Anthropogenic Disturbance of Montane Meadows May Cause Substantial Loss of Soil Carbon to the Atmosphere

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High-elevation wet meadows are biodiversity hotspots that provide critical storage for regional water supplies and contain high densities of soil C. Montane meadows are also often focal points of human activity and valuable components of regional economies.

How does anthropogenic disturbance of Sierra Nevada meadows alter soil biogeochemical cycles and impact regional C budgets?

What are the C stocks and fluxes in degraded montane meadows?

Degraded meadows contain large reserves of soil C that may be vulnerable to decomposition under aerobic soil condition.

Biogeochemical cycles in degraded meadows are dominated by high rates of CO2 production (30 Mg CO2 ha⁻¹ yr⁻¹). CH4 and N₂O production occurred only under saturated soil conditions, resulting in net CH4 uptake (-1 kg CH4 ha⁻¹ yr⁻¹) and net N₂O production (0.84 kg N₂O ha⁻¹ yr⁻¹).

Water content alone best explained CH4 (p value < 0.001, r² = 0.446) and N₂O (p value <0.001, r² = 0.284) fluxes, but greater variation existed within meadows and seasons.

Will restoration of floodplain hydrology decrease CO2 emissions?

In a lab incubation of the same meadow soils, increasing soil moisture did not decrease rates of CO2 emission as expected – even at 115% WHC.

High rates of Fe oxidation in basalt soils and facultative microbial communities may create unexpected responses to restoration.

Take home messages

- Meadows contain large reserves of soil C that may be lost to the atmosphere through decomposition
- Degraded meadows are large net sources of CO2 to the atmosphere
- Response of individual meadows to restoration may depend on soil chemistry and microbial community dynamics

Three seasons in the same degraded meadow in the northern Sierra Nevada range

60-70% of the 134,000 hectares of Sierra Nevada meadows have been degraded as a result of anthropogenic disturbance. Degradation results in disruption of floodplain hydrology, lowered water tables, decreased NPP, and aerobic soil conditions.

What is the impact of disruption of floodplain hydrology on C cycling in meadows?

Hypothesis 1: Despite long histories of anthropogenic disturbance, degraded meadows have high residual C stocks.

Hypothesis 2: Meadow degradation alters soil biogeochemical cycles and converts meadows from a net C sink to a net source to the atmosphere.

Hypothesis 3: Restoration of floodplain hydrology will decrease rates of OM decomposition and result in soil C sequestration.

Biogeochemical cycles in degraded meadows are dominated by high rates of CO2 production (30 Mg CO2 ha⁻¹ yr⁻¹). CH4 and N₂O production occurred only under saturated soil conditions, resulting in net CH4 uptake (-1 kg CH4 ha⁻¹ yr⁻¹) and net N₂O production (0.84 kg N₂O ha⁻¹ yr⁻¹).

Even accounting for differences in global warming potential, CO2 made up 99% of the annual GHG budget.

These meadows produced an average of 30.4 tons of CO2e ha⁻¹ yr⁻¹.

CO2 sequestered by 11.6 ha of forest in 1 year