Biological Responses of Soil Microbes to Increasing Temperature and Moisture Concentration Induced by Glacial Melt in Kilpisjärvi, Finland

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Abstract

An increase in temperature in the Arctic has led to a release of excess water in Arctic soils due to glacial melt. This experiment was conducted to determine the effects of climate change on Arctic soil microbial respiration rate. Soil respiration rate is the primary path by which CO_2 fixed by plants returns to the atmosphere. It was determined that an increase in temperature is an important stimulant that will increase the number of active microbes within the soil. This study measured the effects of increased water as being detrimental on soil microbes, however this could have been affected by a number of factors. The effects of increased moisture and temperature availability on microbial respiration would likely be measured more readily during the Winter months which have experienced higher temperatures than in previous years causing a higher rate of moisture availability.

Hypothesis

Microbes collected near the topsoil level will respond to increased moisture availability and higher temperatures by respiring at a higher rate than in normal conditions, and as a result, will produce more green house gases in the form of CO_2 that will be emitted into the atmosphere.

Background

The polar regions are warming faster than any other part of the world. In these environments, the effects of climate change are intense, and therefore, can be observed readily. Microbes can be especially responsive to change within their environment, allowing for microbial communities to be used as an indicator species for climate change. These organisms are subject to a novel environment that is marked by increased moisture availability in the soils they occupy as well as higher temperatures in the region. These changes can be attributed to accelerated climate change induced temperatures that will facilitate permafrost thawing and glacier melt. The Arctic is located in the northern most point of the world. Due to this, during the Arctic summer, the region experiences a phenomenon called the "midnight sun" or a polar day. This entails that the region is subject to 24 hours of sunlight. Kilpisjärvi is a town located inside the Arctic circle, it experiences 65 days of midnight sun on average. It is also an area that historically has seen a rise in abundance of moisture due to increasing temperature. The aim of this study is to gain an understanding of microbial respiration in the topsoil located in Kilpisjärvi under conditions projected under climate change.

Methods

Topsoil in the A horizon level was collected near the Kilpisjärvi Biological Research Station in Finland. Sixteen 20 g soil samples were placed outside in 40 ml vials in a setting that maximized the amount of sunlight available. Eight vials were placed inside a greenhouse; 3 ml of water were added to half the samples, and 8 vials were placed outside in ambient temperature; 3 ml of water were added to half of these samples. In total, 4 vials were placed in a natural setting without an addition of water to establish a control group; 4 vials were placed in a natural setting with an addition of water to establish the sole effects of increased moisture on the soil; 4 vials were placed inside the greenhouse without an addition of water to establish the sole effects of temperature increase on the soil; 4 vials were placed inside the greenhouse with an addition of water to establish the compounded effects of both an increase in temperature and moisture availability. Over a period of 10 days, we measured microbial activity inside the vials. 12 ml vials were evacuated of atmosphere and then were used to collect gas samples from the 40 ml vials of soil after an incubational period of 6 hours. After the samples were collected the vials were left uncapped over a period of 48 hours to encourage microbial respiration. The gas samples in the 12 ml vials were injected into a LI-7000 gas analyzer to measure CO_2 concentration and calculate respiration rate.

Experimental Phase

Figure 1. Vials inside greenhouse[1]

Figure 2. Vials in ambient temperature

Figure 3. Setup of the experiment[2]

1. Figure 1 shows the temporary greenhouse. The temperature inside was on average 5 °C warmer than the natural setting.
2. Figure 3 exhibits the distance between the two sets of vials.

Results

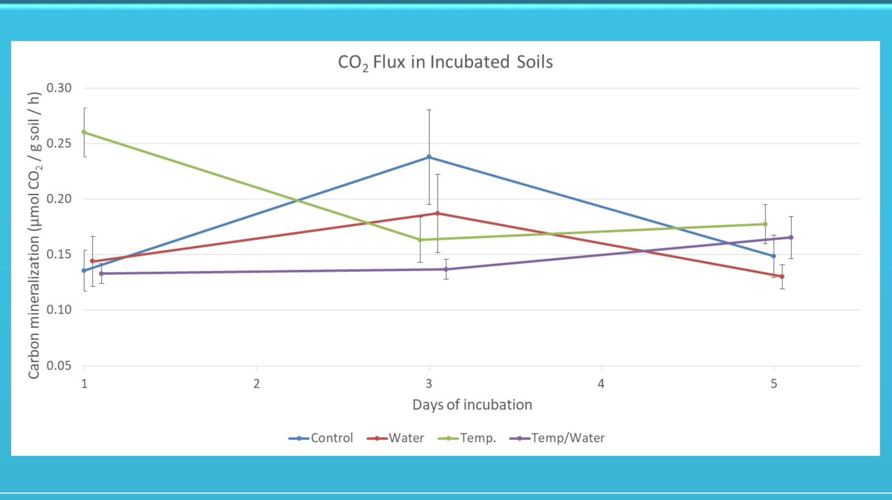

Figure 4. Avg. microbial respiration rate of the four soil sample sets

Microbial respiration rate is calculated as carbon mineralization rate (Cmin). Cmin measurements were obtained on setup (day 1), approximately 48 hours later (day 3), and 96 hours later (day 5). The Cmin rate for the control (C) increased significantly by day 3 from setup on day 1. However, the rate of CO_2 production had decreased again to its initial level by day 5. The vials with added water (W) showed a slight increase in Cmin from the day 1 to day 3, but similarly decreased again by day 5. The vials inside the greenhouse without water (T) showed a very high initial Cmin rate but decreased significantly by day 3. The Cmin then increased slightly by day 5. The greenhouse vials with water added (TW) showed low respiration on day 1 and day 3, then increased slightly by the final day of experimentation.

Discussion

T alone stimulated microbial respiration, however the microbes were unable to maintain the higher respiration throughout the experiment. Also, TW vials ended with a higher rate of Cmin than the W vials. In comparing soil water content (SWC), the difference between the W and TW vials was negligible. Therefore, SWC likely did not cause the difference in respiration rates between W and TW vials. Both the T and TW vials increased by the final day of measurement. It can be speculated that in better laboratory conditions the trendline would have showed a continuous increase. At day 3, it is possible that the T & TW treatment vials were mistakenly deprived of oxygen (O_2). This suppression of O_2 in the vials likely caused the decrease in microbial respiration in T/TW as observed in the data presented. Additionally, this experiment was conducted in late spring, when water is not a limitation. Due to this, it is likely that there would not be a significant increase in Cmin within the W and TW samples in comparison to the C samples. Climate change affects the seasons differently and whereas the warmer seasons are experiencing more moisture than before, winter months are getting shorter and glacial growth rate is decreasing over time. This has caused the Arctic soil to experience increased moisture over a longer period of time.

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