The Influence of Hydrologic Regime, Vegetation, and Land Use on Carbon Dynamics of Northern Sierra Nevada Fens

Dana Flett, David Cooper
Graduate Degree Program in Ecology
Department of Forestry and Rangeland Stewardship, Colorado State University
dana.flett@colostate.edu

Introduction

Fens are a type of wetland meadow supported by ground water in which net primary production exceeds decomposition. They are important carbon reservoirs relative to their abundance on the landscape[1,2]. When degraded, fens can shift from global sinks of soil carbon to sources of carbon emissions[3,4,5]. Analyses of fen carbon dynamics have been conducted in the Rocky Mountains of the United States[6]. However, no data evaluates the effects of disturbance on carbon dynamics of fens in the Sierra Nevada of California. In the Sierras, less herbaceous forage that is palatable to livestock occurs in forested areas than in meadows[7,8] and cattle preferentially graze meadow and riparian areas[9].

To understand the natural functioning of the study fens and the potential effects of cattle grazing, I measured water table dynamics, vegetation composition, CO_2 fluxes, and impacts from cattle trampling at four fens in the Bucks Lake Wilderness in the northern Sierra Nevada of California (Figure 1). I compared visually intact areas to those trammeled by cattle and contrasted the impacts from cattle trampling to the effects of water table drawdown due to gully formation. The primary goal of this study was to understand carbon dynamics related to vegetation and land use patterns, specifically cattle grazing and drainage, in the four study fens.

Photo 1. This project provided training to four undergraduate technicians.

Research Questions

- Do vegetation types support distinct carbon dynamics?
- What are the impacts of cattle on carbon fluctuations?
- How do hydrologic regime and site conditions influence carbon sequestration?

Study Area

- 4 fens in the Bucks Lake Wilderness, northern Sierra Nevada, California (Figure 1).
- California has a Mediterranean climate with dry, warm summers and cold, wet winters.
- Annual average precipitation 1940mm[10].
- Elevation ranges 1832 to 2042 meters.
- Size 0.71 to 2.07 hectares.
- Seasonal cattle grazing (August 1-September 30) at all sites.

Photo 2. Quaking Fen in the Bucks Lake Wilderness.

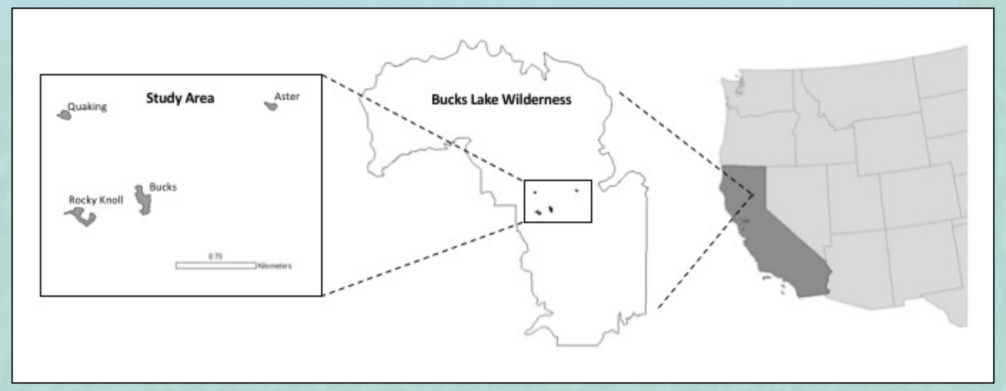

Figure 1. The 4 study fens are located in the Bucks Lake Wilderness in the northern Sierra Nevada of California.

Methods

- 4 vegetation types validated via cluster and indicator species analyses.
- Net ecosystem production (NEP), ecosystem respiration (ER) and gross primary productivity (GPP) measured during 2016 growing season via closed chamber technique (Photo 7).
- % hoof punching measured in SPSU and ORAL communities.
- Hoof punching could not be measured in ELQU and CAAQ communities because influence of cattle was difficult to quantify.
- Measurements separated into unimpaired plots, plots with hoof punching, and plots with deep water tables due to gully formation.
- Replicates averaged across impact type, community, site, and date.
- Mixed model ANOVA with fixed effects (4 veg types, 6 dates, 2 levels impact, all interactions) and random effects (unique IDs for repeated measures in impacted and non-impacted areas).
- All statistical analyses performed using R statistical software version 3.3.1.




Photos 3, 4, 5, 6. The 4 community types analyzed in this study (from right to left): *Oreostemma alpigenum* (ORAL), *Sphagnum subsecundum* (SPSU), *Eleocharis quinqueflora* (ELQU), and *Carex aquatilis* (CAAQ)

Measuring CO_2 Dynamics

- NEP measured throughout growing season in full sunlight (10am-4pm).
- CO_2 concentrations in chamber measured every 5 seconds until linear rate of change established.
- Chamber flushed with fresh air between each measurement.
- ER similarly measured but chamber covered in blackout cloth to inhibit sunlight, halting photosynthesis.
- Measurements in opaque conditions are sum of heterotrophic and autotrophic respiration.
- Carbon stored in ecosystem when NEP is negative.
- Photosynthetically active radiation (PAR), soil moisture, soil temperature at 5 and 10 cm, and air temperature recorded during each CO_2 measurement.

$$NEP = GPP - ER$$ [11,12]

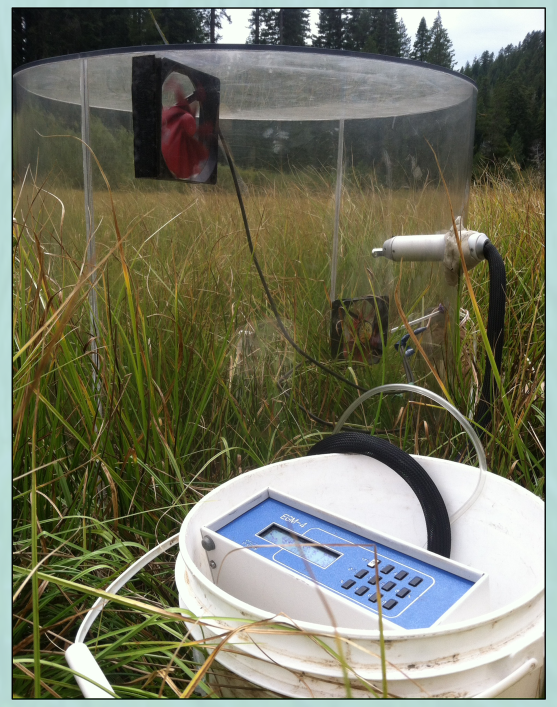

Photo 7. PP Systems EGM-4 Infrared CO_2 Gas Analyzer outfitted with battery powered air circulating fans.

Results and Implications

- Community type not appropriate proxy for NEP, GPP, or ER in study fens (Figure 2).
- Intact communities were carbon accumulating (Figure 2).
- Cattle trampling reduced GPP, negatively affecting carbon sequestration (Figure 3).
- Increased disturbance linearly related to greater potential for carbon loss (Figure 4).
- At low vegetation cover, NEP was positive, indicating carbon loss (Figure 4).
- NEP in plots with water table draw down not different than hydrologically intact areas.
- Cattle trampling had greater negative effect on carbon flux than water table decline.
- With continued grazing in fen ecosystems carbon loss will continue.
- Differences in soil temperatures in impacted and non-impacted areas not significant.

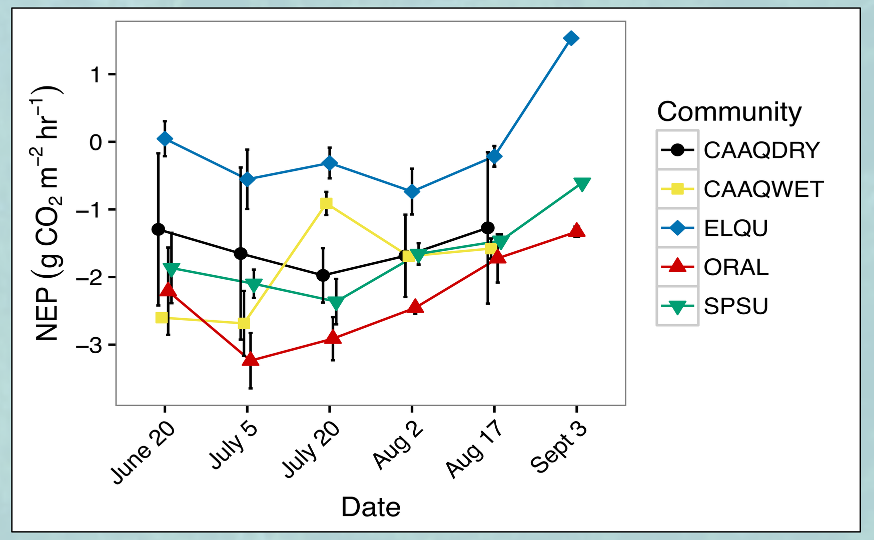

Figure 2. Repeated measures of mean NEP in areas not impacted by cattle trampling during the 2016 growing season. Community type is not an appropriate proxy for NEP, GPP, or ER in study fens.

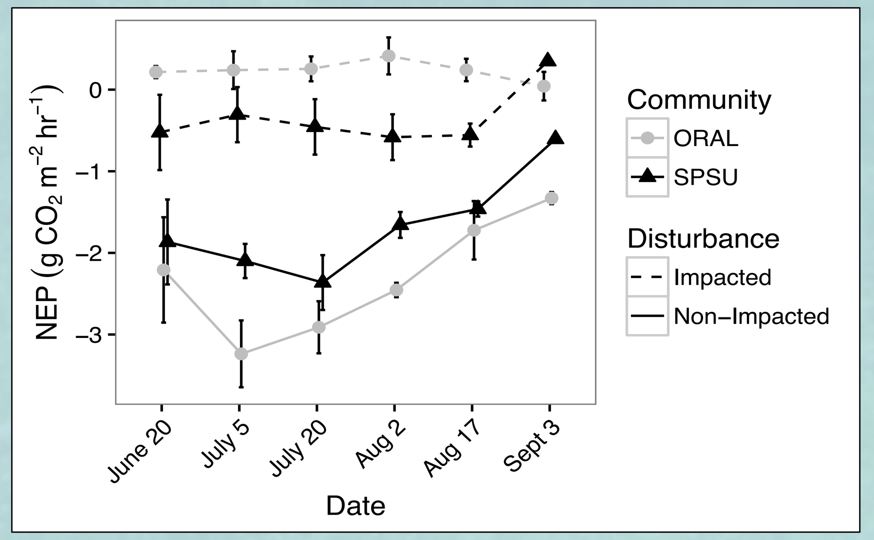

Figure 3. Impacted plots had significantly less potential for carbon storage than non-impacted plots.

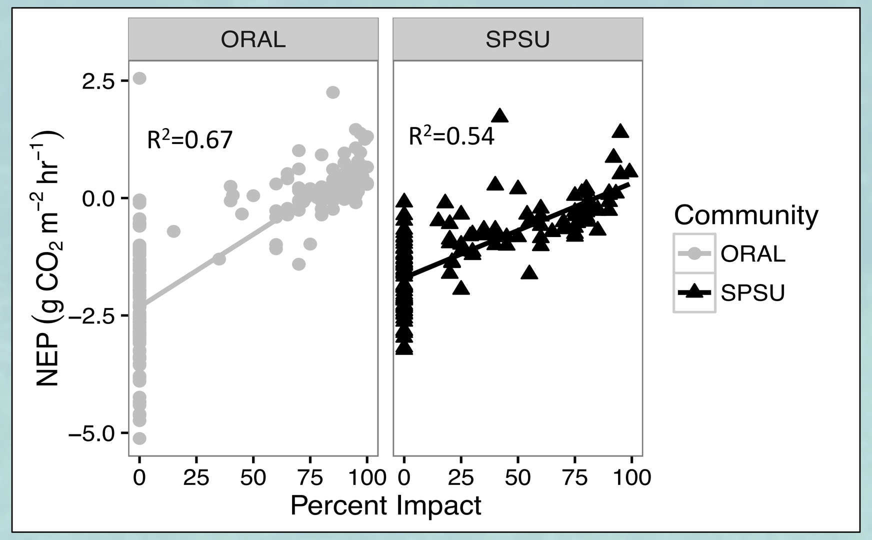

Figure 4. Linear regression indicates cattle trampling negatively affects carbon storage potential.

Future Research Directions

- Vegetation recolonization and changes in carbon dynamics as hoof punches age.
- Macrofossil analysis to infer vegetation change in response to historic land use change.
- Carbon and vegetation responses to fertilization from cattle excrement.
- Annualized, seasonal model of carbon fluctuations in the study area.

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