Decoupling the effects of soil moisture and oxygen on soil carbon dioxide fluxes

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Soil organic matter represents a massive dynamic reservoir of terrestrial carbon and its degradation results in substantial fluxes of carbon to the atmosphere. Greenhouse gas emissions from soils depend on a number of environmental factors such as soil moisture, oxygen and temperature. The responses of soil carbon dioxide (CO_2) fluxes to changes in these conditions remain unclear but will be critical for predictive modeling of carbon fluxes with climate change. Since soil moisture and oxygen are closely linked, few experimental studies have attempted to characterize their effects on soil CO_2 fluxes separately. We conducted a factorial batch experiment to decouple these two factors by incubating soil at different moisture contents (30%-100% saturation) and under oxic versus anoxic conditions. Measurements of gas fluxes (CO_2 and methane), pore water chemistry and microbial biomass were measured at the end of the 21-day incubation. The results demonstrated that, as expected, CO_2 fluxes became moisture-limited at low soil moisture and oxygen-limited at high soil moisture; hence, fluxes were maximal at moderate soil moisture. The results also highlighted that CO_2 fluxes occurred in anoxic conditions and were affected by soil moisture independently of oxygen availability. Methane fluxes and depletion of other electron acceptors indicated that methanogenesis was likely the main pathway. The fluxes of CO_2 under saturation and under anoxic incubation demonstrated that anaerobic production of CO_2 (via fermentation and/or anaerobic respiration) may be an important source that is ignored in existing models which typically only consider aerobic respiration. An improved soil moisture function that includes both aerobic and anaerobic sources of CO_2 was conceptualized and fit to the CO_2 flux results. These findings highlight the need for improved biogeochemical understanding of greenhouse gas-emitting processes in soil and models that can adequately represent these processes when confronted with a changing climate.