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An Assessment of the Vulnerability of Native Phreatophytes to Replacement by Invasive Species in a Mid-Continent Riparian Setting

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I. INTRODUCTION

FIGURE 1:
Like many riparian corridors in the western U.S, the vegetation along the Cimarron River in southwestern Kansas has become dominated by **salt cedar** (left) and **Russian olive** (right).

Replacement of native riparian-zone phreatophytes by non-native species is becoming increasingly common in many semi-arid and arid regions of the United States (Glenn and Nagler, 2005). Non-native species (**Figure 1**) that are particularly prevalent include the **salt cedar** (*Tamarix* spp.) and the **Russian olive** (*Elaeagnus angustifolia* L.).

The factors that contribute to the establishment of invasive phreatophytes are under investigation at a site in south-central Kansas that may be susceptible to invasion by non-native phreatophytes.

The Study Area: The Larned Research Site

The Larned Research Site (LRS) is located in a narrow riparian corridor along the Arkansas River in south-central Kansas (**Figure 2**). The site overlies an unconfined coarse-sand and gravel aquifer, which is in direct hydraulic connection with the Arkansas River.

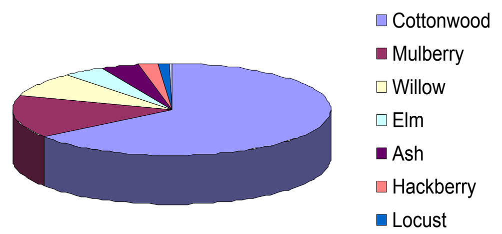
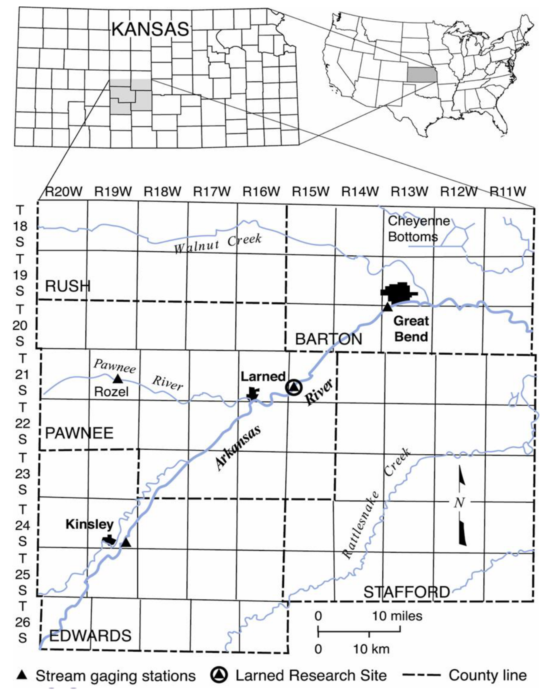


FIGURE 3:
Percentages of tree species by trunk area at the LRS (2002).

Vegetation at the site consists of a community of native phreatophytes common to many watersheds in central Kansas. A tree survey performed in 2002 (**Figure 3**) indicates that the major phreatophytes at the site are the cottonwood (*Populus deltoids*), willow (*Salix* spp.), and mulberry (*Morus* spp.).



Location of the LRS along the Arkansas River in south-central Kansas.

Over the past several years, increasing tree mortality at the site has been visually observed (**Figure 4**). Historically, the Arkansas River was considered one of Kansas' major rivers; however, today the river rarely flows at the site due to upstream diversions and other factors. Additionally, regional pumping activities have likely contributed to a declining water table.

a.

b.

FIGURE 4:
a. No flow conditions are typical for the Arkansas River at the LRS.

b. Dead trees have been increasingly observed at the site over the past several summers. Tree mortality may leave the site vulnerable to replacement by invasive species, transforming the landscape to that observed upstream of the LRS (c.)

c. The native riparian vegetation at the Circle K Ranch, located on the Arkansas River at Kinsley, upstream of the LRS, has been largely replaced by invasive species, particularly salt cedar.

II. ASSESSMENT OF SITE VULNERABILITY (METHODS)

The LRS has been the focus of extensive research on stream-aquifer interactions, so considerable data have been collected on the shallow groundwater flow system underlying the area. On-site instrumentation at the LRS (**Figure 5**) includes:

-18 water-level monitoring wells with sensors taking water-level readings every 15 minutes

-eight neutron-probe access tubes for observation of soil moisture

-a weather station

-a USGS stream gage

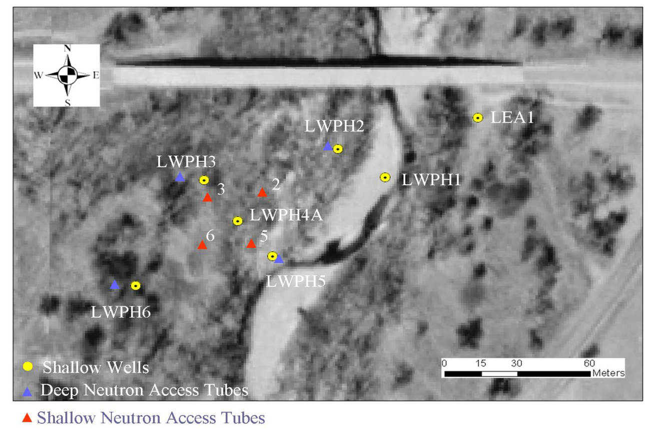


FIGURE 5:
Locations of shallow monitoring wells and neutron access tubes across the riparian zone at the LRS.

The following data are being used to assess the site's vulnerability to replacement by invasive species:

A. Water-level Data

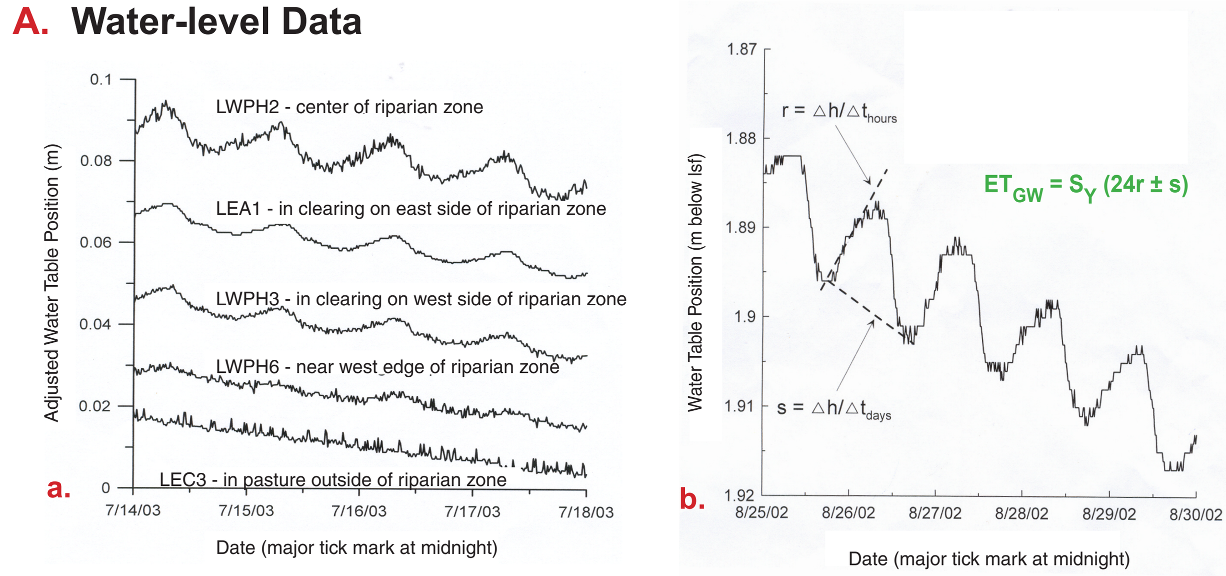


FIGURE 6:
a. Diurnal fluctuations are clearly observed in water-level data from wells within the riparian zone and are a diagnostic indicator of water-use by phreatophytes at the LRS.

b. Diurnal fluctuations may be used to estimate groundwater consumption (ET_{GW}; units of L/T) by phreatophytes using the White (1932) method (Loheide et al., 2005). The variables used in the method, include readily available specific yield (S_Y), net inflow calculated from night-time recovery (r), and the change in water-table position (s).

B. Soil Moisture Measurements

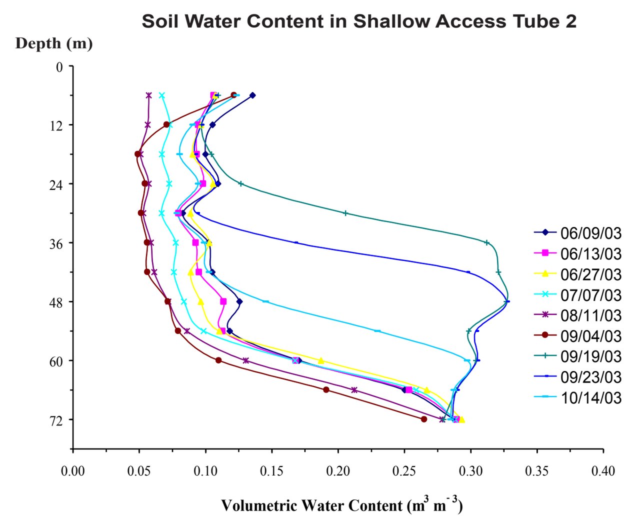


FIGURE 7:
Example of a profile showing soil moisture content with depth. Measurements of soil moisture in the vadose zone are taken biweekly during summer months using a neutron probe in eight access tubes across the riparian zone. These values were used to calculate specific yield values (Skaggs et al., 1978) for use in the White method.

C. Sap Flow Measurements

FIGURE 8:
Sap flow data, using the heat-pulse velocity method, were collected biweekly during the summer months of 2003 and 2004. These data indicate the velocity of sap flowing up the trunk of the tree. A total of 24 trees were monitored at the site.

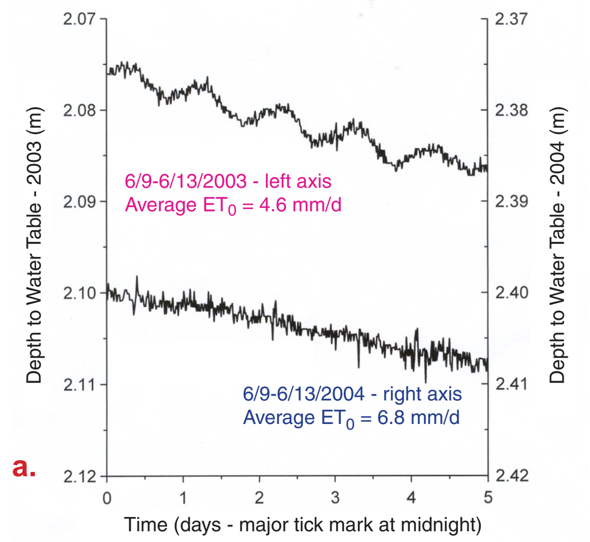
D. Meteorological Data

A weather station, located in a pasture adjacent to the riparian zone, collects a suite of meteorological data, including air temperature, relative humidity, wind speed, global irradiance, and precipitation. From these data, potential evapotranspiration values were calculated.

E. Tree Mortality Survey

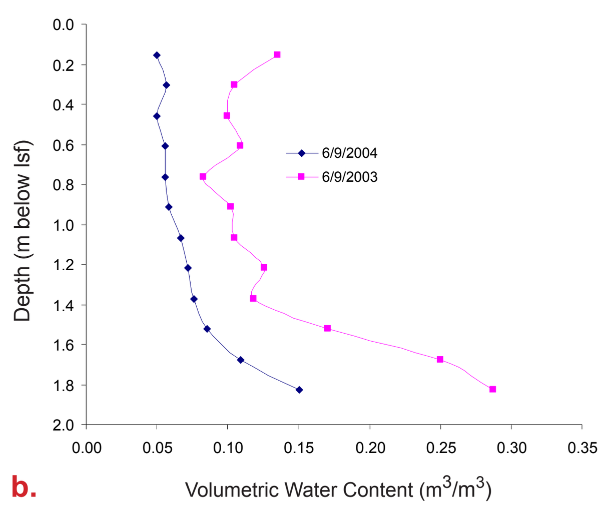
FIGURE 9:
An inventory of trees larger than 0.08 m in diameter at chest height was conducted in a portion of the LRS in the summer of 2002. Tree species and trunk diameter were recorded. Trees species were reinventoried with an emphasis on health in the summer of 2005. These data were used to assess the tree mortality rate at the site.

III. RESULTS AND DISCUSSION

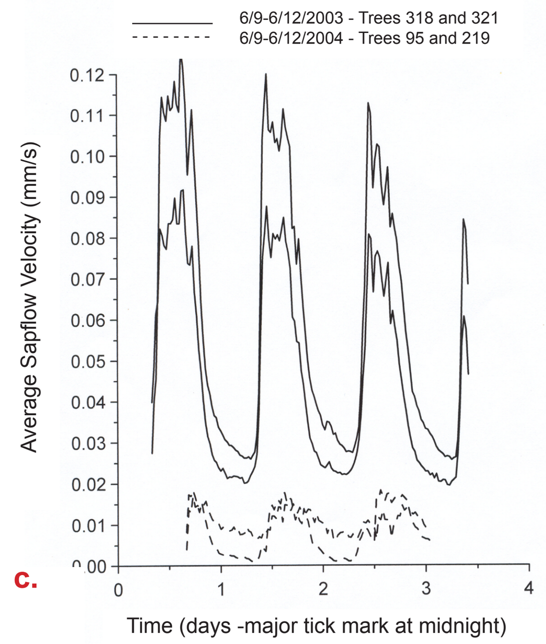


a.

FIGURE 10:
a. Variations in water table position at well LWPH3 during early June 2003 and 2004. Despite much higher potential evapotranspiration (ET_0) during this period in 2004, diurnal fluctuations are significantly dampened compared to early June 2003. In June 2004, water-table elevation was at a near historical low. The absence of diurnal fluctuations in 2004, despite higher ET_0, likely indicates that the water table was out of reach of vegetation in the riparian zone. Field notes (Butler, 6/4/04) report yellow leaves and premature leaf fall on many of the cottonwoods. Analysis of water-table fluctuations with the White method from August 2002 to August 2005 showed a sizable decrease in water use over these three years.



b.



c.

b. Soil moisture profiles from neutron access tubes at the center of the riparian zone support the interpretation that vegetation was under severe water-stress in early June 2004. Volumetric water content was near permanent wilting point over most of the vadose zone.

c. Sapflow velocities from cottonwood trees near the center of the riparian zone are substantially reduced in 2004 compared to 2003. This correlates well with the water-level and soil moisture data.

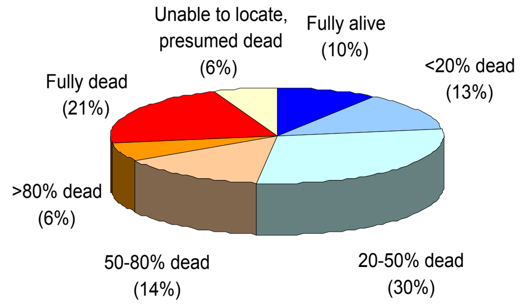


FIGURE 11:
Condition of surveyed phreatophytes in the riparian corridor of the LRS. A comparison of trees surveyed in 2002 and 2005 reveals a high mortality rate of 20-25% over the study period. An additional 20% of trees indicate signs of severe water stress.

IV. CONCLUSIONS

The native phreatophytes appear to be having difficulty keeping pace with the falling water table, leading to severe stress and a high rate of mortality. At present, the canopy is still sufficiently dense to prevent encroachment by salt cedar and Russian olive. However, if the present rate of mortality continues, non-native phreatophytes may exploit open areas created by tree die-off, leading to large changes in the riparian-zone community.

References: **Glenn and Nagler, 2005.** Competative ecophysiology of Tamarix ramosissima and native trees in western U.S. riparian zones. Jour. of Arid Environments 61, 419-446; **Loheide, Butler, and Gorelick, 2005.** Estimation of groundwater consumption by phreatophytes using diurnal water table fluctuations: A saturated-unsaturated flow assessment. Water Resour. Res., W07030, doi:10.1029/2005WR003942, 2005; **Skaggs, Wells, and Ghate, 1978.** Predicted and measured drainage porosities for field soils. Trans. ASAE22, 522-528; **White, 1932.** A method of estimating groundwater supplies based on discharge by plants and evapotranspiration from soil. U.S. Geological Survey Water Supply Paper 659-A, 105 pp.

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