Altered Precipitation Regime Affects Soil Carbon Dynamics in California Grasslands

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How will precipitation change affect the carbon dynamics of California grassland soils?

ABSTRACT The impacts of rising atmospheric concentrations of greenhouse gases on precipitation regimes remain largely unresolved. Climate models forecast potential increases or decreases in California precipitation, depending on the greenhouse gas emission scenarios selected and the global circulation model used. Changes in the amount and distribution of precipitation can have important effects on carbon (C) cycling in California's annual grassland soils, including plant litter inputs to soil, soil respiration, and decomposition. Beginning in 2003, we established a manipulation to explore the effects of increased water inputs and a longer wet season on soil C pools and fluxes in annual grass-dominated sites. During the first year of water manipulation (the 2003-2004 water year) early and late rainfall events released large pulses of heterotrophic CO_2 and increased belowground plant C inputs in annual grasslands. Carbon respired following the early-season wet-up event (respiratory loss 126 ± 40 g C m^{-2} d^{-1} for 1 month following event) greatly exceeded the amount of C respired from unaltered control plots (80 ± 8 g C m^{-2} d^{-1} for 1 month). Belowground net primary production was significantly greater ($p<0.05$) in the wetted plots than in the control plots (87 ± 8 versus 55 ± 4 g C m^{-2} y^{-1}, respectively), partially offsetting the greater respiratory C losses induced with wetting. During year two (the 2004-2005 water year), appreciable natural rains up to ~20 mm occurred unusually early (19 Sep 2004), such that we augmented this rainfall to a total of 30 mm of natural plus artificial precipitation without advancing the seasonal timing. In the month following this September wetup, C respired by wetted plots exceeded that respired by control plots by a factor of 1.6 to 1, which was similar to the ratio of 1.7 to 1 observed in 2003. The absolute amount of C respired in the month following the Oct 2003 wetup was roughly 30-40% greater relative to the Sep 2004 wetup (140 versus 97 g C m^{-2} d^{-1}, respectively) despite a greater overall water amount delivered in Sep 2004. A litter decomposition study begun in Fall 2004 has demonstrated differences in initial litter decomposition rates between wet and control plots. The effects of increased C and N mineralization of litter on soil C gains or losses are not yet known and will require additional study, as will indirect effects of long-term species shifts that might result from wetter conditions. Our results highlight important seasonal differences for the impacts of increased precipitation on soil C dynamics and trace gas losses.

Study Significance

- Annual grasslands cover 5.4 million ha or ~12% of the land cover in California and occupy the understory of an additional 3.6 million ha of oak savanna
- Productivity of annual grasslands influenced greatly by timing and amount of rainfall
- Precipitation frequently understudied as a global change factor relative to temperature
- Biogenic greenhouse gas emissions: climate feedback mechanism of uncertain sign

Research Questions and Hypotheses

(1) How does increasing precipitation affect soil C fluxes?

***Hypothesis I**: Early wet-up and late dry-down of grassland soils favors soil microbial respiration over increased plant C inputs to soil, because of constraints of annual plant phenology, leading to decreased soil C storage and increased soil CO_2 fluxes.*

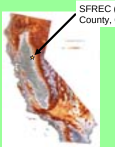
(2) How does timing of additional precipitation affect soil C fluxes?

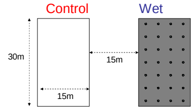
***Hypothesis II**: Microbial respiration will not respond to water additions during the wet season because temperature will be the limiting factor, not water availability.*

(3) Will long-term changes in soil moisture drive changes in the plant community composition, and will this feed back on soil C dynamics?

***Hypothesis III**: Plant community composition will respond slowly to soil moisture alteration and changes will not be evident during the first 1-3 years of study.*

Experimental Approach: n = 3 plot pairs





Plot received ambient rainfall only (~660 mm for 2003-2004 water year, no alterations)

Supplemental irrigation from 28 microsprinklers augmented each storm by 50% using rain gauge and datalogger

Wet season extended via early and late-season wetup events (~20 mm each in 2003-2004 water year)

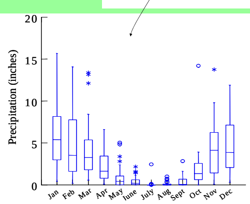


Fig. 1. Historical monthly rainfall totals for Browns Valley (data from CIMIS) showing rainfall predominantly distributed between Oct - Apr.

Fig. 2. Microsprinkler shown in foreground. Photo taken Feb 2005. Rain gauge atop wooden post can been seen in upper left-hand corner.

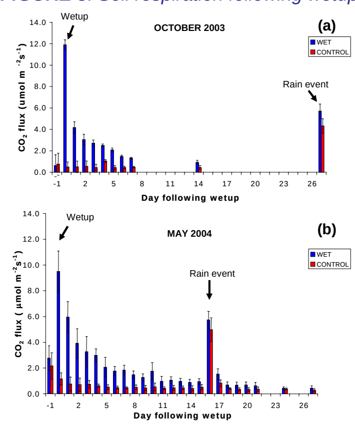
Analytical methods

- Trace gas fluxes measured by LI-COR infrared gas analyzer (for CO_2) and by static flux chambers with gas chromatography with Flame Ionization Detector (CH_4), Pulsed Discharge Detector (CO_2, N_2O), Electron Capture Detector (N_2O), and Thermal Conductivity Detector (CO_2).
- Aboveground biomass measured at peak standing crop (mid-summer) by clipping a subset of the plot to ground level and weighing grass after drying at 60 °C. Belowground biomass estimated from root ingrowth cores (harvested 1 yr after installation, weighed after drying at 60 ° C to constant weight).
- Soil water content from 0-10 cm depth measured bi-weekly by gravimetric methods (Fig. 4) and continuous time domain reflectometry methods hooked to dataloggers (Campbell Scientific).
- Species determined at 20 points along 5 transects per plot using point-intercept method, then species were aggregated into 4 functional groups: annual grass, perennial grass, forb, other (e.g. bare, litter, rock).

RESULTS: Year 1

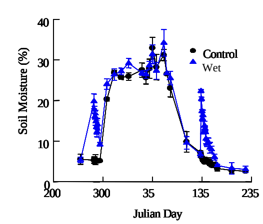
- Soil respiration increased in wet plots and remained elevated above controls for weeks following wetup events (Fig. 3a and b, Fig. 6).
- Large initial CO_2 pulse was microbial in origin (pre-germination in fall, post-senescence in spring).
- Wet treatment affects soil moisture at early and late season only; little effect seen during wet season. (Fig. 4)
- Root biomass greater in wet plots (Fig. 5, $p<0.05$) whereas aboveground biomass not significantly different (data not shown).

FIGURE 3: Soil respiration following wetup



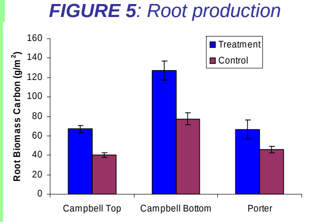
Daily measurements made with IRGA following separate events in Fall 2003 and spring 2004.

FIGURE 4: Soil moisture



Gravimetric soil moisture (0-10 cm depth). Note strong effect of treatment at early and late season; little effect seen during wet season.

FIGURE 5: Root production



Annual root production was greater in wet plots than in controls ($p < 0.05$).

Preliminary Results from Year 2 (partial)

- Soil respiration from wet plots was elevated above controls (Fig. 6). Ratio of wet to control respired C comparable between fall 2003 and fall 2004.
- Faster in-situ decomposition of grass litter (litterbag technique, 7 g litter per bag, 5 replicate bags per timepoint) in wetted plots (Fig. 7).

FIGURE 6

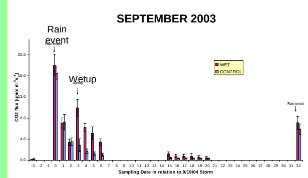
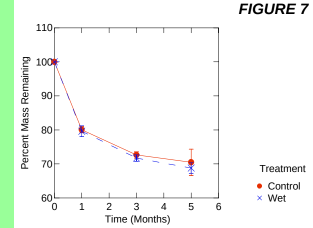


FIGURE 7



We obtained greater temporal resolution for soil moisture data using continuous time domain reflectometry probes inserted to 10 cm depth (3 reps, Fig 8a), installed in 2004, relative to manual gravimetric data (Fig 8b).

FIGURE 8a

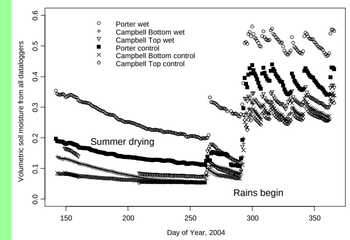
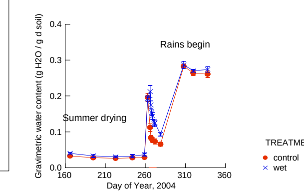
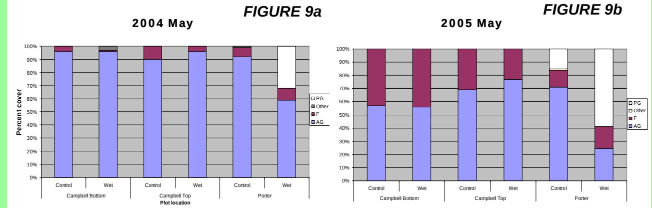


FIGURE 8b



Species cover as defined by functional group varies annually but treatment shows no significant effect at this stage (Fig 9a and b). The 2004-2005 water year has greater abundance of forbs and perennial grasses relative to 2003-2004.

FIGURE 9a / *FIGURE 9b*



CONCLUSIONS

- California's annual grasslands are sensitive to precipitation change on an annual timescale as evidenced by **increased soil respiration** and **increased root growth** under conditions of increased moisture.
- These changes worked in opposite and thus compensatory directions with regards to net soil C balance.
- Lengthened wet season appeared more influential than overall rainfall total.
- Wet treatment appeared to cause a slight increase in C losses from soil and increase rates of litter decomposition, while species composition showed no treatment effect at this stage.

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