Title: **Quantifying Competitive Use of Water by Grasslands and Woodlands in the Edwards Aquifer Recharge Zone**

Principal Investigator: **James L. Heilman, Dept. of Soil and Crop Sciences, Texas A&M University, College Station, TX, and M. Keith Owens, Texas A&M Agricultural Research and Extension Center, Uvalde, TX**

Amount of Funding Requested: $8,000

Need, Description and 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 urgently needed. The Edwards Aquifer recharge zone is dominated by C_4 grasslands and live oak-Ashe juniper savannas. The savannas typically consist of woody clusters containing a central live oak surrounded by juniper beneath its canopy. Populations of Ashe juniper are increasing due mainly to fire suppression. Roots of live oak and Ashe juniper penetrate the limestone bedrock through cracks and fissures, giving them access to water stored in cracks and caves (Jackson et al., 1999). As a result, water use by these species, especially the invasive Ashe juniper, is perceived to be a problem in aquifer recharge and water availability. Efforts are underway to remove brush with the intent of increasing aquifer recharge, in spite of some evidence that indicates the possibility of contrary effects. Measuring the impact of woody species on the water balance of the recharge zone is difficult. Thus, little data exist to develop sound management practices for maintaining and enhancing aquifer recharge, while preserving structure and function of ecosystems in the recharge zone.

In 2003, Drs. James Heilman and Kevin McInnes (Soil and Crop Sciences), and Keith Owens (TAES-Uvalde) received a grant from the DOE National Institute for Global Environmental Change (NIGEC) to establish two flux tower sites on the Edwards Aquifer recharge zone to continuously measure ecosystem-scale net water vapor exchange (F_v) and net carbon dioxide exchange (F_c), one on a C_4 grassland and the other in a mature live oak-Ashe juniper woodland. Dr. Marcy Litvak, Program of Integrative Biology, University of Texas-Austin, is establishing a third site that is in transition from a grassland to a juniper-dominated woodland. Also, in 2003 Drs. McInnes and Heilman received a grant from TWRI to add analyses of H and O isotopic composition of water vapor to our suite of measurements to partition net water vapor exchange into evaporation and transpiration**. In this proposal, we are requesting funds to add sap velocity measurements on live oak and juniper to partition transpiration into respective contributions from grasslands and the two dominant woody species.**

Description – Flux towers for continuous measurement of carbon dioxide and water vapor exchange are being installed this spring on a grassland (TAMU), a mature woodland (TAMU), and a grassland in transition to a woodland (UT) on the Freeman

Ranch near San Marcos. At each site, the total water vapor flux is the sum of water vapor flux from the soil ($F_{v,s}$) and that from the plants ($F_{v,p}$), so that

$$F_v\,(g\,m^{-2}\,s^{-1}) = F_{v,s} + F_{v,p}\,. \tag{1}$$

Total water vapor flux at each site will be measured by the eddy covariance method, with the flux calculated by

$$F_v = \overline{w'\rho'_v} \tag{2}$$

where w is vertical wind speed, ρ_v is vapor density, the prime denotes deviations from mean values, and the overbar a time average, usually 30 min. Fluctuations of w and ρ_v are measured at 10Hz with sonic anemometers and open-path infrared gas analyzers, respectively.

Each flux in Eq. (1) is associated with an isotopic signature so that

$$\delta_n F_v = \delta_s F_{v,s} + \delta_p F_{v,p} \tag{3}$$

where δ_n, δ_s, and δ_p are the isotopic signatures of the flux components in Eq. (3). Respective contributions of soil and plants to F_v can be determined from the isotopic signatures by rearranging Eq. (3) to give

$$F_{v,s}\,(g\,m^{-2}\,s^{-1}) = \frac{\delta_n - \delta_p}{\delta_s - \delta_p} F_v \tag{4}$$

$$F_{v,p}\,(g\,m^{-2}\,s^{-1}) = \frac{\delta_n - \delta_s}{\delta_p - \delta_s} F_v \tag{5}$$

$F_{v,s}$ (soil evaporation) and $F_{v,p}$ (transpiration) will be determined using Eqs. (4) and (5), with H and O isotopic signatures determined from air samples extracted by the sampling system constructed from the previous TWRI funding using the procedures outlined by Yakir and Wang (2000).

The final step in the analyses is partitioning of $F_{v,p}$ into contributions from grassland, live oak and Ashe juniper. At each site, transpiration can be approximated by the equation

$$F_{v,p} = f_g F_{v,g} + f_o F_{v,o} + f_j F_{v,j} \tag{6}$$

where $F_{v,g}$, $F_{v,o}$ and $F_{v,j}$ are transpiration per unit land area of grass, live oak, and juniper, respectively, and f_g, f_o and f_j are respective fractions of land area occupied by grass, live oak and juniper. At the grassland site, essentially all of $F_{v,p}$ will be due to transpiration of grass species so that f_g~1. At the transition site, grass, Ashe juniper and live oak will contribute to $F_{v,p}$ and at the woodland site, nearly all of $F_{v,p}$ will be due to transpiration by juniper and oak so that f_g~0. Transpiration of juniper and oak will be measured directly using the Granier (1985) heat dissipation method in which two cylindrical probes, one a distance down stream of the other, are inserted radially into trunks of trees, and the downstream probe is heated periodically. Granier found that the sap velocity (v) was related to the temperature difference between the heated and unheated probes by the equation

$$v\,(m\,s^{-1}) = 0.119\left(\frac{\Delta T_m - \Delta T}{\Delta T}\right)^{1.231} \tag{7}$$

where ΔT is the temperature difference between the two probes, and ΔT_m is the temperature difference when v=0. The rate of sap flow (F) is calculated as

$$F\,(g\,s^{-1}) = \rho v A \qquad (8)$$

where ρ is the density of water, and A is the cross-sectional area of the sapwood. Multiple pairs of probes will be inserted into oak and juniper at transition and woodland sites, and sap flow will be determined using Eqs. (7) and (8). Sap flow rates will be converted to transpiration per unit land area using estimates of sap wood area, leaf area and crown diameter.

Expected Results **–** The proposed research will provide fundamental, quantitative information on water use by grasslands and woodlands on the Edwards Aquifer recharge zone, and on effects of encroachment by Ashe juniper on the water balance of the recharge zone.

Collaboration and Matching Funds **–** This proposal involves collaboration between Texas A&M and the University of Texas, and is part of a larger project on carbon dioxide and water vapor exchange on the Edwards Plateau funded by DOE-NIGEC in the amount of $484,378. Approximately $150,000 have been invested in the development of the flux tower systems for ecosystem-scale flux measurements.

References

Granier, A. 1985. Une nouvelle méthode pour la mesure du flux de sève brute dans le tronc des arbres. Ann. Sci. For. 42:193-200.

Jackson, R. B., L. A. Moore, W. A. Hoffman, W. T. Pockman and C. R. Linder. 1999. Ecosystem rooting depth determined with caves and DNA. Proc. Natl. Acad. Sci. 96:11387-11392

Yakir, D, and XF Wang. 2000. Using stable isotopes of water in evaporation studies. Hydrological Processes 14:1407-1421.

Budget **–** Funds are requested for two months of a graduate student salary, summer tuition and fees for the graduate student, a Campbell Scientific CR10X data logger ($1,390) and AM16/32 multiplexer ($545) to measure the output from the heat dissipation probes, and supplies to construct the probes.

Expenditure Description	Amount Requested	Other Sources	Total
Staffing Requirements:			
1) Graduate student (2 months)	2,958	0	2,958
2) Post-doctoral assoc. (1 month)	0	2,750	2,750
3)			
Fringe Benefits	600	850	1,450
Total Staff Costs	3,558	3,600	7,158
Travel:	0	500	500
Supplies and Materials:	3,242	4,000	7,242
Capital Equipment (purchases over $5,000)	0	150,000	150,000
Printing and Publications	0	0	0
Other Direct Costs (describe in detail) Summer tuition	1,200	0	1,200
Total Project Costs	8,000	158,100	166,100