Pacific Northwest
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Influence of water flow on heterotrophic respiration of natural soils

September 2022

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Abstract

New evidence highlights the importance of hydrology to microbial decomposition of organic matter in soils. The objective of this study was to build a reproducible and controlled capability for measuring soil respiration in the laboratory and to test the hypothesis: Soil respiration rate in a flowing system will stay higher compared to in static water. We tested replicates for flowing versus non-flowing soil water for two different soils. The water content was maintained at a consistent saturation in the flowing system but significantly desaturated in the no-flow soils over the course of a 10-day and 28-day experiment. The measured respiration had a significantly higher rate of change in the first day for one soil but after the first day and for the entire reaction for the second soil there was no measurable difference in respiration.

1.0 Introduction

New evidence has shown the importance of hydrology in biodegradation of soil organic carbon as measured by respiration (Smith, Bond-Lamberty et al. 2017, Patel, Myers-Pigg et al. 2021). Soil moisture is commonly considered one of the most important factors influencing heterotrophic soil respiration and is a key driver in with ecosystem models (Castellano, Schmidt et al. 2011, Docherty and Thomas 2021). Recent research conducted at PNNL has shown that hydrology have significant effects on soil respiration relative to if the soil is wetting or drying of if the water is coming from the precipitation or groundwater (Smith, Bond-Lamberty et al. 2017, Patel, Myers-Pigg et al. 2021). When considering soils such as those at the terrestrial/aquatic interface issues such as frequent flooding needs to be considered where flood impacted soils will maintain soil moisture and maintain higher soil respiration (Docherty and Thomas 2021). Also, the chemistry of the water flowing into the system will have a profound impact. In coastal regions where the soil respiration can reduce over 50% during a saltwater intrusion and over 50% increase with freshwater inputs (Neubauer 2013). However these systems do not account for the movement of water but rather take an instantaneous measurement that relates to the water chemistry and soil moisture at that moment. However, there has been respiration and oxygen dynamics measured during flowing water conditions for river sediments (Kaufman, Cardenas et al. 2017, Mori, Debeljak et al. 2017). It's been shown that respiration rates from flow-through chambers are higher than closed cells this response increases with flow through finer grained sediments from heterotrophic respiration (Mori, Debeljak et al. 2017). This research will take methodical steps to refining these measurements and elucidating the mechanisms influencing soil respiration with water flow.

As stated in the DOE's Office of Biological and Environmental Research program grand challenge "reactive-transport models… do not adequately represent living components of the Earth system such as microbes."*(U.S.DOE 2018)* This research was designed to reduce the uncertainty of measured biodegradation/respiration rates measured in laboratories for use in Earth system models. The objective of this study was to build a reproducible capability for measuring soil respiration in the laboratory and to test the hypothesis: Soil respiration rate in a flowing system will stay higher compared to in static water.

2.0 Methods

To test how water flow through soil will influence the respiration rates measured from soils selected from coastal and inland (irrigated) settings. These soils experience regular inundation and as result have biogeochemical processes occurring under water flowing conditions. Flowing water translocates solutes through soil which can replenish needed nutrients used by microbes. As such the measured soil respiration where water is flowing through the soil should be different (higher) over time than measurements of respiration using traditional static conditions. We propose to test the hypothesis: Soil respiration rate in a flowing system will stay higher over time (1 week) compared to respiration in static water, due to a constant supply of resource inputs. Water used will be extracted from the soil in a batch reaction. Two primary tasks were determined: 1) to develop reproducible tests, and 2) test water flow effects on soil respiration.

Develop reproducible tests: This experiment combined two common methods of unsaturated flow columns (Rod, Um et al. 2010) and respiration incubations (Rod, Smith et al. 2020). Columns (100 mL volume) were engineered to accommodate influent and effluent flow through the soil while continuously monitoring C lost as CO_2 and CH_4. To accomplish this specialized column set up was engineered. Central to the design was the soil column which was placed on a porous plate (Figure 1). Water will be delivered to the column with a syringe pump and distributed over the top of the soil through a sealed inlet. The top was capped and fitted with gas sampling lines which lead to a gas concentration analyzer (Picarro Inc.). Vacuum was applied to the bottom of the core through the porous plate to facilitate water flow out of the bottom of the soil core and into a sample container. Water content was monitored with soil moisture sensors since water content is a significant variable that effects soil respiration (Castellano, Schmidt et al. 2011, Docherty and Thomas 2021).

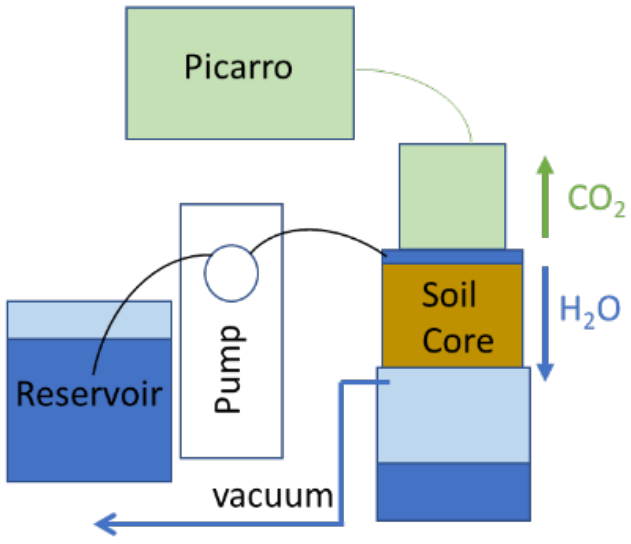

Figure 1. Experimental system of the unsaturated flow through soil column with respiration measurement

Figure 1. Experimental system of the unsaturated flow through soil column with respiration measurement

Since this experimental design is novel and the method used for this research, plus it can be adapted for future research, I ensured that results were reproducible and represent differences between soils. To accomplish this the two soils collected for the study were each sampled with field moisture conditions. Multiple tests were conducted where carbon will be measured in gas, liquid, and solid phase to quantify the mass balance of carbon in the system. These tests were repeated with flow and no flow conditions. ANOVA was used to evaluate the carbon gas flux as reproducible within each soil but different between soils.

Water flow effects on soil respiration: To investigate the influence of flowing water on soil respiration rate a series of tests were conducted on one coastal soil where natural periodic inundation occurs and one irrigated agriculture soil. These tests were done to compare a matrix of two water conditions: 1) flow through tests, 2) static tests. Cumulative CO_2-C was measured over time at regular intervals for over to seven days for Beaver Creek soil and for 28 days for Prosser Soil. Bulk respiration rates were calculated from change in concentration over time (dC/dt). Organic carbon degradation (mineralization measured as CO_2 emitted) was computed from the concentration changes as: A=(dC/dt V/M Pa/RT) where A is the flux (µmol g soil-1 s-1), dC/dt the rate of change in gas concentration (mole fraction s-1), V the total chamber volume (cm3), M dry soil mass (g), Pa atmospheric pressure (kPa), R the universal gas constant (8.3 x 103 cm3 kPa mol-1 K-1), and T air temperature (K). This will provide a rate for comparison between the water treatments of flowing and static. Total organic flux was measured including gas liquid phase and at the end of reaction the soil cores were deconstructed to measure for carbon and carbon forms using NME and FTICR-MS.

3.0 Results

Initial results:

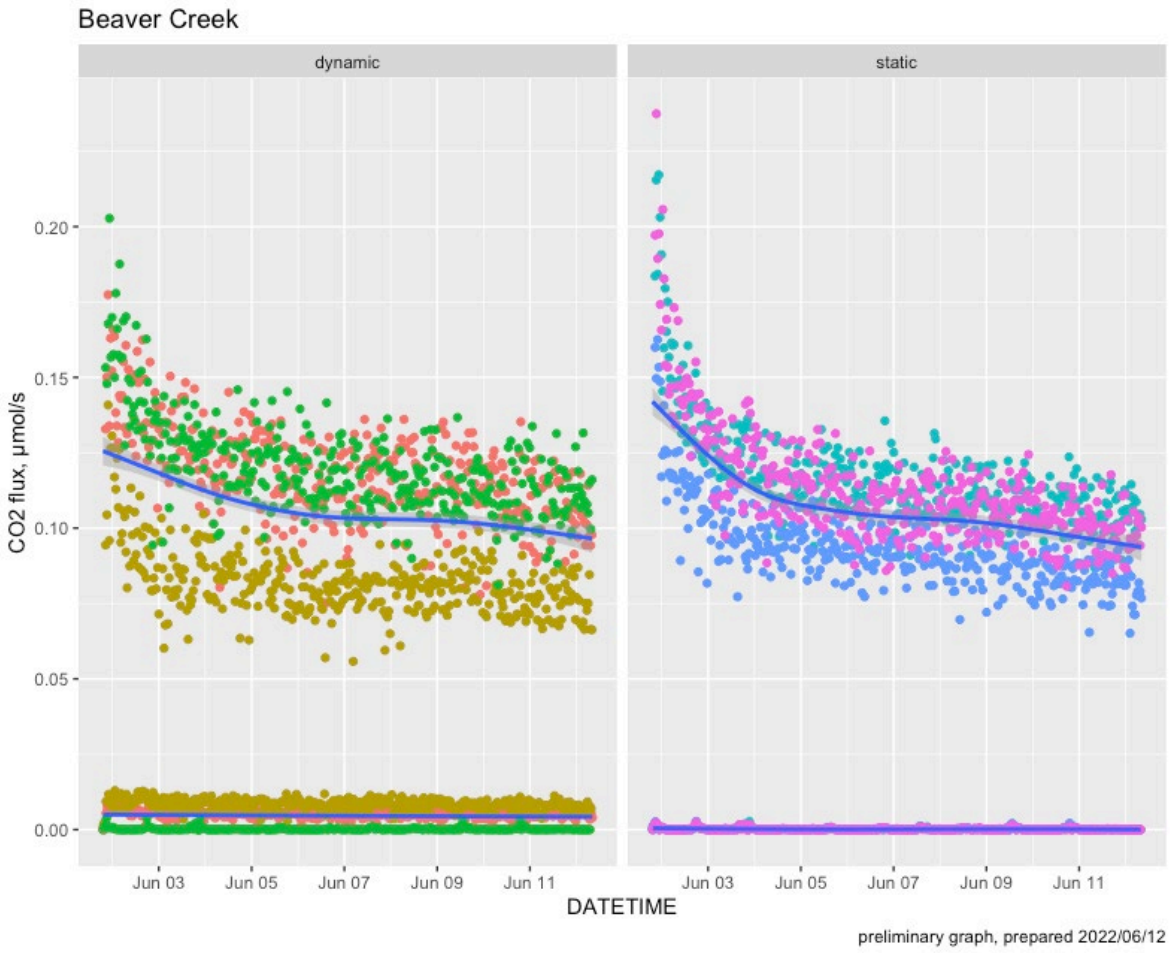

Figure 2. Carbon dioxide flux from 10 days of Beaver Creek soil reaction at 80% soil water content for three flowing water (dynamic) columns and three no-flow water (static) columns.

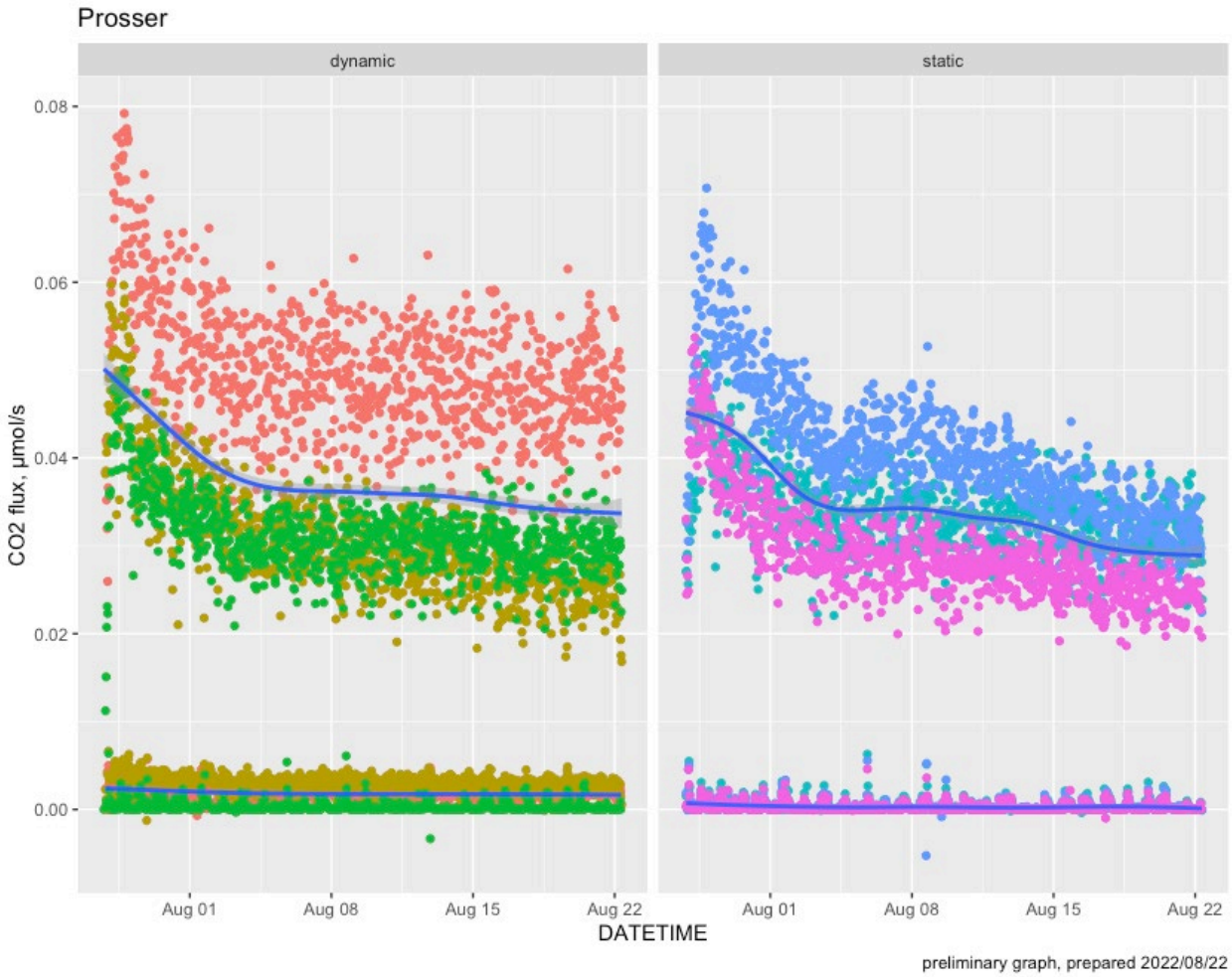

Figure 3. Carbon dioxide flux from 28 days of Prosser soil reaction at 80% soil water content for three flowing water (dynamic) columns and three no-flow water (static) columns.

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