Global Patterns and Interannual Variability of Water Use Efficiency

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Outline: Water use efficiency (WUE) is the ratio of carbon gain during plant photosynthesis to water loss during evapotranspiration (ET), and couples carbon and water cycles. WUE is therefore an essential concept for studying the interactions between the carbon and water cycles. WUE is typically defined as the gross carbon uptake (gross primary productivity, or GPP) per amount of water lost from the ecosystem (WUE = GPP / ET). More recently, researchers have used a new concept – ecosystem water use efficiency (EWUE) to measure the functionality of terrestrial ecosystems (e.g., Emmerich 2007). EWUE is defined as the net carbon uptake (net ecosystem carbon exchange, or NEE) per amount of water lost from the ecosystem. Eddy covariance measurements provide valuable data for examining WUE at the ecosystem level for both definitions. However, the spatial dynamics and interannual variability of WUE at large scales have rarely been quantified largely due to the complex interactions between water and carbon and uncertainty in the interactive influences of multiple environmental factors on WUE (Tian et al. 2010).

Here we plan to combine the LaThuile database of the FLUXNET, satellite observations, biophysical data (e.g., aboveground biomass), and climate data to produce spatially and temporally continuous estimates of WUE at the global scale over the period 2000-2010 using upscaling methods (e.g., machine learning approaches, modeling). We will experiment with two different means for the global estimation of WUE. One means is to predict GPP (or NEE) and ET separately, and WUE is then calculated as the ratio of GPP (or NEE) and ET. The other is to directly estimate WUE, which will likely avoids the compensating errors of GPP (or NEE) and ET. The accuracy of these two means will be compared and the one with higher performance will be used for global-scale predictions. We will estimate WUE for each grid cell (e.g., 0.05 degree) over the globe and for each 8-day interval (or monthly) over the period 2000-present using wall-to-wall MODIS data and climate data.

We will then use these gridded WUE estimates to investigate the spatial patterns, magnitude, and interannual variability of WUE over the globe. We will look at the spatial patterns by examining the changes of WUE across biomes, latitudinal zones, and geographical regions. We expect that different plant functional types have different WUE because of inherent physiological variation in leaf gas exchange characteristics and differences in environmental conditions (Ponton et al. 2006). The environmental controls on WUE will also be examined across biomes and regions. These analyses will be conducted at the temporal scales of weeks, months, and years. In addition, we will examine the interannual variability of WUE, particularly the impacts of drought on WUE. For forest ecosystems, we also expect to examine the changes of WUE with stand age.

References:

Emmerich, W.E. (2007) Ecosystem water use efficiency in a semiarid shrubland and grassland community. *Rangeland Ecol. Manage*., 60, 464-470.

Ponton, S. et al. (2006) Comparison of ecosystem water-use efficiency among douglas-fir forest, aspen forest and grassland using eddy covariance and carbon isotope techniques. *Global Change Biology*, 12, 294-310.

Tian, H. et al. (2010) Model estimates of net primary productivity, evapotranspiration, and water use efficiency in the terrestrial ecosystems of the southern United States during 1895-2007. Forest Ecology and Management, 259, 1311-1327.

Contributing Sites: We plan to use all sites with ≥ 1 year of data (GPP, NEE, EET, micrometeorological data, and other ancillary data on vegetation and soils) in our analysis.

Co-authorship: Co-authorship will be extended to those who make significant intellectual contribution to the analysis and the resulting manuscript.