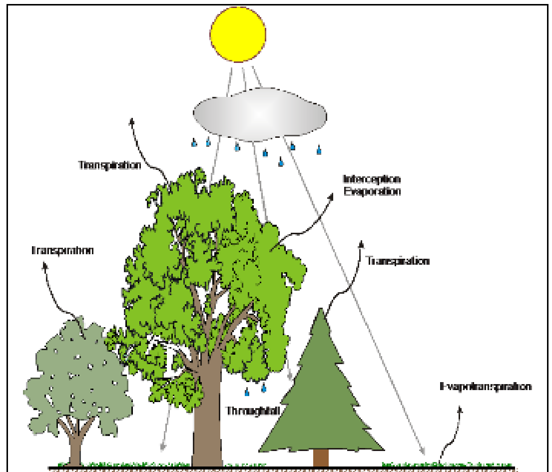
WATER CONSUMPTION BY RIPARIAN VEGETATION

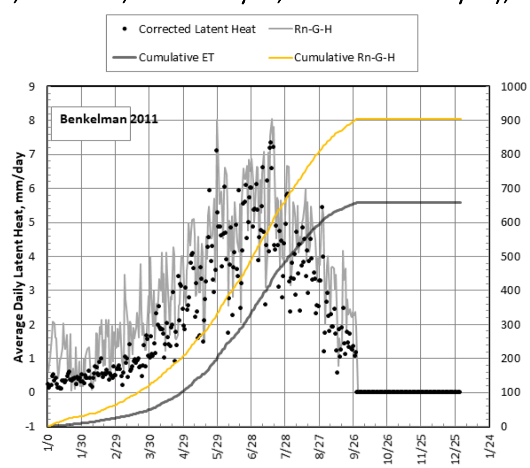
Riparian areas encompass plant communities that are growing inside, as well as outside the hydrological zones. The ecosystem services provided by riparian areas include terrestrial and aquatic biodiversity, corridors and habitats for wildlife, stream-bank stabilization, soil protection, water storage, 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.



Evapotranspiration (ET), comprised of both transpiration (water loss) by plants and evaporation from the surfaces

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}). 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 along 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.



ET in riparian native grasslands (N 40° 01’ 54”, W 101°33’56”), Republican River NE.

Realistic 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.

Huddle J, Awada T., Martin D., Zhou X., Pegg SE., Josiah S. 2011. Great Plains Research, 21:49-71.

Mykleby P.M., Lenters J.D., Cutrell G.J., Herrman K.S., Istanbulluoglu E., Scott D.T., Twine T.E., Kucharik C.J., Awada T., Soylu M.E., and Dong B. (2016). Energy and water response of a vegetated wetland to herbicide treatment of invasive *Phragmites australis*. *Journal of Hydrology*, 539:290-303.

WATER USE OF MAJOR RIPARIAN TREE SPECIES IN THE GREAT PLAINS AS A FUNCTION OF PRECIPITATION (mm), LEAF AREA INDEX (LAI) DEPTH TO GROUNDWATER (DGW m), VOLUMETRIC SOIL MOISTURE (%), OR VAPOR PRESSURE DEFICIT (VPD kPA)

Species	Location	Precipitation	Water Use Rates	Method	Reference
Elaeagnus angustifolia (Russian olive)	Middle Rio Grande, NM		1,230 mm yr^{-1}	Eddy covariance	Dahm et al. 2002
Juniperus ashei (ashe juniper)	Uvalde County, TX 1991-1995	676 mm March – Oct. 945 mm Total yr.	..90 mm day^{-1} (Mar-Oct) (520 mm $season^{-1}$)	Bowen ratio energy balance	Dugas et al. 1998
J. deppeanna (alligator juniper)	Beaver Creek, AZ	553 mm yr^{-1}	432 mm yr^{-1} (1.21 mm day^{-1})	Water balance	Lane and Barnes 1987
J. osteosperma (Utah juniper)	Beaver Creek, AZ	441 mm yr^{-1}	414 mm yr^{-1} (1.13 mm day^{-1})	Water balance	Lane and Barnes 1987
J. osteosperma (Utah juniper)	Rush Valley, UT	239 mm yr^{-1}	0.85 mm day^{-1}	Eddy covariance Mar-Oct 2001	Leffler et al. 2002
J. virginiana One 15.2 cm diameter tree (eastern redcedar)	Odessa, NE 2004	844 mm yr^{-1}	1.0 mm day^{-1} April (62.3 L day^{-1} $tree^{-1}$) 0.8 mm day^{-1} May-Aug (48.4 L day^{-1} $tree^{-1}$)	3 cm Granier sap flow probes.	Landon et al. 2009
P. deltoides 27 trees/ha with 80 trees/ha 9.0 m average distance between trees (Cottonwood)	Odessa, NE 2004	844 mm yr^{-1}	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} $tree^{-1}$) 22.9 cm diameter, tree 0.05 mm day^{-1} Apr (3.2 kg day^{-1} $tree^{-1}$) 1.44 mm day^{-1} May-Aug (91.6 kg day^{-1} $tree^{-1}$)	Granier sap flow 5 cm long probes	Landon et al. 2009
P. tremuloides 70 yr old stand (trembling aspen)	Prince Albert National Park, Saskatchewan, Canada	450 mm in 1994	280 mm yr^{-1} poplar trees (0.77 mm day^{-1})	Eddy flux tower	Black et al. 2006
P. tremuloides (trembling aspen)	Central Saskatchewan, Canada VPD > 1 kPa ·100 W m^{-2} light	Parkland site ꞉75 mm yr^{-1} Boreal site ꞉62 mm yr^{-1}	4.8 mm day^{-1} 9.6 mm day^{-1}	Heat pulse sap flow	Hogg and Hurdle 1997
Populus/Salix (poplar/willow forest)	Middle Rio Grande, NM Upper San Pedro, AZ Lower Colorado, AZ		1,100 – 1,300 mm yr^{-1} (3.0- 3.6 mm day^{-1})	MODIS and EVI data calibrated with eddy covariance	Nagler et al. 2005b
Tamarix ramosissima (salt cedar)	Bill Williams and Colorado rivers, northwest AZ		1,220 mm yr^{-1} (3.34 mm day^{-1})	Steady state porometer, composite 1989-1990 diurnal curve	Busch and Smith 1995
T. ramosissima Nonflooded site	Middle Rio Grande, NM, Sevilleta National Wildlife Refuge	3.4-3.7 m DGW	740 mm yr^{-1} 1999 (2.0 mm day^{-1}) 760 mm yr^{-1} 2000 (2.1 mm day^{-1})	Eddy covariance	Cleverly et al 2002, Dahm et al. 2002
T. ramosissima Flooded site	Middle Rio Grande, NM, Bosque del Apache National Wildlife Refuge	3.7-4.0m DGW	1,220 mm yr^{-1} 1999 (3.3 mm day^{-1}) 1,100 mm yr^{-1} 2000 (3.0 mm day^{-1})	Eddy covariance	Cleverly et al 2002, Dahm et al. 2002
T. ramosissima	Middle Rio Grande, NM Upper San Pedro, AZ Lower Colorado, AZ		300 – 1,300 mm yr^{-1} (0.8-3.6 mm day^{-1})	MODIS and EVI data calibrated with covariance flux towers	Nagler et al. 2005b
Tamarix spp.	Chibola National Wildlife Refuge, AZ	2.7-3.4 m DGW	1,100 mm yr^{-1} (3.0 mm day^{-1})	MODIS vegetation indices	Nagler et al. 2008a
T. ramosissima	Chibola National Wildlife Refuge, AZ	< 100 mm yr^{-1} 2.5-3.3 m DGW	3.7-9.5 mm day^{-1}	Granier sap flow	Nagler et al. 2009
Phragmites australis	South Central, NE	464mm 369 mm	Before herbicide treatment: 4.4 – 8.2 mm day-1 (770mm yr^{-1}) After herbicide treatment: 3 mm day^{-1} (525 mm yr^{-1})		Mykleby et al. 2016