P2.16

SEASONAL ESTIMATES OF RIPARIAN EVAPOTRANSPIRATION (CONSUMPTIVE WATER USE) *USING REMOTE AND IN-SITU* MEASUREMENTS

D.C. Goodrich (1)*, M.S. Moran (2), R. Scott (3), J. Qi (2), D. Williams (3), S. Schaeffer (3), R. MacNish (3), T. Maddock (3), B.F. Goff (1), J. Toth (1), L. Hipps (4), D. Cooper (5), J. Schieldge (6), A. Chehbouni (7), C. Watts (8), W.J. Shuttleworth (3), O. Hartogensis (9) , H. De Bruin (9), Y. Kerr (10), C.L. Unkrich (1), R. Marsett (1), W. Ni (2)

(1) USDA-ARS, Southwest Watershed Research Center, Tucson, Arizona, USA
(2) USDA-ARS, Phoenix, Arizona, USA
(3) University of Arizona, Tucson, Arizona, USA
(4) Utah St. University, Logan, Utah, USA
(5) Los Alamos National Lab, Los Alamos, New Mexico, USA
(6) Jet Propulsion Lab, Pasadena, California, USA
(7) OSTROM/IMADES, Hermosillo, Sonora, Mexico

and Williams (this issue) estimated total daily water use synoptic and remote sensing measurements would be the

Charleston Gage for t e 1996 water year. The shaded portion of the figure is an estimate of the riparian ET that abstracts water from all baseflow stream inputs. For this example it was assumed that steady-state baseflow unaffected by riparian ET was equal to be the average winter discharge. During monsoon storm flows the baseflow was linearly interpolated between June 28 and Oct. 1. Using these assumption the riparian ET is 9,928,800 m^3 (3,185 ac-ft). Although this method is straightforward it invokes several strong assumptions. First that groundwater inflow is steady throughout the river reach of interest. In the San Pedro this assumption is tenuous at best given the significant pumping taking place in the basin. Secondly it assumes baseflows can be easily separated from storm runoff. As noted by Maddock et al. (this issue), this is not a simple task. Finally, this method is only applicable in perennial stream reaches. If a reach becomes intermittent, as occurred on the San Pedro in 1997 downstream of the Charleston gage, this type of analysis cannot be carried out. This also points to another problem in this analysis. A related problem is that there is uncertainty in the length of river reach over which riparian ET losses are reflected in the downstream discharge measurements.

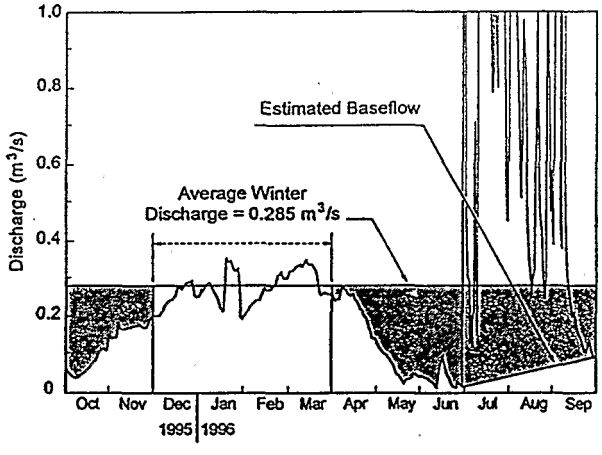


Figure 2. San Pedro River discharge at Charleston, AZ for the 1996 water year.

Other atmospheric controls are also important for estimation of riparian ET. Air temperature, as noted above, is highly correlated to radiation or the available energy for driving ET. However, temperature-based ET-estimation methods are not recommended unless this is the only available data source (Shuttleworth, 1992). Shuttleworth (1992) also notes that preferred methods for estimating ET require a value of the difference between the saturated vapor pressure (e_s) and the ambient vapor pressure (e), or vapor pressure deficit (VPD = e_s - e). VPD and whole-tree transpiration (tree #203) are plotted for several days of the August campaign in Figure 3. A reasonable correlation exists between these quantities indicating a simple model that incorporates VPD could be utilized to estimate the temporal variations in ET between intensive measurement campaigns where remote sensing data was acquired. Variable cloudiness can complicate the sap flow versus VPD relationship. It can be improved if it is constrained to only well lit (high radiation: > 75 W/m^2) conditions.

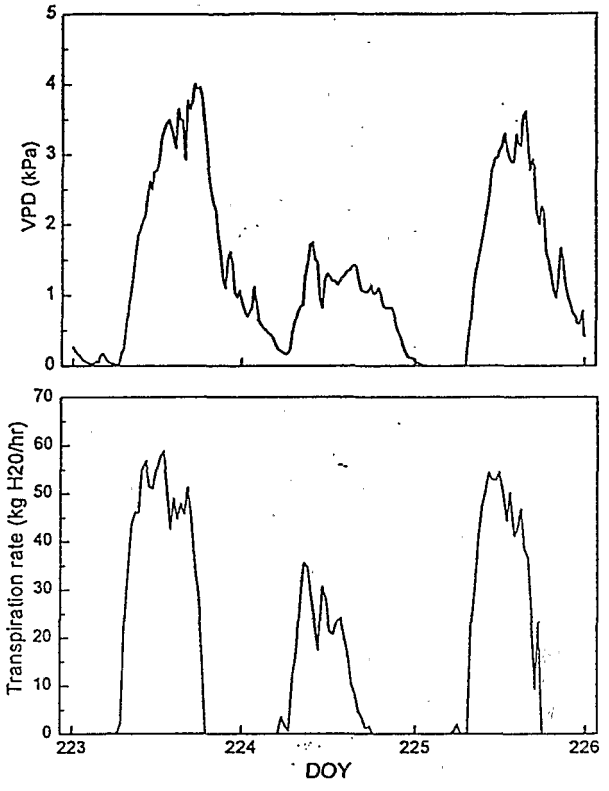


Figure 3. Vapor Pressure Deficit (VPD) and transpiration from a large cottonwood for julian days 223-225 (August 11-13).

Williams et al. (this issue) and Schaeffer and Williams (this issue) noted the strong influence of photosynthetically active radiation (PAR) on the diurnal variations in whole tree transpiration. Their plots of PAR versus whole tree transpiration for a portion of the same time shown in Figure 3 are even more clearly correlated than the VPD plot. Note that air temperature and VPD form the basis for the calculation of potential evapotranspiration which will also be considered in future analysis.

3. CONCLUSIONS - FUTURE DIRECTIONS

Additional variables will be examined to better estimate the temporal variation in riparian ET between intensive measurement periods as well as future work with models. Various space-time interpolation treatments for seasonal changes of the inferred differential riparian stress in space obtained from the multi-temporal remotely sensed data will also be examined. With this information it is expected that reasonable estimates of the seasonal variation in riparian ET as well as the total consumptive water use can be obtained in the near future.

4. ACKNOWLEDGMENTS

Financial support from the USDA-ARS Global Change Research Program, NASA grant W-18,997, NASA Landsat Science Team, grant #S-41396-F, USDA National Research Initiative Grant Program, Electrical Power Research Institute, Arizona Department of Water Resources, U.S. Environmental Protection Agency -Office of Research and Development, CONACYT, ORSTOM, the French Remote Sensing Program (PNTS) via the VEGETATION Project and the ERS2/ATSR2 Project, and US Bureau of Land Management is gratefully acknowledged. Assistance was also provided in part by the NASA/EOS grant NAGW2425, EPA STAR Graduate Student Fellowship Program, National Science Foundation, US Geological Survey, US Department of Energy contract W-7405-ENG-36, California Institute of Technology-Jet Propulsion Laboratory (NASA, EOS/ASTER), WAU (Wag. Agricultural University, Netherlands), Cochise County Highway and Flood Control Dept., and Ft. Huachuca; this support is also gratefully acknowledged. Special thanks are extended to the ARS staff located in Tombstone, Arizona for their diligent efforts and to USDA-ARS Weslaco for pilot and aircraft support. We also wish to extend our sincere thanks to the many ARS and University of Arizona staff and students, and local volunteers who generously donated their time and expertise to make this project a success.

5. REFERENCES

Arizona Department of Water Resources. 1991 Nov. Hydrographic survey report for the San Pedro River watershed. Volume 1: general assessment, *in re* the general adjudication of the Gila River system and source. Phoenix, AZ: ADWR. Filed with the Court, November 20, 1991.

Grantham, C. 1996: An assessment of the ecological impacts of ground water overdraft on wetlands and riparian areas in the United States, EPA 813-S-96-001

Richter, B.D, and H.E. Richter, 1992: Development of groundwater and ecological models for protecting a southwestern riparian ecosystem. In: J.A. Stanford and JJ Simons (eds), Proc. First Intern. Conf. on Ground Water Ecology, Amer. Water Resources Assoc. Technical Pub. Series TPS-92-2, AWRA, Bethesda, Maryland, pp 231-245.

Shuttleworth, W. J., 1992. Evaporation. In Handbook of Hydrology, Chapter 4, Ed. by D.R. Maidment, Pub. by McGraw-Hill, Inc., New York, N.Y., p. 4.18.

Stromberg, J.C., 1994: Draft riparian protection program - Legislative Report. Arizona Dept. of Water Resources, Phoenix, Arizona, 2 volumes.

5.1 References in this Issue

Goodrich, D.C., A. Chehbouni, B. Goff, B. MacNish, T., Maddock, S. Moran, W.J. Shuttleworth, D.G. Williams, J.J. Toth, C. Watts, L.H. Hipps, D.I. Cooper, J. Schieldge, Y.H. Kerr, H. Arias, M. Kirkland, R. Carlos, W. Kepner, B. Jones, R. Avissar, A. Begue, G. Boulet, B. Branan, I. Braud, J.P. Brunel, L.C. Chen, T. Clarke, M.R. Davis, J. Dauzat, H. DeBruin, G. Dedieu, W.E. Eichinger, E. Elguero, J. Everitt, J. Garatuza-Payan, A. Garibay, V.L. Gempko, H. Gupta, C. Harlow, O. Hartogensis, M. Helfert, C. Holifield, D. Hymer, A. Kahle, T. Keefer, S. Krishnamoorthy, J-P. Lhomme, D. Lo Seen, D. Luquet, R. Marsett, B. Monteny, W. Ni, Y. Nouvellon, R. Pinker, C. Peters, D. Pool, J. Qi, S. Rambal, H. Rey, J.Rodriguez, E. Sano, S.M. Schaeffer, M. Schulte, R. Scott, X. Shao, K.A. Snyder, S. Sorooshian, C.L. Unkrich, M.P.L. Whitaker, I. Yucel. 1997. An overview of the 1997 activities of the semi-arid land-surface-atmosphere (SALSA) program.

Hipps, L.E., D. Cooper, W. Eichinger, D. Williams, S. Schaeffer, K. Snyder, R. Scott, A. Chehbouni, C. Watts, O. Hartogensis, J-P. Lhomme, B. Monteny, J-P. Brunel, G. Boulet, J. Schieldge, H. De Bruin, J. Shuttleworth, and Y. Kerr, A summary of processes which are connected to evaporation of riparian and heterogeneous upland vegetation in arid regions.

Maddock, T., III, R. MacNish, D. Goodrich, D. Williams, J. Shuttleworth, B. Goff, R. Scott, S. Moran, D. Cooper, L. Hipps, A. Chehbouni, An overview of atmospheric and surface water coupling to regional groundwater models in semi-arid basins.

Moran, S., D. Williams, D. Goodrich, A. Chehbouni, A. Bégué, G. Boulet, D. Cooper, R. Davis, G. Dedieu, W. Eichinger, J. Everitt, B. Goff, C. Harlow, M. Helfert, L. Hipps, C. Holifield, D. Hymer, A. Kahle, T. Keefer, Y. Kerr, R. Marsett, W. Ni, Y. Nouvellon, J. Qi, S. Schaeffer, J. Schieldge, R. Scott, K. Snyder, J. Toth, C. Watts, M. Whitaker, and I. Yucel, Overview of remote sensing of semi-arid ecosystem function in the upper San Pedro river basin, Arizona.

Qi, J., S. Moran, D. Williams, D. Goodrich, R. Scott, A. Chehbouni, D. Cooper, L. Hipps, and W. Eichinger, R. Marsett, and W. Ni, Estimation of evapotranspiration over the San Pedro riparian area with remote and in-situ measurements.

Schaeffer, S.M., and D.G. Williams, Transpiration of desert riparian forest canopies estimated from sap flux.

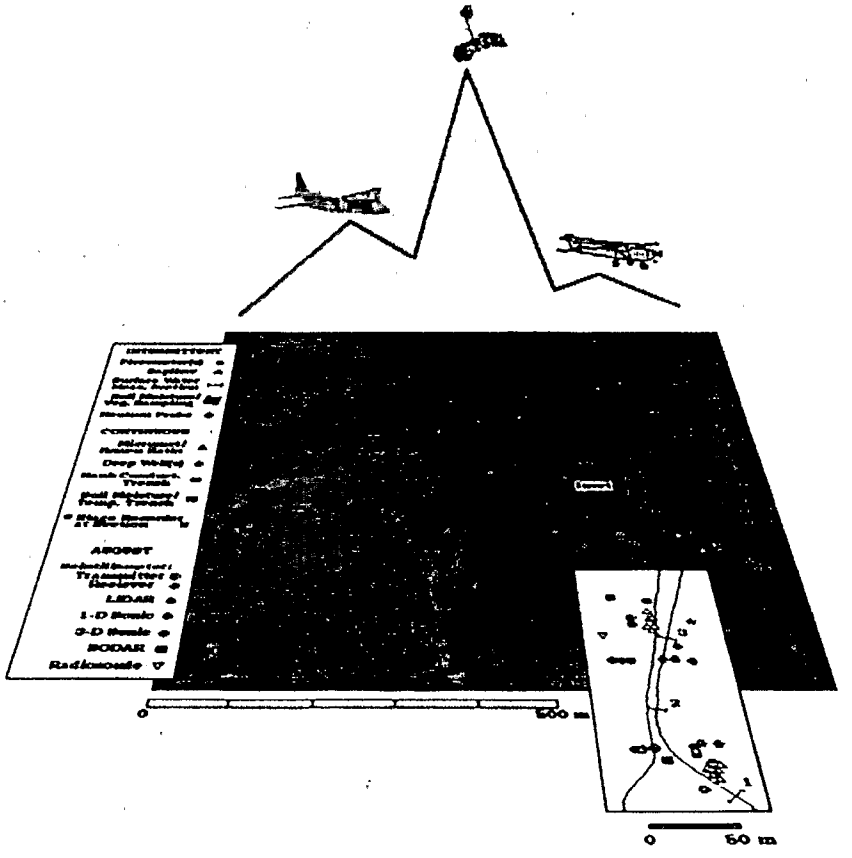
Scott, R., J. Shuttleworth and D. Goodrich, Water use of two dominant riparian vegetation communities in southeastern Arizona.

Williams, D.G., J-P. Brunel, G. Lin, S. Schaeffer, and K. Snyder, Biotic control over the functioning of desert riparian ecosystems.

Semi-Arid Land-Surface-Atmosphere (*SALSA*) Program

Preliminary Results of 1997 Activities

Papers to be Presented at a Special Symposium on Hydrology, Session on Integrated Observations of Semi-Arid Land-Surface-Atmosphere Interactions
American Meteorological Society Meeting
Phoenix, Arizona 11-16 January 1998



USDA Agricultural Research Service, Southwest Watershed Research Center
2000 E. Allen Road, Tucson, AZ 85719

November 1997