Unlocking the complexities of greenhouse gas sources and sinks in forested wetlands

Kabi Raj Khatiwada[1], Benjamin Runkle[1,2]
[1] Environmental Dynamics, University of Arkansas, Fayetteville, AR,
[2] Department of Biological and Agricultural Engineering, University of Arkansas, Fayetteville, AR,

Wetlands

Wetlands generally function as effective carbon sinks, capturing and sequestering carbon dioxide (CO_2) within the plant materials or soil sediments (McLeod et al., 2011, Frontiers in Ecology and Envt).

However, due to anaerobic conditions, and distinctive soil biogeochemistry these wetland ecosystems can facilitate methane (CH_4) production and transportation (Vroom et al., 2022, Aquatic Botany).

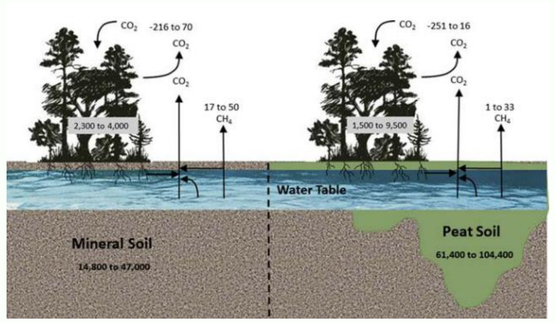


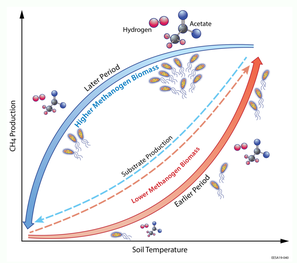
***Figure 1**: Forested wetland carbon pools (g m^{-2}) and fluxes in North America. (Source: Trettin et al., 2019, Book: Developments in Soil Science, Elsevier)*

This interplay between CO_2 uptake and CH_4 release in wetlands is critical because the current growth of CH_4 is in large-scale, rapid, and often exceeds normal climate variability (Nisbet et al., 2023, GBC).



***Figure 2**: Forested wetlands (Source: Wisconsin wetlands association)*

CH_4 is primarily produced in the anaerobic regions of the waterlogged soils where oxygen is limited.



Intra-seasonal variability, driven by substrate-mediated microbial and abiotic interactions, influence the magnitude of the CH_4 flux.

Trees in wetlands have localized gas production and transport mechanisms that help to release CH_4 through stems or modified roots into the atmosphere.

***Figure 3:** Schematic of the microbial substrate-mediated CH_4 production hysteresis. (Source: Chang et al, 2020; EGU Biogeosciences)*

Eddy covariance and flux towers

Eddy covariance is a micro-meteorological method for the observation of the exchange of gas, energy, and momentum between ecosystem and atmosphere.

It measures the sum of soil/stem/land/canopy - atmosphere gas flux

Calculated by the covariance of fluctuations of vertical wind velocity and fluctuations of gas to be measured.

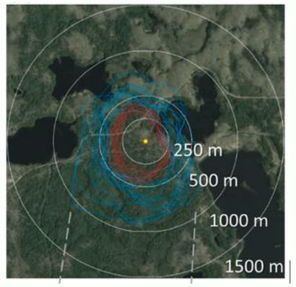


***Figure 4**: Example footprint of tall tower in Ameriflux site (Source: Chu et al., 2021, AFM)*



***Figure 5**: Flux tower at the rice farm (Source: Landscape flux group)*



***Figure 6**: Tall tower flux (Source: Missouri Ozarks AmeriFlux (MOFLUX) site. It is 105 feet tall)*



***Figure 7**: A chamber setup in a tree to measure fluxes from stem, at French Guiana*

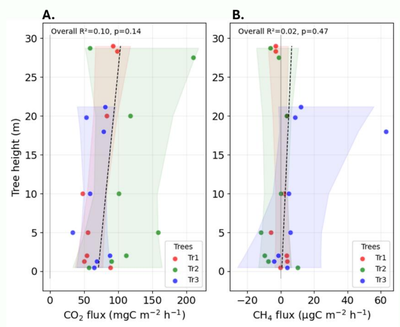


***Figure 8:** Vertical variation in CO_2, and CH_4 fluxes along vertical height of trees (Source: manuscript in progress) .*

Modeling the carbon flux processes

Different modeling strategies are being implemented to incorporate the complex interactions that govern biogeochemical processes and gas flux generation in wetlands.

Improving our ability to model these landscapes is important because wetlands contribute up to 25 % of the total natural and anthropogenic CH_4 sources estimated by bottom-up approaches (Saunois et al., 2025, ESSD).

And the aim of my thesis is to improve the mechanistic understanding of the controls on CH_4 flux in vegetated freshwater wetlands.

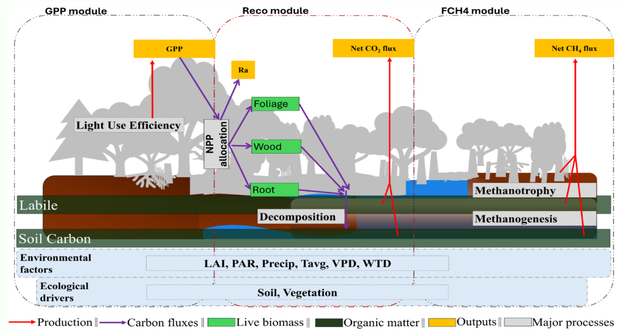


***Figure 9:** Conceptual diagram of a model showing sequential connections among the gross primary productivity, (GPP) ecosystem respiration (Reco/CO_2), and methane (CH_4) fluxes respectively. (Source: manuscript in progress)*

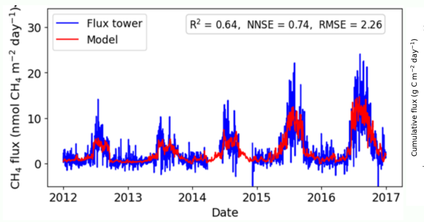


Figure 10: *Comparison of methane flux measured from the flux tower (blue) with the model-simulated flux (red) at the forested wetland US-PFA at Park Falls, Wisconsin (Source: manuscript in progress)*

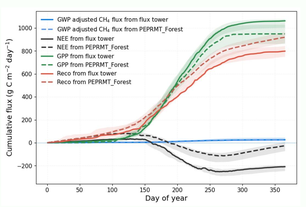


Figure 11*: Annual cumulative fluxes for understanding the summary of carbon dynamics (GWP = Global Warming Potential; NEE = Reco-GPP) (Source: manuscript in progress)*

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