Effects of Mountain Pine Beetle Infestation on Soil Carbon Losses in a Lodgepole Pine Forest Ecosystem in Southeast Wyoming

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Introduction

Approximately 1.4 million acres of northern Colorado and southeast Wyoming forests were impacted by bark beetles in the most recent outbreak. Forest managers and landowners have reported significant losses in timber and recreational values while researchers are predicting impacts on forests’ ability to uptake carbon (C), cycle essential nutrients, and maintain water. Bark beetles (mountain pine beetle) burrow under the bark of lodgepole pine (\textit{Pinus contorta}) to feed and lay eggs over the winter. As a result, within two years after bark beetle attack, trees die due to a shortage of water and nutrients. Forests uptake more C (carbon sink) than they respire to the atmosphere. The disturbance of the processes regulating the flux may change the atmospheric carbon dioxide (\textit{CO}_2) concentration. As forests are devastated by this infestation, large numbers of trees that were C sinks may suddenly become C sources to the atmosphere. Release of C from forest soil—soil respiration—is one of the largest C sources to the atmosphere. Thus, studying soil respiration allows us to achieve a better perspective on how forests contribute to the global C cycle.

Objectives

Our main goals were to learn how soil respiration responds to increasing tree mortality as well as changing environmental drivers (soil temperature and moisture) associated with bark beetle attack.

Materials and Methods

The study site is located at 9,200 feet in the Medicine Bow Range near the Chimney Park Boy Scout camp in southeast Wyoming. We monitored two research-stands since summer 2008, including a stand attacked by bark beetles in summer 2007 (\textit{attacked stand}) and an \textit{unattacked stand}. We measured soil respiration, moisture, and temperature. In each stand, 15 measurements were conducted biweekly from May to October, 2008–2012.

Results and Discussion

Soil respiration in the \textit{attacked stand} was less than half the rate compared to that of the \textit{unattacked stand}. This distinction was maintained during each growing season since the bark beetle attack (2008–2012, Figure 1). However, the relative magnitude of the soil respiration varied by year depending on climate conditions—during the driest year (2012), soil respiration was
reduced in both *attacked* and *unattacked* stands.

Because tree root respiration is a significant portion of soil respiration, we investigated how beetle-induced mortality of trees impacts soil respiration. We used a proxy called live basal area (LBA) to determine beetle-induced tree mortality. LBA defines how many live trees are left within a stand. Figure 2 shows that soil respiration and LBA were highly correlated ($r^2=0.77$). This indicates that soil respiration will continue to decline in attacked stands as the number of surviving trees declines with ongoing mortality.

Soil temperature and moisture are the traditional soil respiration drivers, e.g., an increase in these parameters should increase soil respiration. Soil moisture was almost twice as high in the *attacked stand*, mostly due to reduced water uptake by dead trees, compared to the *unattacked stand*. Beyond two years after the attack, however, we found no effects of soil moisture or temperature on soil respiration.

On the other hand, the research clearly shows that forest die-off due to bark beetle outbreak has a substantial and long-lasting impact on soil respiratory C losses. Finally, our research site is similar to a large area of high-elevation lodgepole pine forests across Wyoming. Thus, the findings from this research may have serious implications for estimating larger-scale forest C balances following beetle infestations in Wyoming and beyond.

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**Figure 1.** Average growing season soil respiration measured in August 2008–2012.

![Graph showing soil respiration (umol m^-2 s^-1) over years and stands.](image)

**Figure 2.** Relationship between soil respiration and live tree basal area from 2008 to 2012.

![Graph showing correlation of soil respiration with LBA.](image)