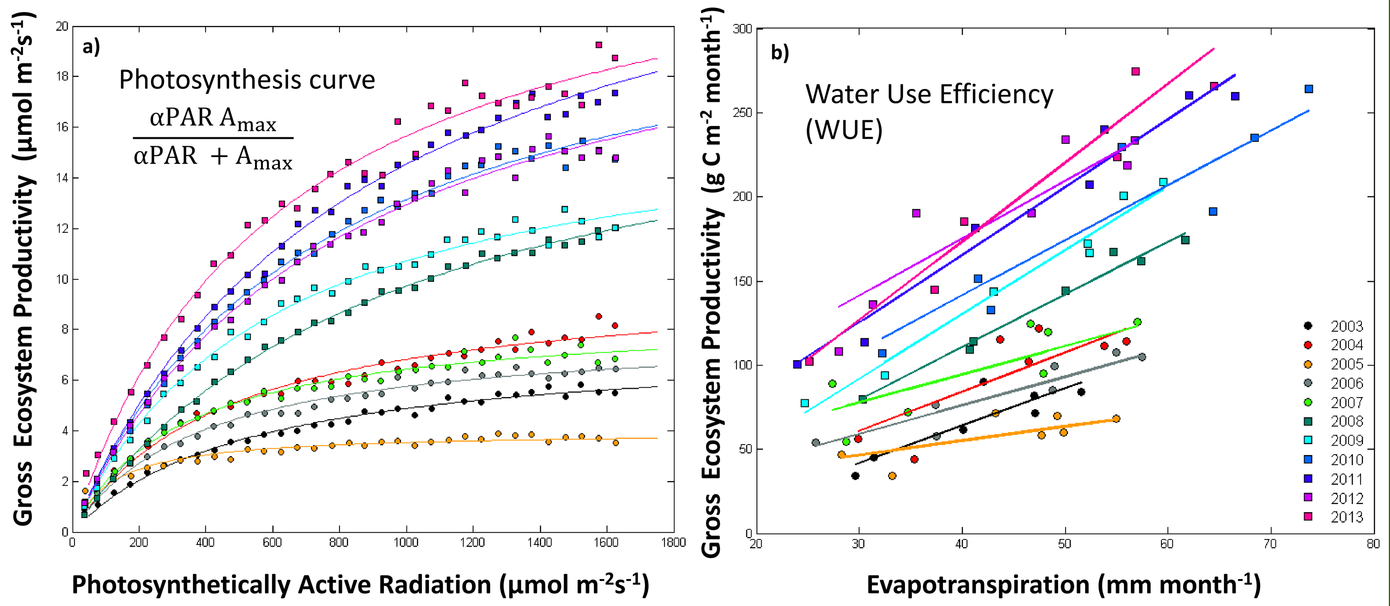


Figure 6. The growing season (a) relationship between GEP and PAR and (b) relationship between GEP and ET (WUE).

- **Photosynthetic capacity** (A_{max}) and **quantum yield** (α) increased steadily as the **size and density of the canopy increased** [2].
- The drastic increase in A_{max}, but not α, from 2007 to 2008 indicates that the photosynthetic capabilities of the canopy have increased greatly due to **increased LAI**.
- Stand structure allowed the forest to **continue to grow** while being **conservative with water usage** [3], thus **maximizing WUE**.

Conclusion

- Energy, C, and water fluxes were largely **influenced by canopy development**. Strong seasonal trends of VWC drawdown and replenishment were **influenced by the root system** in later years.
- The **low soil C stock** within the former cropland allowed the site to have higher NEP rates earlier and **become a C sink much quicker** than most temperate conifer forests in North America.
- Our findings demonstrate the potential of white pine as **a viable plantation species** to **sequester atmospheric CO_2** in North American regions with similar site characteristics (i.e. cropland).

References

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Acknowledgements

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