WATER CONSUMPTION BY RIPARIAN VEGETATION

Riparian areas encompass plant communities that are growing inside, as well as outside the hydrological zones. The ecosystem services provided by riparian areas include terrestrial and aquatic biodiversity, corridors and habitats for wildlife, stream-bank stabilization, soil protection, water storage, groundwater recharge, mediation of seasonal water level fluctuations, improved water quality, nutrient cycling, carbon sequestration, climate regulation, pollution control, aesthetic, educational opportunities, as well as economically important products, food, biofuels, and water production. In recent decades riparian areas have experienced changes in vegetation cover as invasive species spread, affecting the hydrological cycle and water yields in several ecosystems. Competing demands for water resources and the role of riparian evapotranspiration (ET) in depleting watershed-level water budgets are prompting land managers and policy makers to seek better understanding of the ecological and socioeconomic roles of riparian systems so that water resource management can be improved.

In NE, altered hydrological regimes have been shown to change riparian community composition, structure and function and, in many cases, to increase encroachment of native non-riparian aggressive eastern redcedar and non-native species such as phragmites, Russian olive, and salt cedar.

Estimates of evapotranspiration (ET) suggest that 20-50% of water depletion can be attributed to riparian vegetation in semi-arid systems. In NE, average ET has been estimated to be 887 mm yr\(^{-1}\) (~35 in yr\(^{-1}\)) for riparian trees that draw water from near the water table (phreatophytes). Estimates increase significantly as woody species density increases and invasive species spread. For example, ET rates were 20% higher in cottonwood stands with saltcedar and Russian olive understory (1,230 mm yr\(^{-1}\) or 48.4 in yr\(^{-1}\)), and in saltcedar stands (1,110 to 1,220 mm yr\(^{-1}\), 43.7 to 48 in yr\(^{-1}\)), compared to closed canopy cottonwood stands with an understory of willow (980 mm yr\(^{-1}\), 38.6 in yr\(^{-1}\)). P. phragmites ET has been estimated to be 770 mm yr\(^{-1}\) (30.3 in yr\(^{-1}\)). Removing saltcedar and Russian olive from the understory of cottonwood stands reduced groundwater fluctuations by 6.7% and 18.1%, respectively. Herbicide treatment of phragmites decreased ET by 32%. By comparison, ET of native riparian grass community of the Republican River in Benkelman, NE was estimated to be around 600 mm yr\(^{-1}\) (23.6 in yr\(^{-1}\)). Long term studies are few in the literature, inter- and intra-annual weather fluctuations and site management practices will have a significant effect on ET values.

Recollects projections of increased water yields following invasive species removal must consider many variables including land use within the entire watershed, relative water use with each land use category, climate, and pre- and post-treatment vegetation. Literature has shown increases in water yields after removal of invasive species are unpredictable in semi-arid regions, vary within geographic regions and stream type, and are most often temporary with benefits leveling off after few years unless continuous control of woody and weedy vegetation is adopted on these sites.

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Precipitation</th>
<th>Water Use Rates</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Elaeagnus angustifolia</em></td>
<td>Middle Rio Grande, NM</td>
<td>1,230 mm yr⁻¹</td>
<td></td>
<td>Eddy covariance</td>
<td>Dahm et al. 2002</td>
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<td>(Russian olive)</td>
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<tr>
<td><em>Juniperus ashei</em> (ashe juniper)</td>
<td>Uvalde County, TX, 1991-1995</td>
<td>676 mm March – Oct. 945 mm Total yr.</td>
<td>.90 mm day⁻¹ (Mar-Oct) (520 mm season⁻¹)</td>
<td>Bowen ratio energy balance</td>
<td>Dugas et al. 1998</td>
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<tr>
<td><em>Tamarix ramosissima</em></td>
<td>Beaver Creek, AZ</td>
<td>553 mm yr⁻¹</td>
<td>432 mm yr⁻¹ (1.21 mm day⁻¹)</td>
<td>Water balance</td>
<td>Lane and Barnes 1987</td>
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<tr>
<td>(alligator juniper)</td>
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<tr>
<td><em>Tamarix ramosissima</em> (Utah juniper)</td>
<td>Beaver Creek, AZ</td>
<td>441 mm yr⁻¹</td>
<td>414 mm yr⁻¹ (1.13 mm day⁻¹)</td>
<td>Water balance</td>
<td>Lane and Barnes 1987</td>
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<tr>
<td><em>J. osteosperma</em> (Utah juniper)</td>
<td>Rush Valley, UT</td>
<td>239 mm yr⁻¹</td>
<td>0.85 mm day⁻¹</td>
<td>Eddy covariance</td>
<td>Leffler et al. 2002</td>
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<tr>
<td><em>J. virginiana</em></td>
<td>One 15.2 cm diameter tree (eastern redcedar)</td>
<td>844 mm yr⁻¹</td>
<td>1.0 mm day⁻² April (62.3 L day⁻³ tree⁻¹) 0.8 mm day⁻¹ May-Aug (48.4 L day⁻³ tree⁻¹)</td>
<td>3 cm Granier sap flow probes.</td>
<td>Landon et al. 2009</td>
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<tr>
<td><em>P. deltoides</em> 27 trees/ha with 80 trees/ha 9.0 m average distance between trees (Cottonwood)</td>
<td>Odessa, NE 2004</td>
<td>844 mm yr⁻¹</td>
<td>61 cm diameter, tree 0.26 mm day⁻¹ Apr (16.5 kg day⁻¹ tree⁻¹) 3.78 mm day⁻¹ May-Aug 240.5 kg day⁻¹ tree⁻¹</td>
<td>Granier sap flow 5 cm long probes</td>
<td>Landon et al. 2009</td>
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<td><em>P. tremuloides</em> 70 yr old stand (trebling aspen)</td>
<td>Prince Albert National Park, Saskatchewan, Canada</td>
<td>450 mm in 1994</td>
<td>280 mm yr⁻¹ poplar trees (0.77 mm day⁻¹)</td>
<td>Eddy flux tower</td>
<td>Black et al. 2006</td>
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<tr>
<td><em>P. tremuloides</em> (trebling aspen)</td>
<td>Central Saskatchewan, Canada VPD &gt; 1 kPa 100 W m⁻² light</td>
<td>175 mm yr⁻¹</td>
<td>4.8 mm day⁻¹</td>
<td>Heat pulse sap flow</td>
<td>Hogg and Hurdle 1997</td>
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<tr>
<td><em>Populus/Salix</em> (poplar/willow forest)</td>
<td>Middle Rio Grande, NM</td>
<td></td>
<td>1,100 – 1,300 mm yr⁻¹ (3.0–3.6 mm day⁻¹)</td>
<td>MODIS and EVI data calibrated with eddy covariance</td>
<td>Nagler et al. 2005b</td>
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<tr>
<td><em>Populus/Salix</em> (poplar/willow forest)</td>
<td>Upper San Pedro, AZ Lower Colorado, AZ</td>
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<td><em>Tamarix ramosissima</em> Nonflooded site</td>
<td>Bill Williams and Colorado rivers, northwest AZ</td>
<td>3.4-3.7 m DGW</td>
<td>740 mm yr⁻¹ 1999 (2.0 mm day⁻¹) 760 mm yr⁻¹ 2000 (2.1 mm day⁻¹)</td>
<td>Eddy covariance</td>
<td>Cleverly et al 2002, Dahm et al. 2002</td>
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<tr>
<td><em>T. ramosissima</em> Flooded site</td>
<td>Middle Rio Grande, NM, Bosque del Apache National Wildlife Refuge</td>
<td>3.7-4.0m DGW</td>
<td>1,220 mm yr⁻¹ 1999 (3.3 mm day⁻¹) 1,100 mm yr⁻¹ 2000 (3.0 mm day⁻¹)</td>
<td>Eddy covariance</td>
<td>Cleverly et al 2002, Dahm et al. 2002</td>
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<tr>
<td><em>T. ramosissima</em></td>
<td>Middle Rio Grande, NM, Sevilleta National Wildlife Refuge</td>
<td>3.4-3.7 m DGW</td>
<td>740 mm yr⁻¹ 1999 (2.0 mm day⁻¹) 760 mm yr⁻¹ 2000 (2.1 mm day⁻¹)</td>
<td>Eddy covariance</td>
<td>Cleverly et al 2002, Dahm et al. 2002</td>
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<tr>
<td><em>Tamarix spp.</em></td>
<td>Chibola National Wildlife Refuge, AZ</td>
<td>2.7-3.4 m DGW</td>
<td>1,100 mm yr⁻¹ (3.0 mm day⁻¹)</td>
<td>MODIS and EVI data calibrated with covariance flux towers</td>
<td>Nagler et al. 2005b</td>
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<tr>
<td><em>T. ramosissima</em></td>
<td>Chibola National Wildlife Refuge, AZ</td>
<td>2.7-3.4 m DGW</td>
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<td>MODIS and EVI data calibrated with covariance flux towers</td>
<td>Nagler et al. 2005b</td>
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<tr>
<td><em>Phragmites australis</em></td>
<td>South Central, NE 464mm</td>
<td>1,100 mm yr⁻¹ (3.0 mm day⁻¹)</td>
<td>MODIS and EVI data calibrated with covariance flux towers</td>
<td>Nagler et al. 2005b</td>
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<td>369 mm</td>
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