Soil Carbon Cycling in Spring-fed Wetlands in a California Annual Grassland Matrix: Response to Declining Water Availability

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How will increased drought affect the soil carbon dynamics of California spring-fed wetlands?

ABSTRACT Permanent and ephemeral spring-fed wetlands are a functionally important component of the annual grass-dominated matrix in California. Plant productivity is substantially greater in perennially moist wetlands than in adjacent grasslands which experience severe seasonal drought stress. Low redox potential in wetland soils can increase C storage relative to well-drained soils. However, the role of wetlands in soil C sequestration is likely to be partially offset by emissions of CH_4, a greenhouse gas with greater radiative warming potential per molecule than CO_2. In coming decades, climate change is likely to become a significant driver of biogeochemical cycling in California ecosystems. Given uncertainties in precipitation forecasts for California, we are studying the effects of increasing moisture (via annual grassland manipulation) and increasing drought (via spring-fed wetland manipulation, this study). We hypothesize that drying of wetland soils should release microbes from O_2 limitation and increase rates of C loss via aerobic respiration, while reducing soil emissions of CH_4. We collected 6 months of baseline data, then trenched upslope of wetland plots in November 2003 to collect and monitor their groundwater sources prior to a 50 % reduction in water inputs. Several months were allowed to elapse before initiating water reduction to account for re-equilibration following trenching disturbance. We measured trace gas fluxes and above- and belowground net primary production to determine if trenching had a significant impact on soil C dynamics. Aboveground productivity measured at its summer peak in 2004 ranged from 550 to 750 g m^{-2} and followed no trend with treatment. Fine root production was higher in treatment plots. Fluxes of CO_2 appeared higher in treatment plots prior and subsequent to trenching disturbance, and fluxes of CH_4 were slightly lower in pre-treatment plots. We compared the ^{13}C signature in soil (0-10 cm) inside and outside wetland plots to assess patterns in photosynthetic strategy of the overlying vegetation. Annual grassland-dominated areas were C3-dominated, while wetland plants included both C3 and C4 types. The drydown will begin in summer 2005. Our results will contribute to our understanding of the effects of climate change on the C sequestration potential of spring-fed wetlands.

Research Questions and Hypotheses

(1) How does decreasing precipitation affect soil C fluxes in wetlands?

***Hypothesis I**: Decreased water inputs to spring-fed wetlands will decrease the role of wetlands as carbon sinks due to lower net primary productivity and greater CO_2 emissions. Gradual drying of wetlands will also decrease CH_4 emissions and increase CH_4 consumption rates, but these fluxes are likely to be small and have a minimal effect on the net carbon balance for the soil.*

(2) Will long-term changes in soil moisture drive changes in the plant community composition, and feed back to soil C dynamics?

***Hypothesis ii**: Changes in soil C cycling with increased drought will initially be driven by changes in microbial activity. Only after several years of lowered rainfall will shifts in plant community composition occur and subsequently affect soil C dynamics.*

Site Characteristics

- UC Sierra Foothills Research & Extension Center (Yuba County, CA)
- Elev 90 to 600 m, steep to moderately sloping terrain
- Mean ann precip: 750 mm y^{-1}
- Air temp: 32.0 °C (Jul) to 2.2 °C (Jan)
- Soils: shallow clay loams (alfisols, inceptisols) of Auburn and Argonaut series
- Wetlands are perennially moist despite lack of summer precipitation
- Flora: rushes (*Juncus* spp.), reeds (*Typha angustifolia*) and perennial grasses (typically exotic).

Fig. 1. Perennially moist wetlands with perennial vegetation are bordered by annual grasses.

Fig. 2. Photo taken after trenching upslope and installing PVC standpipe (near center) for water collection.

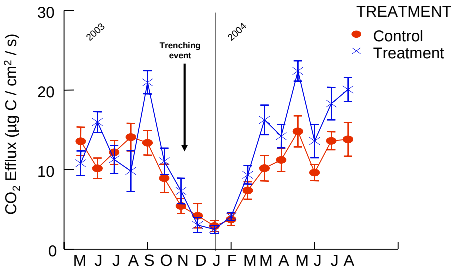
Experimental approach and analytical methods

- In Nov. 2003, we trenched diffuse wetlands (n = 2) on the upslope side to capture and re-release groundwater source to estimate the effects of trenching. The third treatment wetland has a point source for water inputs and was not manipulated.
- Trace gas fluxes measured with static flux chambers and gas chromatography at UCB.
- Soil water content from 0-10 cm depth measured monthly by weighing soil aliquots before and after drying at 100 °C for 48 hours and taking the difference of these weights (Fig. 5).
- Aboveground biomass measured at peak standing crop by non-destructive allometry and incident photosynthetically active radiation. Belowground biomass estimated from root ingrowth cores (harvested 1 yr after installation, weighed after drying at 60 ° C to constant weight).

RESULTS

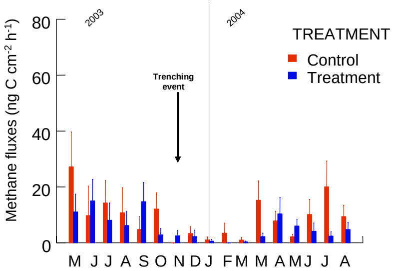
- ➢ Soil respiration was slightly higher in treatment plots prior to manipulations and may be diverging from controls during the growing season following trenching (Fig. 3).
- ➢ There were no statistically significant effects of trenching on methane fluxes (Fig. 4) or soil moisture (Fig. 5).
- ➢ There was no effect of trenching on aboveground production (Fig. 6a), but belowground production was significantly in treatment plots which may be responsible for higher soil respiration in the treatment plots (Fig 6b).

Figure 3: Soil Respiration



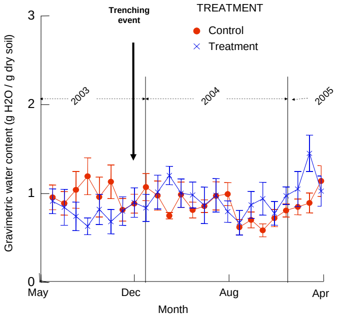
Static flux chamber measurements of CO_2 between May 2003 and Aug 2004. Note two samplings were done in Mar 2004. Standard errors shown. Blue "x" symbols refer to future dry down plots.

Figure 4: Methane Fluxes



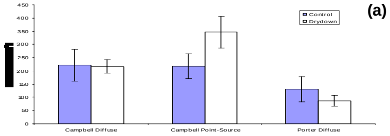
Static flux chamber measurements of methane from May 2003 to Aug 2004. Note two samplings were done in Mar 2004. Standard errors shown.

Figure 5: Soil Moisture

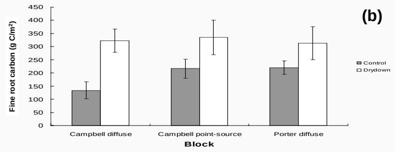


Soil moisture from 0-10 cm depth using gravimetric technique, 5 replicates per plot.

Figure 6: Plant Production



Aboveground biomass C from wetlands from 2004, contrasting control with treatment plots. No statistically significant difference.



Belowground biomass C from wetlands from 2004, contrasting control with treatment plots. $P < 0.05$

FUTURE DIRECTIONS

- Determine effects of drying on C and N trace gas fluxes, soil C fractions, and plant and soil contributions to soil respiration
- Assess impacts of drought on nitrogen transformations in wetland soils and feedbacks to C cycling
- Determine moisture effects on litter decay as an indicator of the plant-soil interface
- Model soil C dynamics with drying using the Century Soil Organic Matter Model.
- Scale up patterns in soil C dynamics up to the Northern California region using GIS and remote sensing.

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