Seasonal and Spatial Variation of Soil Respiration in a Pacific Northwest Second-Growth Forest

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Abstract

This study seeks to address seasonal and spatial patterns, as well as potential abiotic controls on CO_2 efflux within a Pacific Northwest second-growth forest. Forests in this region have the capacity to store and cycle more biomass carbon per unit area than most ecosystems. Soil respiration is a large component of ecosystem respiration that largely determines whether or not a given ecosystem acts as a carbon sink or source. Soil CO_2 efflux was measured continuously for seven years within the Evergreen Ecological Observation Network. Soil respiration exhibited seasonal trends in our system, with peaks occurring in summer, and continuing through early fall. Soil respiration varies spatially in our system, perhaps due to plant community differences. Soil respiration is higher at higher soil and air temperatures. Our results show that there is no significant relationship between soil respiration and precipitation or soil moisture. This may be due to the high levels of rainfall in this temperate rainforest system.

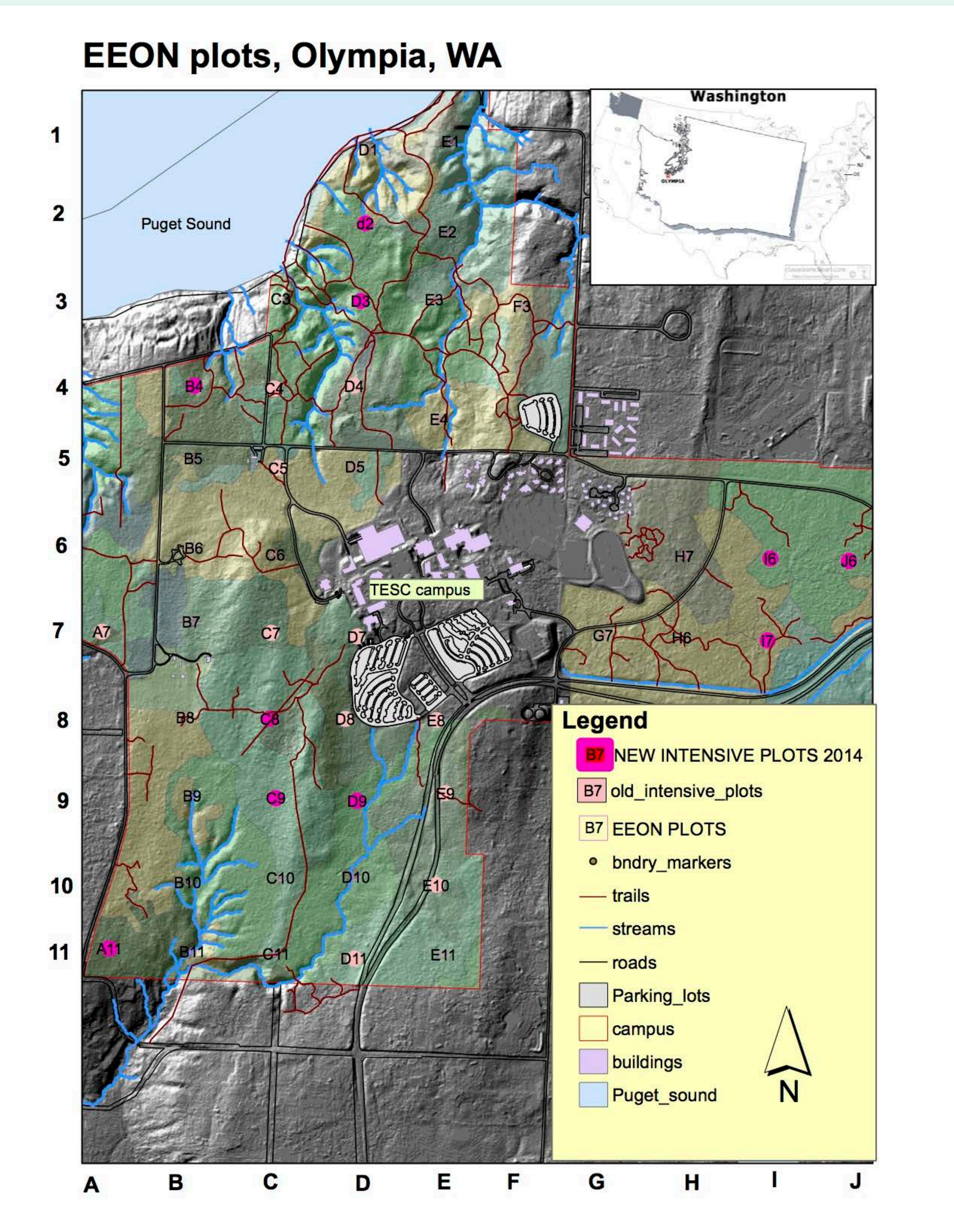

Figure 1. Map of study area showing 44 permanently monitored 10m radius plots oriented along a 250 m grid. Light pink dots represent plots that were intensively monitored from 2008-2014. Bright pink dots represent the set of plots that we began intensively monitoring in August 2014.

Introduction

- Forests of the Pacific Northwest store and cycle more biomass carbon per unit area than most other ecosystems. Forests in this region directly impact the global carbon budget. Thus it is important to gain an understanding of the carbon dynamics of these forests, both above and belowground.
- Ecosystem respiration is a dominant process that determines whether or not a given ecosystem acts as a carbon sink or source. More than half of ecosystem respiration comes from soil CO_2 efflux, which includes both root respiration and soil microbial respiration.
- Here, we present preliminary analyses of seasonal and spatial trends in soil CO_2 efflux in a seven-year data set in the Evergreen State College forest reserve experimental plot network (EEON).
- We address seasonal patterns and potential abiotic (soil temperature and moisture) controls on CO_2 efflux.

Methods

- This study was conducted in the Evergreen Ecological Observation Network (EEON; Figure 1), 44 permanent ecological monitoring plots located within the 380 ha Evergreen State College forest reserve in Olympia, Washington.
- Of the 44 plots, 10 have been monitored intensively since 2008, with a new set of 10 intensively monitored plots established in August of 2014.
- Each intensive plot contains four permanent subplots oriented in the cardinal directions, where long-term net soil carbon efflux rates (NCER) were measured.
- Measurements were made during a 7-year period (2008-2014). NCER was measured using an LC Pro+ Infrared Gas Analyzer (ADC BioScientific Ltd. Hoddensdon, UK) every month.
- These data were compiled and analyzed for temporal trends. We also used simple linear regression to examine relationships between soil temperature, moisture, and NCER in the seven-year data-set, and for measurements taken in summer of 2014. All data analyses were conducted using JMP Pro 10 software (SAS Institute 2014).

Figure 2. Undergraduate researchers learn how to use an infra-red gas analyzer used to measure soil CO2 efflux. The commonly-used method measures CO_2 accumulation in a chamber placed tightly against the forest soil.

Results

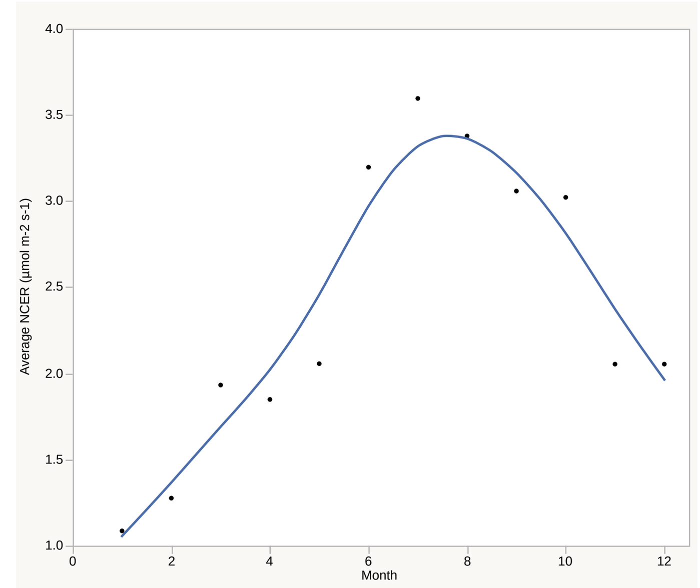

Figure 2. Graph depicting average net carbon efflux rate (NCER) for all intensively monitored plots averaged by month throughout sampling period (2008-2014).

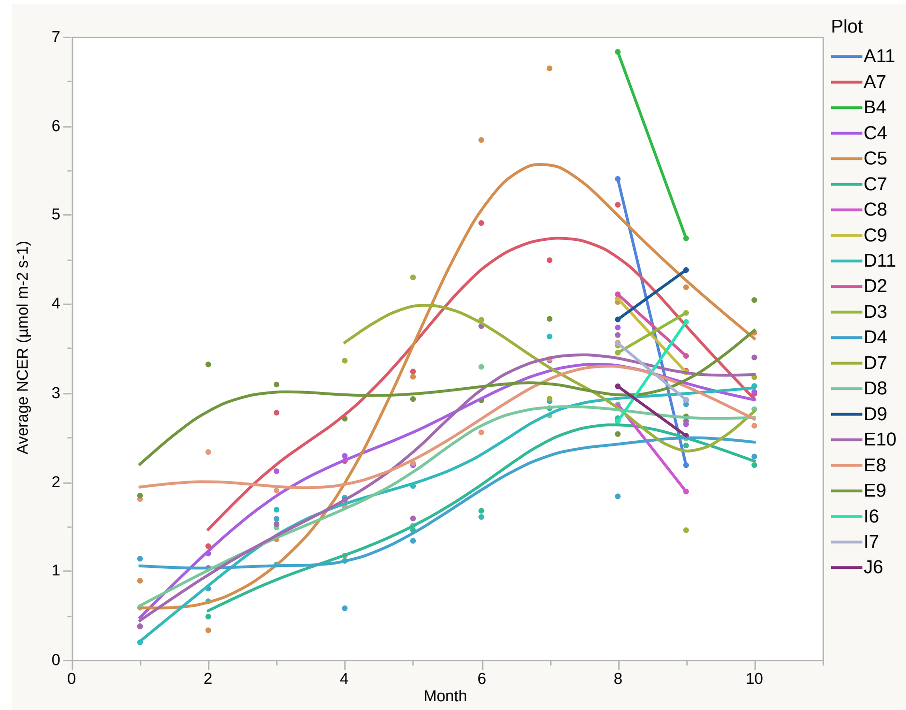

Figure 3. Graph depicting average net carbon efflux rate (NCER) averaged by month throughout sampling period (2008-2014). Data is separated by EEON plot in order to illustrate variation of NCER among plots.

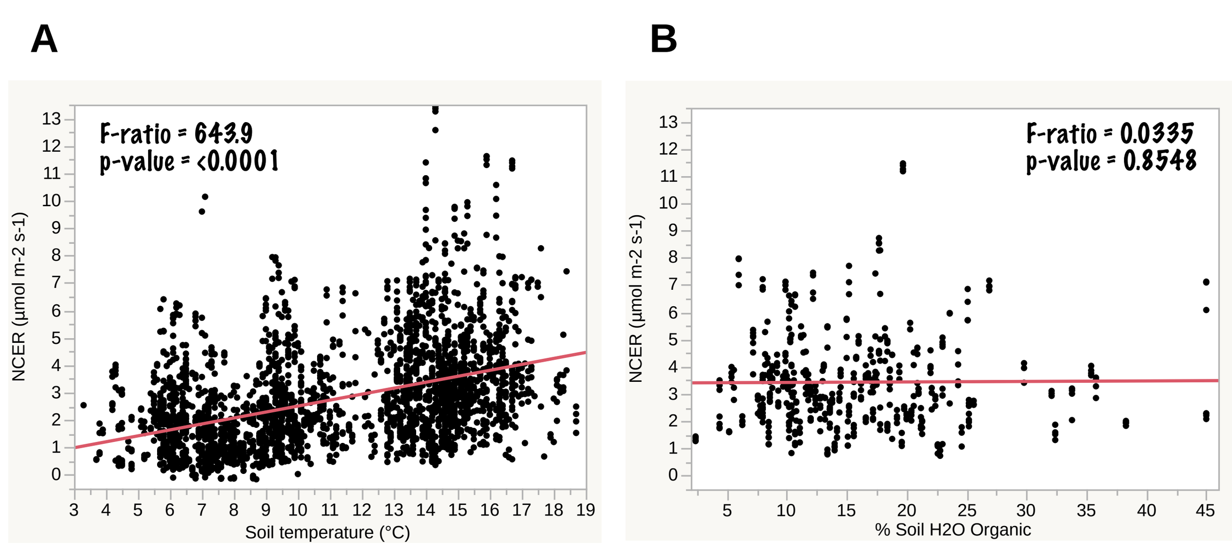

Figure 4. Comparison of NCER among intensively-monitored plots by soil temperature (A) and percent organic soil moisture (B). Regression analyses suggest that soil temperature has a significant effect on NCER ($F = 643.9$, $r^2 = 0.1793$, $P = <0.0001$), but percent organic soil moisture does not ($F = 0.0335$, $r^2 = 6.646e\text{-}5$, $P = 0.8548$).

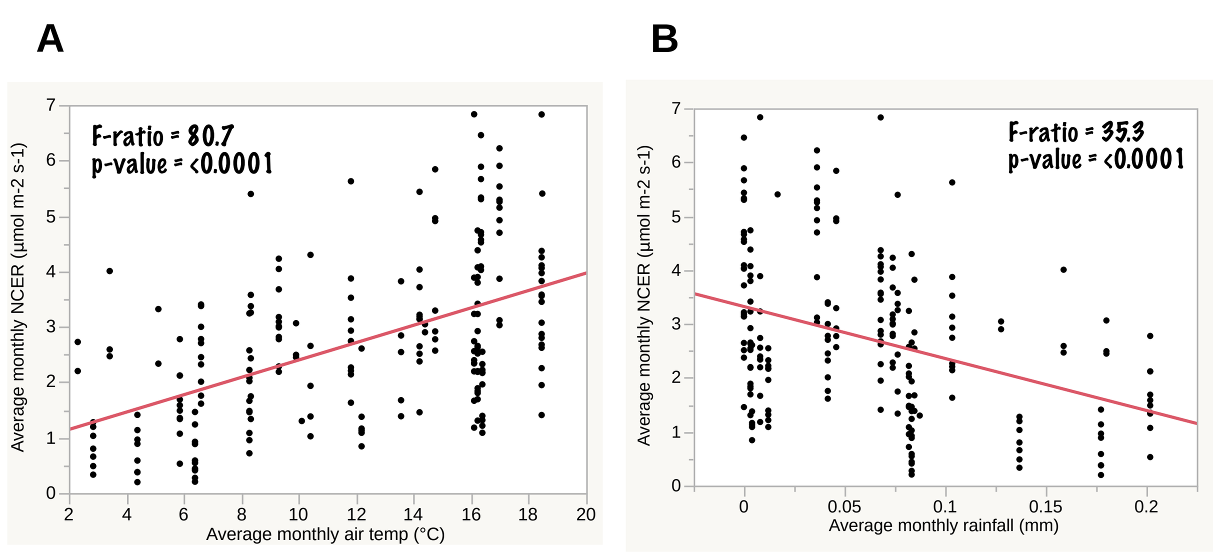

Figure 5. Comparison of average monthly NCER by average monthly air temperature (A), and average monthly rainfall (B). The regression analyses suggest that monthly NCER varies concomitantly with both air temperature ($F = 80.7$, $r^2 = 0.278$, $P = <0.0001$) and monthly rainfall ($F = 35.3$, $r^2 = 0.146$, $P = <0.0001$).

Major Findings

1) Seasonal trends in soil respiration exist in our system, with peaks occurring in summer, and continuing through early fall.
2) There is variation in average soil respiration between plots where certain plots (e.g., A7, C5) have NCER that is 2x higher, potentially due to plant community differences.
3) Soil respiration is generally higher at higher soil and air temperatures.
4) There was no clear significant relationship between soil CO_2 efflux and soil moisture, and soil CO_2 efflux was negatively related to monthly average precipitation.

Future Work

- Researchers at The Evergreen State College continue to collect monthly NCER readings throughout 2014-2015.
- Differences in soil net CO_2 efflux rates will be evaluated to determine is differences are related to patterns in vegetation
- Previous work (Kirsch et al. 2012) demonstrated that higher CO_2 efflux was common when tree diversity was high in the EEON. New plots will be evaluated to see if patterns of diversity predicting NCER continue.

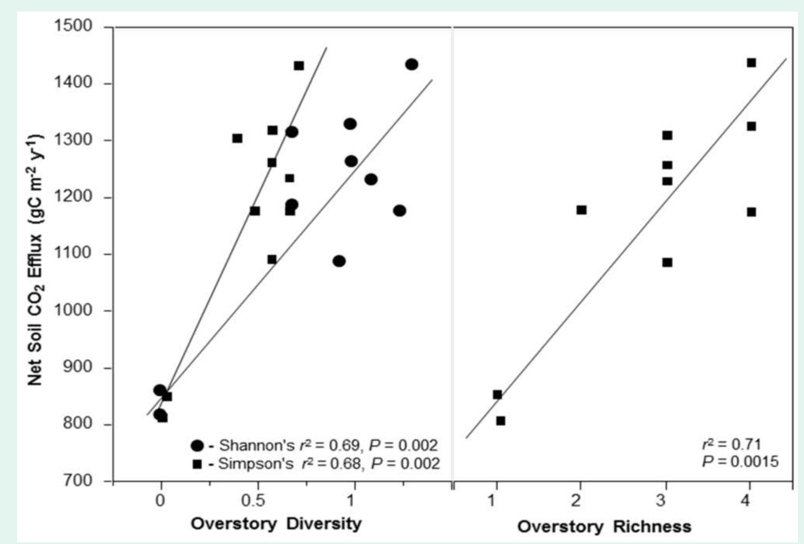

Figure 6. From Kirsch et al. (2012). Positive relationships between soil CO_2 efflux and overstory diversity represented by Shannon's and Simpson's diversity indices (which includes all 12 overstory species **(A)**), and Overstory Richness 5 which includes the five most dominate tree species; *P. menziesii, A. macrophyllum*, *A. rubra*, *T. heterophylla,*and *T. plicata* **(B)**.

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