The Influence of Interannual Carbon Variability on Long-Term Carbon Sequestration in Proximate Northern Forests and Wetlands

Nikaan Koupaei-Abyazani[1]

[1]University of Wisconsin-Madison

November 22, 2022

Abstract

Carbon dioxide (CO2) levels have been shown to be rising dramatically as a result of increased anthropogenic activity. One way of countering excessive CO2 emissions is by restoring natural ecosystems that have historically been found to be efficient carbon sinks. In order to be economically viable, these efforts must consider biomes with *long-term sustained* carbon sequestration capacities. Low interannual variation in this sink capacity minimizes risk of sequestration reversal. The goal of this study was to compare the interannual variability of carbon at four proximate Ameriflux eddy covariance sites across northern Wisconsin and Michigan's upper peninsula with up to two decades of observations per site. Two wetlands (Allequash Creek (US-ALQ) and Lost Creek (US-Los)) and an unmanaged and managed forest (Sylvania Wilderness Area (US-Syv) and Willow Creek (US-WCr), respectively) were considered. To consider the fuller carbon budget for wetlands, we also incorporated stream discharge data from the United States Geological Survey. In most of the measured years, on average, NEE in both types of ecosystems was negative (carbon uptake by the ecosystem). US-ALQ and US-Los had a yearly averaged standard deviation of ˜4.3 µmol CO2 m^{-2} s^{-1}, while for US-Syv and US-WCr it was ˜5.5 and ˜6.3 respectively, implying greater variability for the forests than wetlands. Interannual water availability (precipitation and discharge) was the main driver for wetland carbon variation while radiation was the best predictor of carbon dynamics in the forests. Our results demonstrate that for this region, wetlands are a more reliable biome for carbon storage on a decadal scale than forests. In addition, this capacity may be enhanced through restoration efforts focusing more on water availability rather than afforestation/reforestation.

The Influence of Interannual Carbon Variability on Long-Term Sequestration in Proximate Northern Forests and Wetlands

Authors: Nikaan Koupaei-Abyazani[1], Ankur R. Desai[1]

1. Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison

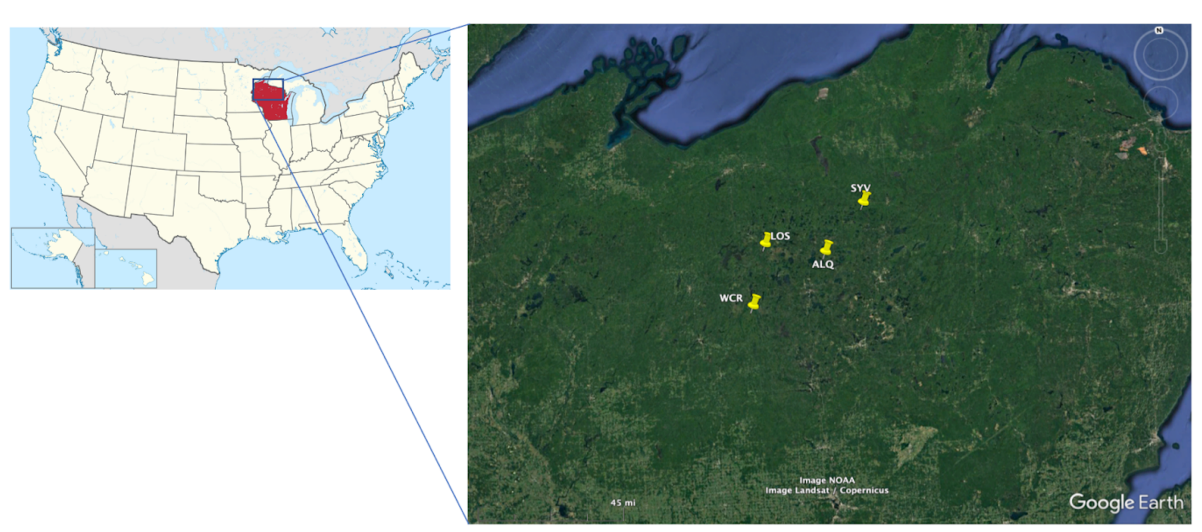
Email: koupaeiabyaz@wisc.edu

Introduction and Motivation

- To counter anthropogenic emissions, ecosystem restoration is essential
- Wide variety of biomes may be considered for restoration
- **Which biomes will provide *sustained* carbon sequestration on decadal scales? And what drives year-to-year variability between sites?**

Sites

Figure 1: Site locations in northern Wisconsin and Michigan's Upper Peninsula, USA



- Wetlands → US-ALQ, US-Los
- Unmanaged Forest → US-Syv
- Managed Forest → US-WCr
- To incorporate another possible carbon driver, streamflow data was used via the United States Geological Survey (USGS)
  - US-ALQ → 3 gages
  - US-Los: → 1 gage
  - US-Syv: → 1 gage
  - US-WCr: → No gage

Figure 2: Relative locations of Ameriflux sites and USGS streamflow gages. From Bear River gage to US-Los is ~4 km (left). Distance from gage at Cisco Lake Outlet and US-Syv is ~8 km (top right). HWY M, Sayner, and No. 3 gages are ~3.7 km, ~0.6 km, and ~0.24 km from US-ALQ respectively (bottom right).

Methods and Results

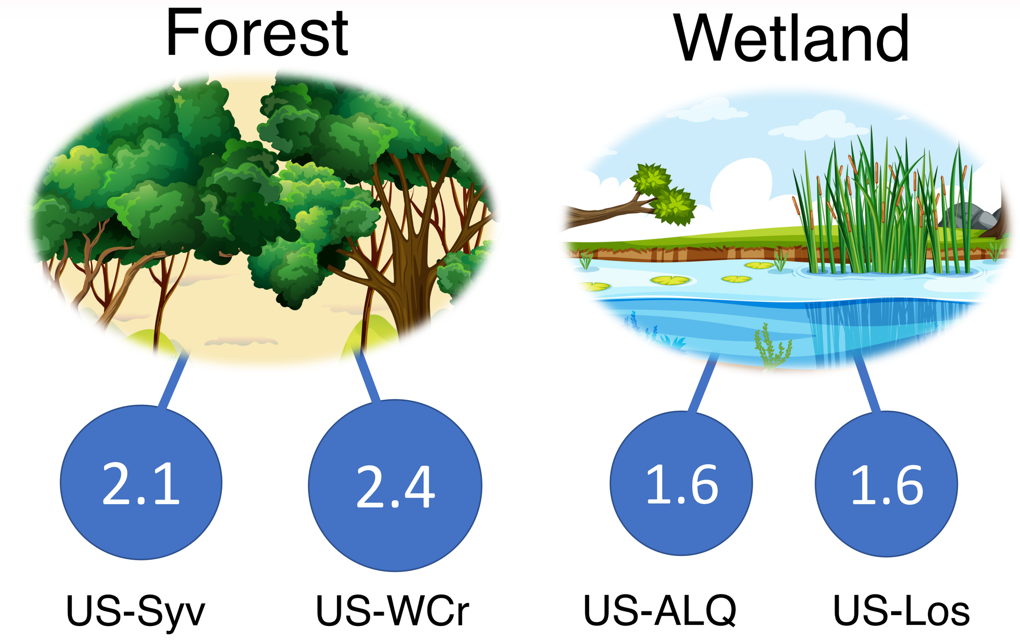


Figure 3: Averaged standard deviation of NEE across years for the wetland and forest sites. Units are kg C m^{-2} yr^{-1}.

Clipart from vecteezy.com

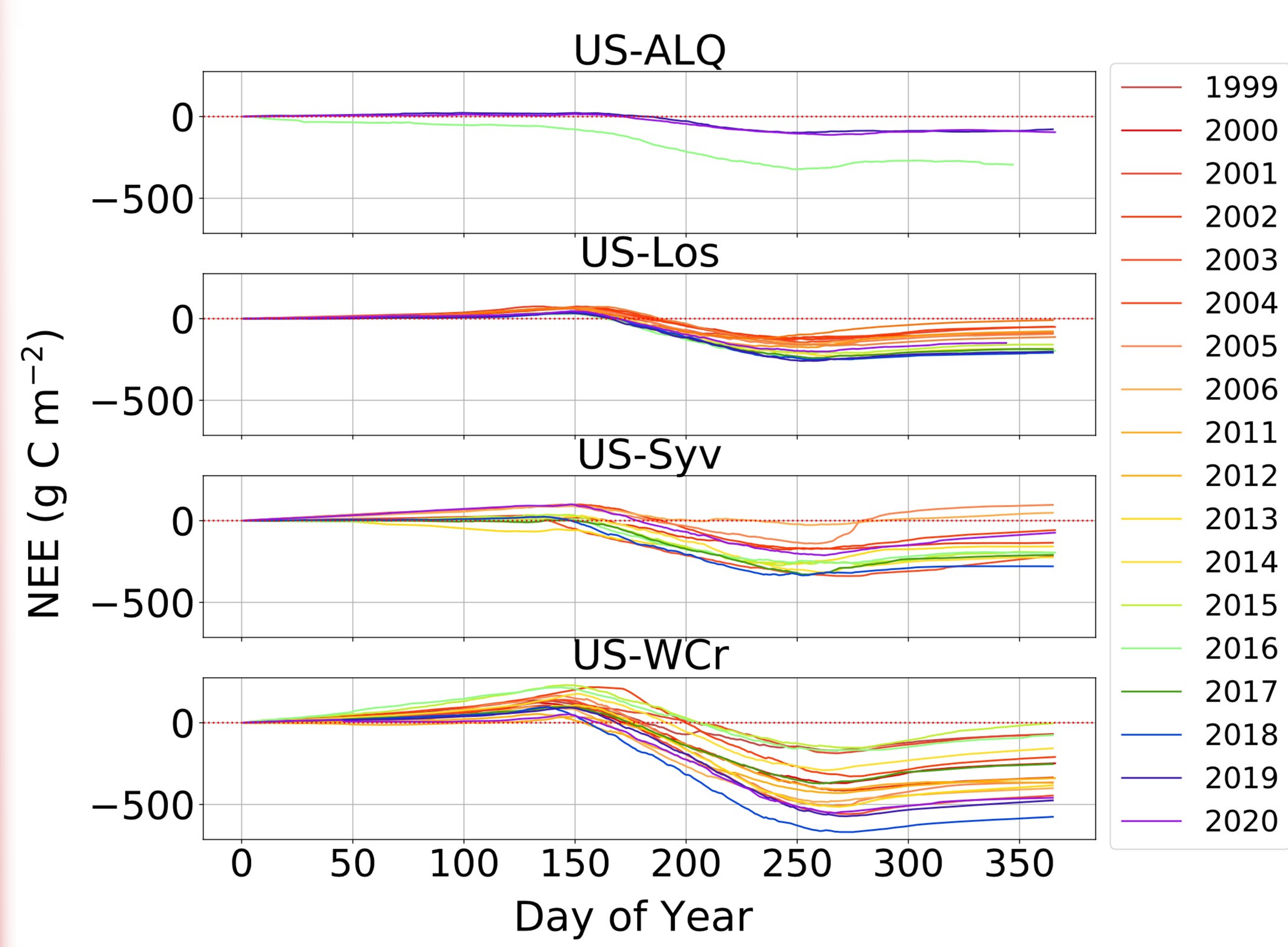


Figure 4: Cumulative NEE across all sites and years

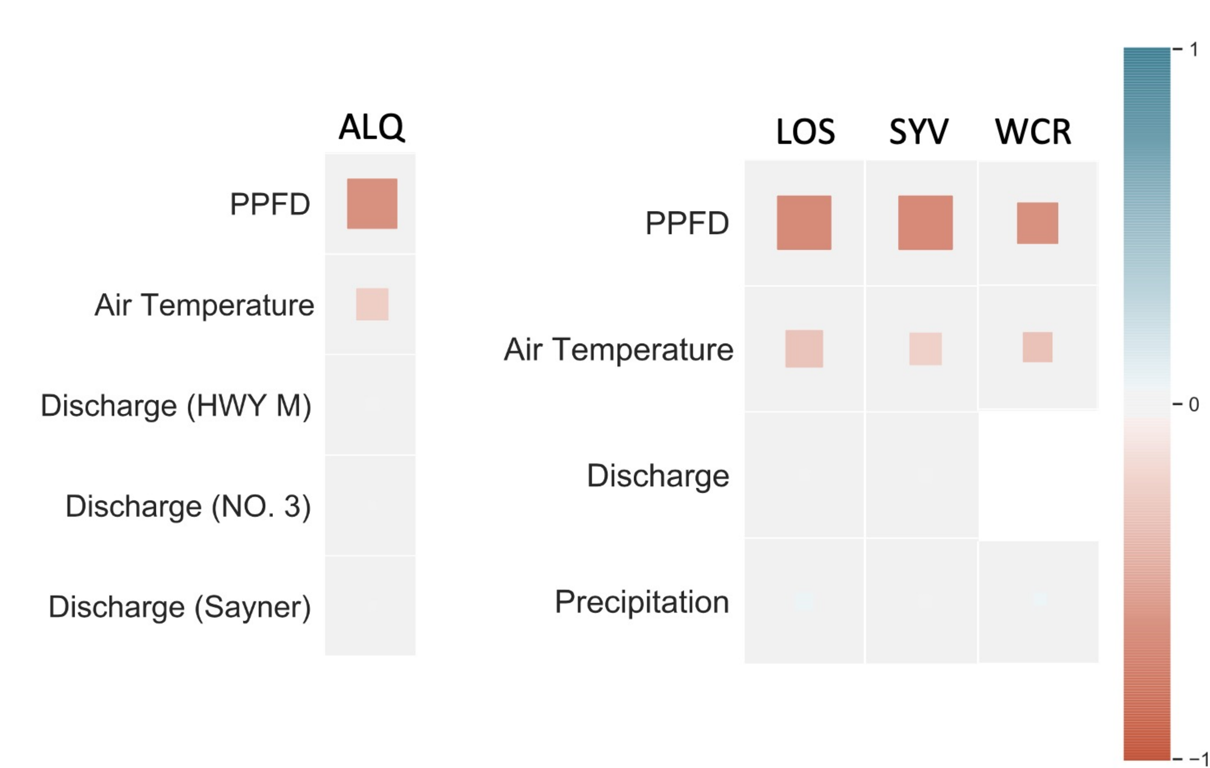


Figure 5: Carbon drivers listed for each site with square size and color representing magnitude of Pearson correlation coefficient when plotted against NEE.

- Forest sites were found to have more interannual variability than wetland sites (Figure 3 and 4)
- Forest sites accumulated substantially more carbon per year on average than wetland sites (Figure 4)
- Pearson regression analysis shows that radiation and air temperature were dominant drivers of NEE across years, with little to no correlation with discharge or cumulative precipitation (Figure 5)

Discussion

- A trade-off between forest and wetland carbon sequestration:
  - **Forest** carbon dynamics are **highly variable** but have **high rates of uptake** from year to year.
  - **Wetlands** are **less variable** but have **lower rates of uptake**
- Risks of sequestration reversal make wetlands more reliable for long-term carbon storage
- Maximizing received PPFD via afforestation or other means will maximize uptake for both ecosystem types

Future Work and Implications

- Further investigation to be carried out on carbon-water dynamics via wavelet coherence analysis
- Findings will
  - Help **tailor restoration efforts** across different ecosystem types based on drivers
  - Inform policy on the most economically viable methods for **maximizing sequestration in the long-term**
  - **Generate other research pathways** by conducting similar studies in other regions

Acknowledgments

We acknowledge USGS for providing streamflow data and the Department of Energy Ameriflux Network Management Project for supplying carbon and micrometeorological measurements. We would also like to thank Ankur Desai, Brent Olson, and Jonathan Thom for their support of the sites considered in this study.