Abstracts — Session 5: *Tamarix* Water Use
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Drought, restoration, and evapotranspiration in the Middle Rio Grande riparian corridor, New Mexico

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Abstract:

The purpose of this research is to investigate ecosystem water budgets and tamarisk invasion in the Middle Rio Grande corridor of New Mexico. Specifically, this study compares water use patterns across a multi-year severe drought in native (cottonwood), non-native (tamarisk and Russian olive), and restored forests. To measure water use by each of these forests, three-dimensional eddy covariance (3SEC) systems were mounted upon towers above the canopy. This is the only method available for directly measuring fluxes of water, energy, and carbon dioxide between terrestrial ecosystems and the atmosphere. Four towers were erected in 1999, located at Bosque del Apache National Wildlife Refuge (NWR) (monospecific tamarisk), Sevilleta NWR (tamarisk-saltgrass mosaic), near the towns of Belen and Rio Communities (native cottonwood forest), and in Albuquerque's south valley (cottonwood forest with tamarisk and Russian olive understory). The non-native understory in Albuquerque's south valley was removed during the winter of 2003-2004. A fifth tower was installed in 2003 over a Russian olive and coyote willow stand at the La Joya State Game Refuge. Drought struck this region in September 2001 and persisted into the winter of 2005, when record snowfall generated three months of spring and summer flooding. Vapor pressure deficit, or the leaf-to-air moisture gradient, increased with drought from 2.35 to 2.55 kPa over the tamarisk stands and from 1.95 to 2.25 kPa over the cottonwood forests. Ecosystem water use was highest in the invaded cottonwood forest (128 +/-2 cm/yr), intermediate at the monospecific tamarisk, native cottonwood, and Russian olive sites (110 +/-6), and lowest at the site dominated by tamarisk and saltgrass (79 +/-4 cm). Crown dieback in cottonwood was observed at a location where the water table was deeper than 3-m, while tamarisk and Russian olive showed no chlorosis. At the site where the non-native understory was removed, a first-year 26% reduction in ET during the following year was measured, but water salvage relative to the un-restored sites was negligible during the second year. Regrowth of cut tamarisk stumps accounted for the transience in ET reduction, implying that efficacy of removal is a crucial factor in applying restoration of tamarisk forests. Attention to post-removal control is especially important during drought, when native species are more vulnerable to deepening groundwater than tamarisk and Russian olive.

ET estimation by remote sensing and GIS approaches for management

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Abstract:

For effective system-wide management of tamarisk, a crucial and often overlooked first step is to assess the current state of the river, to evaluate processes and treatments already undertaken, and to project potential cost/benefits and risks to the system. The Pecos River in New Mexico has undergone extensive multi-year, helicopter-based herbicide spraying in an attempt to control tamarisk from its banks and along several tributaries. This study was undertaken to provide an

estimate of water salvaged by tamarisk control to provide the basis for conducting a cost/benefit analysis. An estimate of salvage was made as the residual between evapotranspiration (ET) estimated for the year prior to commencement of herbicide spraying (summer 2002) and for the year following final treatments (summer 2005). Accurate estimation of ET quantifies the potential salvage through the decrease of ET in the system. Rather than going to tamarisk use, the salvaged water becomes available to provide increased supply for native vegetation, increased soil water storage, and as the agencies that funded, planned and undertook the herbicide spraying hoped, discharge of the salvaged water to the river.

Color aerial photography was used as a visual reference of the phreatophyte vegetation and LANDSAT TM7 satellite imagery were used to assess water use by riparian vegetation. Image processing techniques expanded the accuracy and precision of Normalized Difference Vegetation Index (NDVI) by conversion to NDVI* that controls non-systematic variation in the data. NDVI* was calibrated to annual totals of precipitation and reference ET (ET0) to yield an estimate of annual ET consumption that was applied to the imagery through the entire study reach from Sumner Dam northeast of Fort Sumner to Brantley Dam north of Carlsbad (about 230 km). The calculations of ET before and after herbicide application were made within a GIS using 30-m pixels. The aerial coverage of the analyses was defined by GPS logs taken by helicopter during aerial application on the main stem (areas that were sprayed outside of our study area--above Sumner Dam, below Brantley Dam and on tributaries were not analyzed).

From the before-after comparison, an estimated savings of 3.1 AF/acre were realized on the approximately 6,000 treated acres (annual salvage of 18,600 AF). Projection of these results to the herbicide treated areas outside our study area increased estimated water salvage by another 16,700 AF/yr. The water in the Pecos system has an actual value between $13 and $30/AF. Thus, were all of the salvaged water realized in river flow (only a portion would be expected) the value of total salvage of 35,300 AF/yr would be between $460,000 and $1,060,000. The amount of salvage is expected to decline each year as regrowth by tamarisk or other species occurs. The value of "realized" salvage and its dollar value on the Pecos River must be balanced against risks for bank erosion and reservoir sedimentation: in combination these may exceed a billion dollars.

Saltcedar management and water salvage estimates on the Pecos River in Texas, 1999-2005

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Abstract:

A large scale ecosystem restoration program was initiated in 1999 on the Pecos River in Western Texas. Saltcedar (*Tamarix* spp.), a non-native invasive tree, had created a near monoculture along the banks of the river by replacing most native vegetation. Local irrigation districts, private landowners, federal and state agencies, and private industry worked together to formulate and implement a restoration plan, with a goal of reducing the effects of saltcedar and restoring the native ecosystem of the river. An initial management phase utilizing state-of-the-art aerial application of herbicide began in 1999 and continued through 2005. Over 13,000 acres of saltcedar have been treated within the Pecos River Basin over 6 years. Intensive monitoring and research to assess the affects of saltcedar removal on water loss and water salvage has been conducted at a site near Mentone, Texas since the fall of 2000. Stand-level and stem-level water loss resulting from evapotranspiration, and water salvage from saltcedar control are being estimated. Stand-level losses are estimated by monitoring groundwater diurnal fluctuations within

two saltcedar sites along the river channel. Shallow groundwater monitoring wells were installed at each site, each well equipped with a pressure transducer water level loggers to provide data on the diurnal fluctuation of the groundwater table. Mathematical models were developed to estimate total water loss from the sites based on the magnitude of the diurnal fluctuations. Sites were monitored for one growing season, then saltcedar was treated on one site and comparisons made between the treated and untreated sites through 2006. Additionally, sap flow measurements were made on individual trees during the growing seasons of 2004, 2005 and 2006. Heat dissipation probes were installed in 12 to 20 trees each year. The trees were selected in 3 groups based on the distance from the tree to the edge of the river. The probes were interrogated every 10 seconds and a 30 minute average sap flux was reported. Zero flow calculations were based on nighttime maximum temperature differences. The amount of sapwood per unit ground area was sampled by harvesting all stems in a 10 * 10 m area and recording sapwood using digital cameras. Diurnal fluctuation in sap flux was modeled and compared to the diurnal fluctuations from the monitoring wells. Transpiration was partitioned from evapotranspiration resulting in estimates of stand level water use.

Quantifying ground-water savings achieved by tamarisk control: A demonstration project in the riparian zone of the Cimarron River, Kansas

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Abstract:

Low streamflows are an increasing problem in Kansas and other areas of the U.S. One factor thought to be responsible for stream-flow reductions in western Kansas is the consumption of ground water by phreatophytes in riparian corridors. Extensive control measures, primarily focusing on invasive species such as salt cedar and Russian olive, are being considered in response to concerns about the impact of phreatophytes on water resources. At present, there is no generally accepted means of quantifying the ground-water savings that might be achieved through these measures. Recently, an approach based on diurnal fluctuations in the water table has been shown to have potential for quantifying ground-water consumption by phreatophytes. A demonstration project is underway to evaluate this method for assessing ground-water savings achieved through phreatophyte-control measures.

The site for the demonstration project is on the Arnold Ranch near Ashland in an area of salt-cedar infestation along the Cimarron River in southwestern Kansas. Four plots, each approximately four hectares in size, have been established at the site. Different salt-cedar control measures are being applied in three of the plots and one plot (background monitoring plot) is being used to collect data unaffected by control measures. Wells have been installed at the site to monitor water-table responses at the site; each is equipped with an integrated pressure-transducer and datalogger unit programmed to take a pressure head readings at 15-minute intervals. Water content in the vadose zone is monitored biweekly during the summer months using a neutron probe in access tubes located adjacent to each well. A weather station has been installed to collect the meteorological data required to estimate potential evapotranspiration. Salt-cedar control measures were initiated in March of 2005. At that time, three of the four plots were clear cut except for circles ranging from 2030 m in radius, centered at each well. The radii of those circles of vegetation were progressively reduced through repeated cuttings in the summer of 2005. Only the invasive phreatophytes (salt cedar and Russian olive) were cut at the site; grasses, forbs, and

low-lying bushes were largely unaffected. A chemical treatment (Remedy and diesel-fuel mix) was applied to the salt-cedar regrowth in one plot following the cutting. Water levels, soil moisture, and meteorological parameters were monitored during these activities.

Water levels from wells in the background-monitoring plot were compared with water levels from wells in the other plots prior to cutting. A similar comparison following cutting and chemical treatment shows a reversal in the relative magnitude of the fluctuations. The changes in the relationships between water levels in the background-monitoring plot and those in the cutting and chemical treatment plot enabled initial estimation of the reduction of ground-water consumption resulting from control measures. The reduction appears to be on the order of 30-40%. Apparently, the shallow depth to water at this site allows substantial ground-water consumption by other mechanisms, such as transpiration by shallow-rooted vegetation and direct evaporation from the water table. Work has been initiated to assess the relative importance of ground-water consumption by these other mechanisms. Unless the impact of these mechanisms is better understood, it will be difficult to reliably estimate the potential water savings to be achieved through control of invasive phreatophytes.

Evapotranspiration by tamarisk from three 1-km^2 sites at Cibola NWR on the lower Colorado River

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Abstract:

Saltcedar (*Tamarix ramosissima*) has become the dominant plant species on the Lower Colorado River. Over 90% of the riparian corridor is classified as saltcedar habitat, growing in monocultures or in association with other salt tolerant shrubs such as arrowweed (*Pluchea sericea*) or saltbushes (*Atriplex* spp.). There is concern that saltcedar uses large amounts of water that could otherwise be used for agriculture or municipal water needs. Foliage density, leaf area index and evapotranspiration rates of saltcedar have been measured at the plant or small-plot scale, but little information is available for these parameters at the landscape level of measurement from which water budgets can be constructed. We used remote sensing methods and ground surveys to characterize the stand structure and evapotranspiration (ET) of three large (1 km^2), densely vegetated stands of saltcedar in the Cibola National Wildlife Refuge on the Lower Colorado River near Blythe, California. The centers of the plots were 200 m (Plot 1), 800 m (Plot 2) and 1600 m (Plot 3) from the river channel. Depth to groundwater varied from 3.0 m for Plot 1 to 3.7 m for Plots 2 and 3, and salinities of the groundwater varied from approximately 2,000 ppm for Plot 1 and 10,000 ppm and 5,000 ppm for Plots 2 and 3, respectively. All plots were virtual monocultures of saltcedar and were selected as typical of the large, dense stands of saltcedar that grow along the river within this wildlife refuge. Percent vegetation cover, determined by aerial photography, was 56%, 71% and 85%. LAIs for individual plants averaged 5.0 for all plots, and global LAIs for plots ranged from 2.8 to 4.3, as determined by % cover times LAI of individual plants. Plants in Plot 1 exuded copious amounts of water from leaves each summer morning, and appeared to moisten the soil in the vadose zone at 1-3 m depth through hydraulic lift. These phenomena were not as pronounced in the other two plots, which had deeper and more saline water tables. ET was

estimated by an algorithm developed for saltcedar and other riparian plants on southwest rivers, which regressed moisture flux tower data against MODIS Enhanced Vegetation Index values from the Terra satellite and ground-level air temperature measurements. Applied to these stands, peak ET rates ranged from 7-9 mm d-1 among sites. Projected annual rates were 1.6 m, 1.9 m, and 1.8 m for Plots 1-3, respectively. Annual ETo is about 2.0 m at this location. These rates compare to annual rates of 0.8 m to 1.2 m measured for dense stands on the Middle Rio Grande (LAI 3.0-3.5), and 0.8 m to 1.0 m for mixed arrowweed/saltcedar stands at the Havasu National Wildlife Refuge on the Lower Colorado River near Needles, CA. For whole river stretches, rates projected from MODIS imagery are approximately 0.8 m yr-1, as they incorporate areas of sparse vegetation as well as saltcedar stands.

Impacts of the saltcedar leaf beetle on saltcedar (*Tamarix* spp.) water use in central Nevada

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Abstract:

In this study we document the impacts of the saltcedar leaf beetle *(Diorhabda elongata*) on the water use of saltcedar trees (*Tamarix* spp.) at two field sites in central western Nevada. *Diorhabda elongata* is the first approved biological control agent for saltcedar in the U.S.A. Within 3 years from release beetles defoliated most to all of the trees at each field site and had spread over 25 km.

We used stem sapflow gauges and canopy evapotranspiration towers to measure the impacts of defoliation by *D. elongata* on saltcedar water use. We document that during the first year of defoliation by *D. elongata* transpiration decreased by up to 55% over the course of a season. During the second year the reduction in transpiration was 33%. However, in locations closer to the release site where beetle activity was more intense and little canopy foliage remained, the reductions in water use was over 95%. Across a broader area the impacts of beetles on saltcedar water use are dependent on a variety of factors including the timing and intensity of beetle defoliation and the canopy coverage of trees. In this study the greatest impacts on water use occurred closer to the release site. Beetle impacted trees did not have higher rates of water use per unit leaf area therefore estimates of canopy cover provide useful insights into reductions in water use. Collectively these results indicate that *D. elongata* is effective in reducing saltcedar water use across a large area. More information is needed to understand how to effectively establish *D. elongata* in other sites throughout the western U.S.A.; and how its impacts will alter long term community dynamics and ecosystem level water use.

A groundwater modeling tool for estimating water salvage

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Abstract:

A groundwater modeling tool based on the water balance approach can be used to estimate changes in net infiltration/potential recharge when salt cedar is replaced by other plant associations.

Net infiltration, defined as the water that passes out of the active soil zone or root zone into the underlying soil/bedrock, is estimated based on a daily water balance calculation of the near-surface soils. The water balance includes net precipitation as input, water storage and movement within the soil including evapotranspiration, and water moving from the active zone into the underlying soil/bedrock. The model domain is composed of a number of cells that extend from the surface to the contact with the underlying soil/bedrock. The description of each cell includes the cell depth as defined by the soil layer depth; soil type and associated properties; cell elevation, azimuth and slope; fraction of the surface covered by the vegetation canopy; and vegetation related characteristics.

Each cell is composed of one to three soil layers, depending on the active soil zone depth. Downward water movement from layer to layer within a cell is based on the field capacity concept. Estimation of evapotranspiration (ET) is derived from the dual crop version of the FAO-56 method, which produces separate estimates of evaporation and transpiration. Both the field capacity approach and the FAO-56 method are computationally straightforward and do not require iterative numerical solutions. The water balance modeling tool has been implemented in MathCad, a widely available commercial software package.