Semiarid ECohydrological Array – SECA

Russell L. Scott, G. Darrel Jenerette, Travis E. Huxman

> *"The Southwestern ECohydrology Array (SECA)) is a multi-user network that serves to assess biosphere / atmospheric exchange processes, as well as surface hydrology in semiarid ecosystems. SECA is administered through the USDA-ARS Southwestern Watershed Research Center and the University of Arizona's B2 Earthscience. The components of the array were constructed with funds from the USDA-ARS, University of Arizona, and the NSF-Science & Technology Center SAHRA."*

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 CO_2 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 CO_2, 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-limitation 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 CO_2 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-

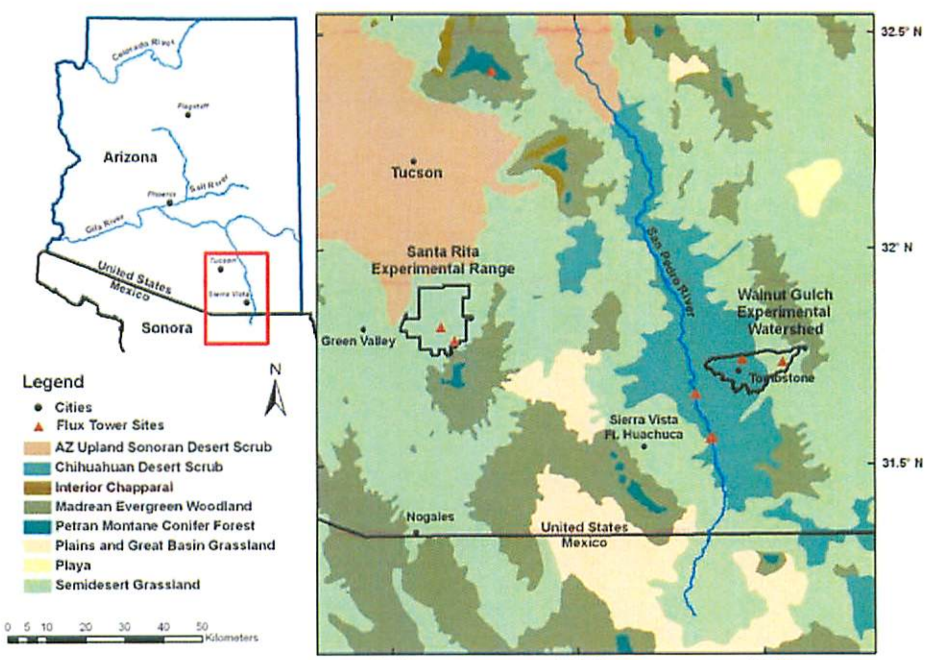

Figure 1: Figure 1 (low resolution): Location of the flux towers associated with SECA. Also, shown is the vegetation classification of Brown *et al.* [1979].

Semiarid ECohydrological Array – SECA

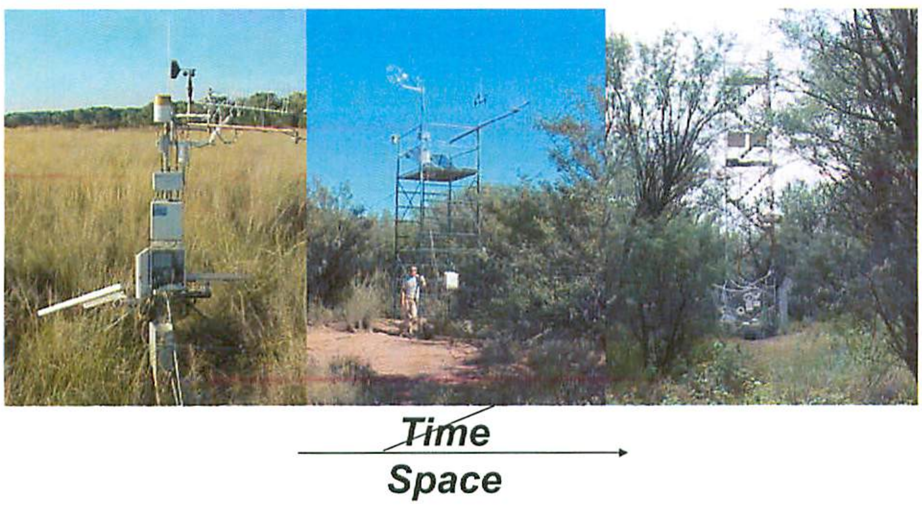

Figure 2. Using space for time substitution to study mesquite encroachment effects on riparian grasslands.

cits, and low rainfall amounts, but deep-rooted vegetation can access groundwater that can result in a decoupling of above-ground hydrometeorology and below-ground hydrology. Accordingly, we have observed large fluxes of CO_2 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" 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 CO_2 flux response (Potts et al, 2006) We are also seeing that drought in these rainfall-dependent ecosystems results in net annual CO_2 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-

Semiarid ECohydrological Array – SECA

Figure 3. Santa Rita mesquite savanna from the air. The site is representative of a fully encroached desert grassland.

tains surrounding our deserts to look at an elevation/precipitation transect and with *amigos* south of the U.S.-Mexico border in the state of Sonora (Instituto Tecnologico de Sonora, Universidad de Sonora) to look across gradients in the strength and importance of the summer rainfall from the North American Monsoon. Of course, we always welcome new collaborations.

contact:

Russell L. Scott

Southwest Watershed Research Center, United States Department of Agriculture, Agricultural Research Service, Tucson, AZ

Russ.Scott@ars.usda.gov

References

Brown, D.E., Lowe, C.H., Pase, C.P., 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. Journal of the Arizona-Nevada Academy of Science 14 1-16. Republished 1994 in Biotic Communities: Southwestern United States and Northwestern Mexico, edited by David E. Brown, pp. 302-315. University of Utah Press, Salt Lake City.

Goodale, C.L., Davidson, E.A., 2002. Uncertain sinks in the shrubs. Nature 418, 593-594, doi:10.1038/418593a.
Jenerette, G.D., Scott, R.L., Barron-Gafford, G.A., Huxman, T.E., 2009. Gross primary production variability associated with meteorology, physiology, leaf area, water supply in contrasting woodland and grassland semiarid riparian ecosystems. J. Geophys. Res. [Biogeo.]G04010,

Jenerette, G.D., Scott, R.L., Huxman, T.E., 2008. Whole ecosystem metabolic pulses following precipitation events. Funct. Ecol. 22, 924-930,

Nagler, P.L., Cleverly, J., Glenn, E., Lampkin, D., Huete, A., Wan, Z., 2005. Predicting riparian evapotranspiration from MODIS vegetation indices and meteorological data. Remote Sens. Environ. 94, 17-30,

Potts, D.L., Huxman, T.E., Scott, R.L., Williams, D.G., Goodrich, D.C., 2006. The sensitivity of ecosystem carbon exchange to seasonal precipitation and woody plant encroachment. Oecologia 150, 453-463,

Saleska, S.R., Miller, S.D., Matross, D.M., Goulden, M.L., Wofsy, S.C., Da Rocha, H.R., De Camargo, P.B., Crill, P., Daube, B.C., De Freitas, H.C., Hutyra, L., Keller, M., Kirchhoff, V., Menton, M., Munger, J.W., Pyle, E.H., Rice, A.H., Silva, H., 2003. Carbon in Amazon forests: Unexpected seasonal fluxes and disturbance-induced losses. Science 302, 1554-1557,

Scott, R.L., 2009. Using watershed water balance to evaluate the accuracy of eddy covariance evaporation measurements for three semiarid ecosystems. Agric. For. Meteorol. in press,

Scott, R.L., Cable, W.L., Huxman, T.E., Nagler, P.L., Hernandez, M., Goodrich, D.C., 2008. Multiyear riparian evapotranspiration and groundwater use for a semiarid watershed. J. Arid Environ. 72, 1232-1246,

Scott, R.L., Edwards, E.A., Shuttleworth, W.J., Huxman, T.E., Watts, C., Goodrich, D.C., 2004. Interannual and seasonal variation in fluxes of water and carbon dioxide from a riparian woodland ecosystem. Agric. For. Meteorol. 122, 65-84,

Scott, R.L., Huxman, T.E., Williams, D.G., Goodrich, D.C., 2006a. Ecohydrological impacts of woody-plant encroachment: Seasonal patterns of water and carbon dioxide exchange within a semiarid riparian environment. Global Change Biol. 12, 311-324,

Scott, R.L., James Shuttleworth, W., Goodrich, D.C., Maddock Iii, T., 2000. The water use of two dominant vegetation communities in a semiarid riparian ecosystem. Agric. For. Meteorol. 105, 241-256.

Scott, R.L., Jenerette, G.D., Potts, D.L., Huxman, T.E., 2009. Effects of seasonal drought on net carbon dioxide exchange from a woody-plant-encroached semiarid grassland. J. Geophys. Res. [Biogeo.] 114, G04004,

Scott, R.L., Williams, D.G., Goodrich, D.C., Cable, W.L., Levick, L.R., McGuire, R., Gazal, R.M., Yepez, E.A., Ellsworth, P., Huxman, T.E., 2006b. Chapter D: Determining the riparian groundwater use within the San Pedro Riparian National Conservation Area and the Sierra Vista Subwatershed, Arizona.