Vertical Distribution of Soil Moisture As A Control on Respiration in Dryland Ecosystems

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1. Introduction

Total ecosystem respiration (Reco) incorporates both autotrophic (Ra) and heterotrophic (Rh) components of respiration, which may respond differently to various environmental controls. Typically, soil temperature is considered the dominant control on soil respiration. However, in semi-arid ecosystems, soil moisture is also a key driver. Many recent studies have investigated this soil moisture control on respiration, yet none have considered how the temporal and spatial variability in the vertical distribution of that soil moisture influences soil respiration. In pulse-driven semiarid ecosystems, considering the vertical distribution of soil moisture is critical. Frequent small pulses of precipitation wet only the surface soil, while large pulses of precipitation wet the deeper soil layers.

The spatial extent of drylands (over 30% of the land surface is arid or semi-arid) suggest that changes in their carbon flux behavior may strongly impact global climate patterns.

2. Hypotheses

Here we examine several hypotheses, using a Q10-type exponential relationship between respiration and temperature.

1. Among several environmental variables (soil temperature, season, vegetation type, and soil moisture) temperature and soil moisture are the major factors affecting respiration.
2. The soil moisture control on respiration acts as a threshold response, not a continuous response.
3. Variability in the vertical distribution of soil moisture will alter the pattern of soil respiration in these ecosystems (Kurc and Small 2007).

These hypotheses were tested using data from five Ameriflux sites located in the southwestern US (two grasslands, two shrublands, and one savannah).

3. Flux Measurement Sites

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Location</th>
<th>Ecosystem Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedona</td>
<td>Arizona</td>
<td>Grassland</td>
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<tr>
<td>Creosote</td>
<td>Arizona</td>
<td>Shrubland</td>
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<td>SRER</td>
<td>Arizona</td>
<td>Grassland</td>
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<td>Shrubland</td>
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<tr>
<td>SRER</td>
<td>Arizona</td>
<td>Grassland/Semi-desert</td>
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<tr>
<td>SRER</td>
<td>Arizona</td>
<td>Shrubland/Semi-desert</td>
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</tr>
<tr>
<td>SRER</td>
<td>Arizona</td>
<td>Savannah</td>
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</tbody>
</table>

4. Why a Q10-type relationship?

A Q10-type relationship, where Reco = aQ10b provides several benefits:

• A continuous function (vs. the categorical variables tested here)
• Ease of interpretation when comparing performances on categorical variables
• Simple parameter estimation procedure
• Ready comparison to other studies which apply similar models
• A continuous function (vs. the categorical variables tested here)

Here, we use a model of the form: Reco = aθθ⁰ and report parameter values and variance explained for each fit.

5. Categorical Variables

5.1 Season

• Seasonal groupings explain little Reco-Tsoil variance
• Suggests that ecosystem respiration is not dependent on seasonal changes in productivity

Winter (a), spring (b), summer (c) and fall (d) Q10 relationships

6. Soil Moisture

6.1 Reco-Soil Moisture

For the entire dataset, an exponential relationship performs poorly, especially when compared to other ecosystems (inset from Borken et al. 2003)

7. Conclusions

The most effective respiration model found for semi-arid upland sites used inputs of soil temperature and soil moisture.

Seasonality and vegetation type have little influence on ecosystem respiration in drylands.

Soil moisture acts as a threshold variable for respiration. Thresholds can be adequately identified via a two-zone soil moisture approach.

The two-zone soil moisture approach also leads to hypotheses about the source of respired carbon dioxide, from autotrophic and heterotrophic pathways (see Section 8).

References


8. Future Work: Case 2 and Rh

To evaluate the hypothesis that the flux is predominantly Reco, we compare results from nighttime and daytime fluxes.

Overall, the nighttime (black data) and daytime (red and blue crosses) models are not very similar (p = 0.11). Removing the two grassland sites eliminates many of the instances of carbon uptake, and the new data (red crosses) has a trend similar to that of the nighttime data (p > 0.05).

Acknowledgements

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