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Experimental soil warming leads to sustained carbon losses from alpine treeline ecosystems

Frank Hagedorn, Sonja Wipf, and Melissa Martin

Swiss Federal Institute for Forest, Snow and Landscape Research, Soil Sciences, Birmensdorf, Switzerland (hagedorn@wsl.ch)

The impact of climatic warming on the C balance of terrestrial ecosystems is uncertain because rising temperature increases both C gains through net primary production, but also respiratory C losses. 'Cold' ecosystems such as treeline ecotones will respond particularly sensitive to climatic changes because many processes are limited by temperature and soils store particular large amounts of labile soil organic matter. In our study, we investigate responses of carbon fluxes to 4 years of experimental soil warming by 4°C. The warming study was conducted in a 9-year CO2 enrichment experiment, in which the added CO2 carried another d13C signature than normal air, which allows the tracing of new carbon through the plant and soil system. This provides new insight into carbon cycling at the treeline and it shows which C flux respond most sensitive to climatic changes.

Results showed that soil warming increased soil CO2 effluxes instantaneously and persisted for at least four vegetation periods (+35-45%; +80 to 120 gC/m2/y). Annual C uptake of new shoots was not significantly affected by elevated soil temperatures, with a 10 to 20% increase for larch, pine, and dwarf shrubs, respectively, resulting in an overall increase in net C uptake by plants of 20 to 40 gC/m2/y. The temperature dependency of soil respiration did not change through 4 years of experimental soil warming, suggesting little impact of warming-induced lower soil moisture (-15% relative decrease) or a depletion in labile soil C. The fraction of recent plant-derived C in soil respired CO2 from warmed soils was smaller than that from control soils (25 vs. 40% of total C respired), which implies that the warming-induced increase in soil CO2 efflux resulted mainly from mineralization of older SOM rather than from stimulated root respiration.

In summary, the 4°C soil warming led to C losses from the studied alpine treeline ecosystem by increasing SOM decomposition more than C gains through plant growth.