Monitoring surface-atmosphere exchanges in a partly degraded Sierra Nevada meadow

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Presentation Outline

Research objective

Introduction

Healthy vs. degraded meadows

Methodological Approach: eddy covariance

Seasonality of meadows

Results: annual CO₂ budget

Discuss impacts of climate change on Sierra Nevada meadows
Research Objective

The objective of this project is to investigate ecosystem CO$_2$ exchanges of a partly degraded meadow in the northern Sierra Nevada. In particular:

• Seasonal patterns of ecosystem functioning
• Environmental controls on CO$_2$ exchange
• Estimates of annual CO$_2$ budget for the ecosystem
Introduction

Mountain meadows are important niche ecosystems spread across the Sierra Nevada. Viers et al. (2013) estimate that there are 17,039 meadows in the SN covering 77,659 hectares.

Benefits:
- Attenuate flood flows and sustain base flows
- Biodiversity hotspots
- Improve water quality
- Enhance groundwater storage

Land Use:
- Grazing
- Mining
- Logging
- Development
- Recreation
Introduction - Eddy Covariance

CO₂ fluxes can be determined by measuring the covariance between fluctuations in vertical wind velocity and the mixing ratio of CO₂.

**Simplified eddy covariance equation:**

\[ F \approx \bar{p}_d w's' \]

- **F** = Flux density of the scalar
- **\( p_d \)** = air density
- **W** = vertical wind velocity
- **S** = mixing ratio of the scalar in air

Source: Burba et al. 2013

**Flux:**

Describes how the concentration or quantity of a scalar of interest moves through a unit of area per unit time.

- energy, trace gases, momentum
Methods - Site Description

Elevation: ~2,000 m
Area: 138,307 m²

Mediterranean climate: cool wet winters and warm dry summers.

Located in the Tahoe National Forest and managed by the U.S. Forest Service.

Land Use: Recreation (hiking) and grazing. Cattle present between June and September.
## Methods - Instrumentation

**Study Period:** May 17th – September 9th

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Type</th>
<th>Variable(s) Measured</th>
<th>Units</th>
<th>Measurement Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermistor (a.)</td>
<td>Vaisala HMP45C</td>
<td>Air Temperature / Relative Humidity</td>
<td>°C / %</td>
<td>2.44 m</td>
</tr>
<tr>
<td>Hygristor (a.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonic Anemometer (b.)</td>
<td>CSAT3 3D Campbell Scientific Inc.</td>
<td>3D Wind Speed / Sonic Temperature</td>
<td>m/s / °C</td>
<td>2.44 m</td>
</tr>
<tr>
<td>Infrared Gas Analyzer (c.)</td>
<td>LiCOR 7500</td>
<td>CO₂ / Water Vapor</td>
<td>mg C m⁻² s⁻¹ / g H₂O m⁻² s⁻¹</td>
<td>2.44 m</td>
</tr>
<tr>
<td>Pyranometer (d.)</td>
<td>HukseFlux NR01</td>
<td>Shortwave Radiation</td>
<td>W m⁻²</td>
<td>1.25 m</td>
</tr>
<tr>
<td>Pyrgeometer (d.)</td>
<td></td>
<td>Longwave Radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Flux Plates (e.) (2)</td>
<td>HukseFlux HFP01</td>
<td>Ground Heat Flux</td>
<td>W m⁻²</td>
<td>-5 cm</td>
</tr>
<tr>
<td>Ground Temperature Thermistor (e.) (2)</td>
<td>CS107 Campbell Scientific</td>
<td>Soil Temperature</td>
<td>°C</td>
<td>Tg1: -2 cm; Tg2: -10 cm</td>
</tr>
<tr>
<td>Ground Thermocouples (4) (e.)</td>
<td>E Type: Omega</td>
<td>Soil Temperature</td>
<td>°C</td>
<td>-1 &amp; -2.5 cm</td>
</tr>
<tr>
<td>Soil Moisture Probe (e.)</td>
<td>CS616 Campbell Scientific</td>
<td>Volumetric Water Content</td>
<td>m³ m⁻³</td>
<td>-1: -10 cm</td>
</tr>
<tr>
<td>Rain Gauge (f.)</td>
<td>TR-5251: Texas Electronics</td>
<td>Precipitation</td>
<td>mm</td>
<td>43 cm</td>
</tr>
</tbody>
</table>
Methods – Quality Control

Data Rejection:

- Low friction velocity (<0.2 m/s)
- Data outside plausible limits
- Flux data was rejected if more than 10% of the flux came from outside the meadow boundary

Source: Burba et al. 2013
Methods –
Modeling Respiration

Net Ecosystem Exchange (NEE) = Gross Primary Production (GPP) – Respiration (Re)

Daytime respiration values are modeled based on observed nighttime Re and soil temperature.
Methods – CO₂ Flux Partitioning and Gap Filling

Gross Primary Production is derived as a residual: \( \text{GPP} = \text{NEE} + \text{Re} \)

Gaps in data are filled with modeled GPP values based on light use efficiency curve (below)
Results - Seasonality of Meadows

Ecosystem functioning changes based on seasonal patterns
- Transitioning from a wetland to a grassland over the course of the growing season
- Wetland/grassland characteristics also vary spatially across meadows

Emergence  Senescence
Period 1    Period 2    Period 3    Period 4
Results – Daily Total CO₂ Exchanges
Results – Environmental Drivers

- PAR
- Soil Moisture
- Air Temp/Soil Temp/
- Precipitation
- GPP
- Re
- NEE
### Results - Estimating the Annual Carbon Budget

<table>
<thead>
<tr>
<th>TIME PERIOD (Day of Year)</th>
<th>GPP (gC m$^{-2}$ d$^{-1}$)</th>
<th>RE (gC m$^{-2}$ d$^{-1}$)</th>
<th>NEE (gC m$^{-2}$ d$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period 0</strong> (116 – 137)</td>
<td>16.64</td>
<td>9.38</td>
<td>-7.35</td>
</tr>
<tr>
<td>April 25 – May 16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Period 5</strong> (251 – 329)</td>
<td>5.01</td>
<td>14.16</td>
<td>8.97</td>
</tr>
<tr>
<td>September 2 - November 24</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Annual Carbon Budget Estimate

| Total Snow Free Period (116-329) | 4336 | 3473 | -360 |
## Discussion – Comparing CO\textsubscript{2} Exchanges with other Ecosystems

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Ecosystem Type</th>
<th>Climate Patterns</th>
<th>Elevation (m)</th>
<th>Annual NEE (gC m\textsuperscript{-2} y\textsuperscript{-1})</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacramento-San Joaquin Delta, CA</td>
<td>Restored wetland (old)</td>
<td>Mediterranean Precipitation: 278 mm</td>
<td>-9</td>
<td>-397</td>
<td>Knox et al. 2015</td>
</tr>
<tr>
<td>Loney Meadow</td>
<td>Mountain meadow - semiwetland</td>
<td><strong>Mountain Mediterranean Precipitation: 51 mm (May - Sept)</strong></td>
<td>2000</td>
<td>-360</td>
<td>Blackburn et al. 2017</td>
</tr>
<tr>
<td>Shidler, OK</td>
<td>Tallgrass prairie</td>
<td>Humid-subtropical Precipitation: 1869 mm (1.7 years)</td>
<td>352</td>
<td>1.7 year total: -268</td>
<td>Suyker &amp; Verma 2001</td>
</tr>
<tr>
<td>Tonzi Ranch, CA</td>
<td>Oak/grass savanna</td>
<td>Mediterranean Precipitation: 562.1 mm (multi-year average)</td>
<td>177</td>
<td>Max: -155 Min: -56</td>
<td>Ma et al. 2007</td>
</tr>
<tr>
<td>Songnen Plain - Northeast China</td>
<td>Meadow Steppe (grassland)</td>
<td>Temperate, semi-arid continental monsoon Precipitation: 384 mm</td>
<td>171</td>
<td>-160</td>
<td>Dong et al. 2011</td>
</tr>
<tr>
<td>Vaira Ranch, CA</td>
<td>Open grassland</td>
<td>Mediterranean Precipitation: 562.1 mm (multi-year average)</td>
<td>129</td>
<td>Max: -88 Min: 141</td>
<td>Ma et al. 2008</td>
</tr>
</tbody>
</table>
Discussion - Climate Change

1. Climate impacts on CO₂ budget:
   - Interannual variability in snowpack will change growing season dynamics
   - Decreased snowpack lowers growing season water availability and changes timing
   - Changes in surface hydrology due to larger winter runoff
   - Longer, earlier start to dry season

2. Impacts of meadow health on CO₂ budgets:
   - Healthy mountain meadows have a greater potential to sequester CO₂ from the atmosphere if the naturally occurring high water table is protected

Source: https://lpdaac.usgs.gov/user_resources/data_in_action/observing_drought_in_california_remote_sensing
THANK YOU

Andrew Oliphant
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References


