

Partitioning Water Exchange in Live Oak-Ashe Juniper Savanna and C4 Grassland Ecosystems on the Edwards Plateau

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Project Need, Description and Expected Outcomes:

Rationale

The Edwards Plateau is the principal recharge zone for the environmentally sensitive Edwards Aquifer that provides drinking water for many municipalities, including San Antonio and San Marcos. Most water resources on the Plateau have been tapped and supply is limiting growth and development. Management practices to conserve and protect water resources are desperately needed. Water use by shrubs and trees is perceived to be a problem in aquifer recharge and water availability. Efforts are underway to decrease brush with the intent of increasing aquifer recharge, in spite of some evidence that indicates the possibility of contrary effects. Measuring the effects of woody species in a water balance of the area is difficult, and, hence, little data exist upon which to base sound management practices. Recent improvements in field and laboratory equipment, however, suggest that combining isotopic analyses of carbon, hydrogen, and oxygen with micrometeorological eddy covariance and relaxed eddy accumulation measurements of water vapor and carbon dioxide fluxes may significantly improve our understanding of the complex partitioning of fluxes and improve our ability to manage water on the Edwards Plateau.

Description

In 2003, Drs. James Heilman, Kevin McInnes, and Keith Owens (TAES, Uvalde) received a grant from DOE through its National Institute for Global Environmental Change (NIGEC) program to establish two sites on the Edwards Plateau to continuously measure net water vapor exchange (NVE) and net carbon dioxide exchange (NCE), one on live oak-ashe juniper savanna and the other on C4 grassland. To our knowledge, there are no other such sites on the Edwards Plateau. As part of this project, NVE and NCE will be measured with above-canopy, tower-based eddy covariance techniques where flux densities are calculated as:

$$NVE = \mathbf{r}_a \overline{(w' \mathbf{c}_{H_2O}')}$$

$$NCE = \mathbf{r}_a \overline{(w' \mathbf{c}_{CO_2}')} .$$

Here \mathbf{r}_a is the density of dry air, w' is the deviation from the mean vertical wind speed, \mathbf{c} is the mixing ratio for the gas of interest, and the overbars represent temporal means. Unfortunately, the data collected from these measurements alone will not allow partitioning of fluxes from individual sources (e.g., grasses, trees, and shrubs).

Recent improvements in isotopic analysis allow measurements of C, H, and O isotope composition of water vapor and carbon dioxide in fluxes. Information gained from such measurements could be used for separation of net water flux into soil evaporation and leaf transpiration components, and NCE into photosynthesis and respiration components (Yakir and Sternberg, 2000; Wang and Yakir, 2000). Simplistically, the methodology can be understood as a mixing model by considering the net flux F_{net} of chemical constituents composed of two gross

flux components F_1 and F_2 (e.g., transpiration and evaporation) with isotopic compositions d_{net} , d_1 and d_2 , respectively. Mass balance requires that

$$F_{net}d_{net} = F_1d_1 + F_2d_2.$$

From algebraic manipulations, it follows that the fluxes of the individual components are

$$F_1 = F_{net}f_1, \quad f_1 = (d_{net} - d_2)/(d_1 - d_2)$$

$$F_2 = F_{net}f_2, \quad f_2 = (d_1 - d_{net})/(d_1 - d_2).$$

Unfortunately, d_{net} is influenced by the isotopic composition in downward flux of atmospheric gases (e.g., water vapor or carbon dioxide). Direct measurement of isotopic fluxes is a solution and the micrometeorological gradient approach has been successfully used, but use of the gradient approach is not practical above a forest canopy. Fortunately, we can take advantage of the recently developed hyperbolic relaxed eddy accumulation technique (Bowling et al., 1999). Relaxed eddy accumulation relates the flux density of a gas to the product of the standard deviation of the vertical wind velocity s_w (measured with a sonic anemometer) and the difference in mean concentration of gas in updrafts and downdrafts. This relationship is expressed in terms of differences in mixing ratios as:

$$F_{net} = b s_w r_a (\overline{c \uparrow} - \overline{c \downarrow})$$

where b is a semi-empirical proportionality factor. Air is sampled into updraft or downdraft lines, and mixing ratios of those two sample lines are measured. The hyperbolic version of the methodology includes use of a deadband based on the magnitude of both the vertical wind speed and the gas whose flux is being measured. This modification increases the measured difference in concentration and allows for the potential analysis of isotopic fluxes. Use of a deadband involves setting criteria for sampling air from updrafts and downdrafts such that while the criteria is not met, air is not sampled into either updraft or downdraft sample lines. The most commonly used deadband is based solely on the vertical wind speed. The criterion for the hyperbolic relaxed eddy accumulation deadband is based on a threshold determined from both the vertical wind speed and the concentration of gas. The hyperbolic criteria is calculated as

$$D = \left| \left(\frac{w'}{s_w} \right) \left(\frac{c'}{s_c} \right) \right|.$$

This modification version allows for larger differences in concentration. A threshold value of $D=1.1$ was found to produce a concentration difference about 3 times greater than that found without a deadband (Bowling et al., 1999).

Application of these equations to partition fluxes into components will require that d , d' be measured from the hyperbolic relaxed eddy accumulation system, and that d_s from the individual flux components to be separated (e.g., from plants and soil) be measured. Funds from this project will be used solely to construct the hyperbolic relaxed eddy accumulation gas sampling system. As required by the relaxed eddy accumulation technique, we propose to develop the system to sample air at the location where eddy covariance flux measurements are made (towers). We will use the signals from the sonic anemometer and open path laser detector (which are supplied from the NIGEC grant) to determine the deadband criteria D . With a deadband of $1.1D$, each sample line will be active only about 10% of the time. We will use a pump to collect air from near the measurement paths of the anemometer and laser detector and push it through the sample lines to the collection apparatus. The advantage of the pump is that flow is easier to reestablish when air is pumped from upstream. During a period where the

deadband is active, pumped air will be vented back to the atmosphere. Water vapor or carbon dioxide will be collected from updraft and downdraft lines with methodology appropriate for isotopic analysis (Wang and Yakir, 2000).

Expected Results

There should be considerable differences in the isotopic composition of air from the different components adding to the net flux (Boutton et al., 1999). Evaporation produces greater discrimination than transpiration. Grass species utilize soil water which has a different isotopic composition than deeper water that oak and juniper roots have access to as they penetrate the cracks and fissures in the limestone bedrock (Jackson et al., 1999). Grasslands on the Plateau are dominated by C4 species. C4 species have considerably different isotopic composition than C3 species. From the combined isotopic measurements, we will be able to separate the sources of water vapor and carbon dioxide. This will provide much needed areally integrated data on water use of woody species compared to grasses on the Edwards Plateau. We will be able to make some isotopic analyses from the NIGEC grant funds, but we will seek additional funds in collaborative projects with experts in stable isotope research such as Dr. Tom Boutton, TAMU.

References

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