Semiarid ECOhydrological Array – SECA

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In this article we would like to highlight a little of the history of water vapor and carbon dioxide flux monitoring in our small part of the world (southern Arizona, USA) and highlight some of the research results and challenges. In comparison to more mesic regions, there is a general lack of data on net ecosystem exchange of carbon dioxide (NEE) in arid and semiarid regions. In these areas, water is the dominant control of NEE, and precipitation is much more variable in time and space. Someone remarked at an Ameriflux conference a few years ago that nothing goes on down here in terms of globally-relevant CO2 exchange processes. Perhaps when looking at long-term and large-area means this might be true, but we have found that semiarid ecosystems can be both significant sinks and sources of CO2, with much greater interannual variability than a “typical” forested site. Additionally, we argue that water limitation affects ecosystem carbon exchange for at least some part of the growing season in all but the wettest ecosystems around the world. By looking at the drier end of this water-limited spectrum, we have ample opportunities to better understand these effects.

Our research using eddy covariance started in 2001 by establishing three sites over dominant riparian ecosystems of the San Pedro River in southeastern Arizona (Fig. 1). At the time, we were driven by basic water balance questions like, “how much water do the plants use?” Riparian ecosystems are hotspots for ecosystem flora and fauna diversity. Since many riparian ecosystems share the same groundwater resource as the human population in these basins, quantifying their role in a basin’s water balance is vital to sound water resource management. Accordingly, our results have highlighted the large evapotranspiration (ET) amounts with annual ET often exceeding precipitation by 2-3 times (Scott et al., 2008; Scott et al., 2004; Scott et al., 2000) and this data has been instrumental in reducing the uncertainties in the water budget of the basin (Scott et al., 2006). These data have also been used to develop satellite-data-driven models which are used to scale up along river reaches in this and other basins (Nagler et al., 2005; Scott et al., 2008).

With the advent of low power and combined open-path water vapor and CO2 IRGAs, our interest in the interaction between the water and carbon cycle was piqued. Riparian sites in arid lands experience high radiation loads, high vapor pressure defi-

Figure 1: Figure 1 (low resolution): Location of the flux towers associated with SECA. Also, shown is the vegetation classification of Brown et al. [1979].
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Figure 2. Using space for time substitution to study mesquite encroachment effects on riparian grasslands.

ecosystems, which we started monitoring around 2004 (Fig. 3). Because of the lack of groundwater access we are discovering that ecosystems with similar composition (e.g., a riparian mesquite shrubland and upland mesquite savanna) operate much differently, resulting in altered magnitudes and seasonality of the CO₂ flux response (Potts et al., 2006). We are also seeing that drought in these rainfall-dependent ecosystems results in net annual CO₂ loss and that this response varies depending on whether the drought occurs from lack of winter or summer rains (Scott et al., 2009). Finally, we have been able to combine our site ET data with surface hydrological measurements of small watershed water balances to show that the eddy covariance technique appears to provide a highly accurate estimate of ET with the two independent measures agreeing on an average within 3% of each other annually and differed from -10 to +17% in any given year and site (Scott et al., 2009). We have contributed some of our data to the global Fluxnet community (Santa Rita Mesquite and Kendall Grassland) with aims to eventually offer all of it for global use. As a prototype regional network our sites have initially been used to describe variation in whole ecosystem respiration pulses following rain events (Jenerette et al., 2008) and this work is leading into a global Fluxnet synthesis analysis. We also continue to expand our domain and scope with a nearby mixed conifer site in the moun-

Time

Space

cists, and low rainfall amounts, but deep-rooted vegetation can access groundwater that can result in a decoupling of aboveground hydrometeorology and below-ground hydrology. Accordingly, we have observed large fluxes of CO₂ in these riparian systems that highlight the role of water limitation on ecosystem carbon fluxes. First, we have found that there are large amounts of net carbon uptake—resulting from the consequences of the general lack of water limitation for the dominant phreatophytic plants (deep-rooted grasses and trees) that can access groundwater and strong water limitation for the microbial community that have only fleeting opportunities following rain events to break down carbon (Jenerette et al., 2008). The result of this interaction is that these ecosystems accumulate more carbon in the driest parts of the growing season (Scott et al., 2004), a result that has been mirrored in the wettest parts of the world (Saleska et al., 2003). We are using these data to develop whole ecosystem carbon models to project likely changes associated with climate and land-cover change (Jenerette et al., 2009). We have also begun to understand the consequences, in terms of mass and material exchange, of woody plant encroachment, a phenomenon that is occurring here and in many dryland regions around the world (Goodale et al., 2002). Along the San Pedro and in the upland (non-riparian) regions of southern Arizona (Fig. 1), we have established sites that represent various levels of encroachment (Fig. 2). We are just starting to pull all of our results together to begin making mature conclusions. Early results for riparian systems suggest that as floodplain terrace grasslands are replaced by woody, mesquite-covered ecosystems the shallower-rooted grasses are less able to fully exploit stable groundwater sources, whereas the ecohydrological exchanges of encroached ecosystems become more decoupled from precipitation as the ecosystems become more woody (Scott et al., 2006; Jenerette et al., 2009). This results in a tradeoff between more carbon sequestration at the expense of greater water use in an region of over-exploited groundwater resources. With the exception of our sole remaining mesquite woodland tower that has been in operation since 2001, we are now moving beyond the riparian areas and into the surrounding "desert"
Figure 3. Santa Rita mesquite savanna from the air. The site is representative of a fully encroached desert grassland.


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