Carbon and Water Dynamics of a Young White Pine Plantation Forest

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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 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**.
- Among temperate forests, **pine stands** are considered one of the **most productive forests**.
- To date, only a few **decadal-scale CO_2 flux studies** have been published.

Turkey Point Flux Station

- Planted in 2002 on 5 ha abandoned agricultural land.
- Eastern White Pine (*Pinus strobus* L.), a preferred plantation species.
- Grows efficiently in dry environments with nutrient poor, sandy soil.
- Facilitates the return of native forest species through succession.

Figure 1. The station is 10 km from the northern shore of Lake Erie

Objectives

1. Examine **seasonal and interannual dynamics** of GEP, NEP, and Re over a period of eleven years (2003-2013).

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. To determine key **environmental controls** on carbon fluxes and how their impact changes due to stand development.

Methods

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

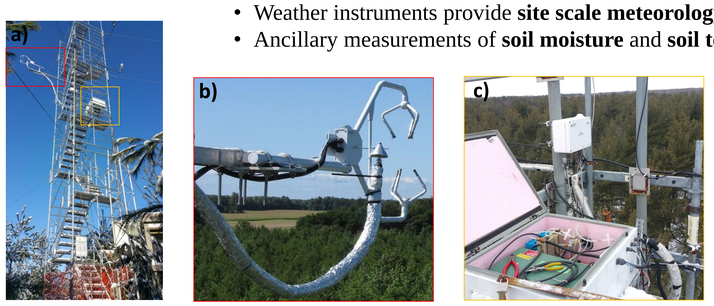
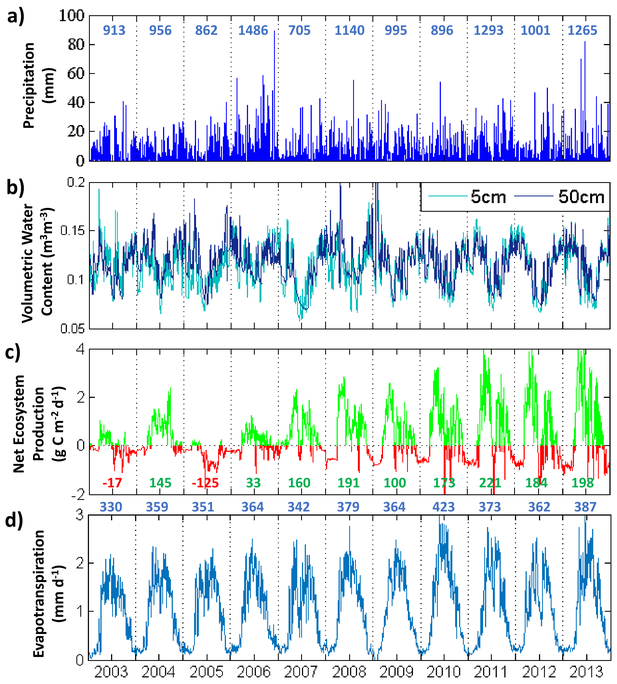


Figure 2. a) Eddy covariance tower extending above the canopy, b) 3-D sonic anemometer (CSAT), and c) Infrared gas analyzer (IRGA)

Results and Discussion



Net ecosystem productivity (NEP) has steadily increased since **2006**, when it became a **consistent sink of carbon** (Fig. 4c).

Soil moisture (VWC) at 5 cm and 50 cm have become more similar as the forest grows (Fig. 4b), suggesting that the **root system has developed deep enough to tap deep soil water**.

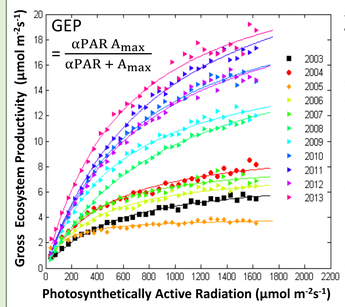
Low values in soil moisture reduced NEP during the summer months. From 2007 onwards, a **double peak in NEP** is observed which is typical of other conifer forests in the area [2].

Evapotranspiration (ET) increases slightly over time. Decreases in soil moisture from **drought were observed in 2007 and 2012**, resulting in reductions in peak evapotranspiration.

Figure 3. Daily precipitation (a), soil moisture (b), net ecosystem productivity (c), and evapotranspiration (d). The annual totals of P, NEP, and ET are displayed.

Results and Discussion

Photosynthesis



Water Use Efficiency

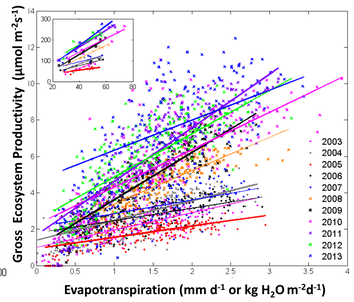


Figure 4. The growing season a) relationship between GEP and photosynthetically active radiation (PAR) and b) water use efficiency (WUE)

- From 2007 to 2008, there was a **rapid increase in GEP and Re** (not shown) likely due to increased leaf foliage and photosynthesis and increased biomass respiration.
- **Photosynthetic capacity** (A_{max}) and **quantum yield** (α) increased steadily as the basal area of the stand [3] as well as **size and density of the canopy increased**.
- Forest growth increased at a greater rate than water loss, resulting in the **gradual increase in WUE**. Stand structure allowed for **continued growth during dry periods** by **conserving water usage** [4].

Stepwise regression analysis:

- GEP = Soil Moisture + **PAR** + **Air Temperature** + Precipitation
  - $R^2 = 0.86$
- Re = PAR + **Air Temperature** + Precipitation
  - $R^2 = 0.90$
- NEP = Soil Moisture + **PAR** + Precipitation
  - $R^2 = 0.52$

Conclusion

- The plantation functions as a **carbon sink after 5 years of planting**, continuously sequestering CO_2.
- **PAR** and **air temperature** are **key environmental controls** that have an **increasingly positive effect** on carbon fluxes (GEP, Re, NEP) as the stand develops.
- These results demonstrate that White Pine will be a **viable plantation species** through **future climate variability** (e.g. drought).

References

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Further Information

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