Effects of acequias and groundwater levels on riparian vegetation, evapotranspiration, and restoration

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Project Summary:
Traditional irrigation systems, known as acequias, as well as the fields they irrigate have been shown to recharge the shallow groundwater along an irrigated valley of the northern Rio Grande. The increase in shallow groundwater from the field and acequia deep percolation may supply additional water to the river during dryer months and could have beneficial implications for the sustainability and restoration of riparian areas. We are expecting to find that a fair amount of the shallow groundwater is drawn out by riparian evapotranspiration decreasing the amount of return flow to the river. We also expect to find that acequia-related seepage creates localized areas where riparian plantings are highly successful. An estimate of the riparian evapotranspiration will be formed using the SCS Blaney-Criddle method with crop coefficients that have been calibrated for the Rio Grande. To determine acequias' role in riparian restoration and sustainability, cottonwood pole cuttings will be planted at varying distances from the acequias. The amounts of growth will then be measured and compared at each location. Once the amount of ground water used by riparian plants is determined, a more accurate estimate of the recharge rate of the river in the Alcalde area can be created. Restoration of riparian areas is important for water conservation, water quality, wildlife habitat, and for reducing the spread of invasive plants. This information can be used to determine possible acequia benefits and the overall water budget, which will help in future management decisions regarding the region and the Rio Grande.

Introduction:

The Rio Grande is an extremely important water source for the arid southwest. Irrigation through the use of acequias has been a long-term practice along the Rio Grande river valley in Northern New Mexico. These acequias may provide additional benefits apart from supplying water for crops. The acequias as well as the irrigated fields have been shown to recharge the shallow groundwater (Fernald *et al*., 2007). This recharge may increase groundwater return flow and supply additional water to the river during dryer months. The increase in shallow groundwater from the acequia seepage could also have beneficial implications for the sustainability and restoration of the riparian area.

Currently the amount of water lost due to riparian evapotranspiration (ET) is poorly quantified along the Northern Rio Grande. Riparian vegetation in arid regions withdraws large amounts of water from the groundwater supply (Dahm et al., 2002) and could have a considerable impact in this region. The riparian ET needs to be estimated to determine how much of the additional return flow, provided by the acequias and irrigation, remains available for the river.

The acequia seepage could possibly be used as a tool for the restoration of native riparian vegetation. The addition of levees along the Rio Grande resulted in a loss of the connectivity between the river and the floodplain. Much of the native vegetation along the river is adapted to the previous flow regimes and as a result has suffered a decline (Lite, S.J. et al., 2005, Johnson, 2002).

Maintaining the riparian vegetation is very important for both wildlife habitat and reducing the spread of non-native plants that have been slowly taking over riparian areas previously vegetated by natives (Sher et al., 2002). The more drought tolerant species such as Russian olive (*Elaeagnus angustifolia*) and siberian elm (*Ulmus pumila*) are more adapted to survive under the new conditions and can out-compete the native plants reducing habitat diversity (Vandersande et al., 2001). Tabacchi et al. emphasizes the importance of riparian vegetation as a tool to reduce sediment and nutrient inputs, and providing shade to channels. This would be beneficial to the acequia reducing the amount of nutrients and sediments carried back to the river as well as helping to minimize an increase in water temperature. The acequias seepage may help to alleviate these problems by creating areas with a high restoration potential.

This study has great importance to the agricultural region of Northern New Mexico. Water conservation is becoming a more prevalent topic as increased development puts higher demands on the regions water supplies. Once the amount of ground water used by riparian plants is determined a more accurate estimate of the recharge rate of the river in the Alcalde area can be created. Restoration of riparian areas is important for water conservation, water quality, for providing vital habitat requirements, and reducing non-native spread. This information can be used to determine possible acequia benefits and the overall water budget, which will help in future management decisions regarding the region and the Rio Grande.

Objectives/ Hypotheses:

Riparian characterization and ET estimation:

- **Objective**: Estimate the evapotranspiration of the riparian area through field measurements and modeling to determine approximately how much groundwater should be deducted from the additional return flows to the river.
- **Hypotheses**: A moderately large amount of groundwater is withdrawn by the riparian vegetation decreasing the return flows to the river.

Riparian Restoration:

- **Objective**: Determine whether lateral seepage from the acequias create areas where restoration efforts of native riparian vegetation could be focused to aid in maintaining a functioning riparian area with less susceptibility to encroachment of non-native species.

- **Hypotheses**: Acequias create localized areas where restoration efforts are highly effective and are occurring naturally as a result of the elevated water tables from acequia seepage.

Site Description

The study area was a semi-arid region located near Alcalde, NM. The Rio Grande's riparian area in this region consists of variable densities and widths of vegetation. The study site for the riparian ET included an approximately 10 mile stretch of river starting in Alcalde and going north. The cottonwood plantings study took place at the New Mexico State University's Sustainable Agricultural Science Center in Alcalde. Much of the region had dense vegetation with areas of sparser xeric vegetation mixed throughout. Some areas have been mostly cleared out for farm land while in other areas a fairly large riparian buffer still exists. The river has been channelized so little over bank flooding occurs, but some low spots still exist forming wetlands and side channels. Acequias are channeled off of the river throughout the valley at various diversion dams (figure 2). The riparian area was bordered by agricultural fields as well as small residential areas. The primary woody vegetation in the region consisted of *Populus Freemontii* (freemont cottonwood) , *Elaeagnus angustifolia* (Russian olive), *Forestiera neomexicana* (New Mexico olive), *Ulmus pumila* (Siberian elm), *Juniperus monosperma* (one-seed juniper), and *Salix exigua* (coyote willow).

Methods:

Riparian characterization and ET estimation:

A 10km stretch of riparian vegetation was characterized during the summer of 2007. The vegetation was characterized through aerial photographs and field sampling of randomly selected fixed area plots placed throughout the study area. The study reach was narrowed into three categories of vegetation cover (low <30% cover, medium 30%-60% cover, and high >60%cover), and separated into upland, acequia border, and river border locations. Multiple sampling plots were placed in each category and the overstory, shrubs, and the understory were measured and identified.

The overstory plots had an area of 20 meters squared in the upland areas and 5 meters squared on the river or acequia border sites. The overstory plots measured trees greater than 6 centimeters in diameter. Each tree within the plot was identified to species and the basal area and height were measured (Avery and Burkhart, 2002). The basal area was measured using a standard diameter tape. The canopy cover was measured using a densitometer at four points within each plot (2 diagonal meters inward from each corner).

The shrub plots were 2 meters squared in area and included woody vegetation less than 6 centimeters in diameter. Two shrub plots were measured in each upland plot and 1 in each river/acequia border plot. The species were identified as well as the percent cover of basal area measured.

The understory plots include all other non-woody vegetation such as grasses and forbs. Three understory plots were sampled within the upland plots and two in the river/acequia plots. The understory sampling involved identifying the species present, with sample vouchers taken for positive identification, and recording projected cover. The projected cover was measured using a style similar to the Daubenmire method. A 1m x 1m frame was placed on the ground at the sampling point. The percent of cover was recorded within the frame. As in Daubenmire's method, six cover classes were used to designate the amount of cover.

From the sampling plots and images the riparian species composition of the entire study area was approximated. The evapotranspiration rates were found using a combination of the field measurements and the SCS Blaney-Criddle method with crop coefficients that have been calibrated for the Rio Grande from work completed by Wan Luo. 1994.

Riparian Restoration:

The restoration potential of acequias was investigated by planting cottonwood pole cuttings at varying distances from the acequia. There were two sets of three plots: a plot bordering the acequia, a plot in the middle of a fallow field that was periodically irrigated, and a plot near to the Rio Grande. These plots showed acequia effects, irrigation effects, and the river's effects on pole growth.

The plots bordering the acequias had two planting depths, half the plot at one depth and half at the other. The depths were randomly designated at each plot with a coin toss. One set of six was planted at a depth in line with the bed level of the acequia (about 1.2m from the ground surface), and another set of six were planted at a depth 1 meter below that level (about 2.2m from the ground surface). There were three rows planted parallel with the acequia to determine how far out the lateral seepage of the acequia reaches. Each row had a set of twelve poles, six at each depth.

The first row was 1 meter from the acequias' edge, with 1 meter separating the second and third rows, making the last row 3 meters out from the acequia.

The mid-field plots and river plots only had one row of cottonwood poles seen as there was no seepage gradient. The mid-field plots were planted at two depths one set of six at 2m depth and one set of six at 1m depth, again randomly assigned. The river plots were planted with two depths as well. One set of six 0.2 meters below the surface of the water table, and one set of six 0.5 meters above the water table surface. The gravel substrates at the water table level prevented deeper planting depths at the river site so these poles were less than a meter in planting depth difference.

The survival and vitality was measured and compared for each pole through the growing season. Each pole was measured approximately every three weeks. The pole measurements included: Initial height and diameter (2cm above the ground surface), the number of branches and leaves, the leaf sizes, the amount of new branch growth, the amount of wilt, and any mortalities were noted (Francis et al. 2005, Kranjcec et al. 1998, Horton and Clark 2001). At the end of the growing season the vitality and survival of the cottonwood poles was compared within and between sites using these measurements.

The relative water content (RWC) of each tree was measured by taking a leaf at solar noon and weighing the leaves to the nearest milligram to obtain a fresh weight. The leaves were then placed in de-ionized water for 24 hours to get a fully hydrated weight, and then the leaves were placed in an oven at 60ºC for 72 hours and weighed again. The RWC was determined by the formula ((fresh weight-dry weight)/(wet weight-dry weight))*100 (Barr and Weatherly, 1962).

Water table depths were recorded continually from Campbell scientific data loggers installed in wells at each site to monitor water sources contributing to the cottonwoods growth. The water table depths were also measured manually as a backup reference during field visits.

Leaf area was examined by netting the trees in the late summer and capturing all the leaf fall. The leaves were weighed and a leaf area was found on a sub-sample of leaves using a Li-Cor leaf area meter. This estimate of area was then be scaled up to all the trees based on the weight of the leaves collected for each tree (Breda, N.J.J. 2003).

Soil water content probes (Campbell Scientific) were installed to look at soil moisture differences between areas. A set of three probes were installed in each cottonwood pole plot, one probe at 30cm from the soil surface, one at the shallower planting depth, and one at the deeper planting depth. The acequia plots have one set at the poles that were planted closets to the acequia and one set at the poles planted furthest from the acequia to look at the moisture gradient. Soil temperature probes were installed along with the moisture probes, one at each planting depth. The data from the probes was downloaded from Campbell Scientific data loggers during field visits and compared at the end of the growing season.

Other variables that were measured include soil chemistry, texture, and profile data, as well as canopy cover. This soil data was collected when the moisture and temperature probes were installed. Any differences between sites were recorded, and may help to explain any cottonwood growth variability between sites.

Preliminary Results and discussion:

Riparian characterization and ET estimation

Populus deltoids sp. wislizenii (Rio Grande cottonwood) and *Elaeagnus angustifolia* (Russian olive) were the predominant riparian trees in the region. Other trees found included *Juniperus monosperma* (One seed juniper), *Ulmus pumila* (Siberian elm), *Morus spp*. (Mulberry), *Robinia pseudoacacia* (Black locust), and *Tamarix chinensis* (Salt cedar). Russian olive had a higher presence than cottonwood within 5 meters of the rivers edge (Figure 1). *Forestiera neomexicana* (New Mexico Olive) was a prominent shrub species. Other woody shrub species found included *Salix exigua (coyote willow*), mainly along the river border. Cottonwood and willow saplings were primarily found within the river channel along gravel bars, 42% of the river plots contained saplings. Only one site contained willow and cottonwood saplings outside of the river channel, 6%, this site directly bordered an acequia. The general vegetation differences between the river border regions and the riparian area further inland are outlined in figure 1.

The riparian ET will be calculated this fall from the field data and the SCS Blaney-Criddle method. There was very little cottonwood recruitment in this region due to the regulated river flows, and the seedlings that were present were in locations that were very vulnerable to scouring (Braatne et al. 2007, Scott et al. 1997). This is a concern seen as non-native species such as Russian olive seem to be becoming the more dominant species which could have an impact on the hydrology and biodiversity of the valley and shows that the area would be benefited by restoration activities.

Riparian Restoration

Most of the trees survived the growing season. The highest loss rates were at the more water limited mid-field sites with only 75% survival (figure 2). The rest of the sites were at or above 90% survival. Early results for the pole planting study showed that cottonwood poles planted at the deeper depth bordering the acequia and in the mid-field were more successful than those planted at the shallower depth as shown in figure 3. The river plots exhibited more growth when planted at the shallower depth; this could be due to reduced oxygen levels at the deeper planting depth from continuous inundation of the trees in the water table (Fancis et al. 2005).

The acequia was able to support the cottonwood pole cuttings and the trees were very successful showing the highest amounts of growth of all three locations as shown in figure 3. All the sites showed similar rates of shoot growth early in the growing season. After the end of June the acequia sites showed the most rapid growth, followed by the river sites, with the mid-field sites showing the slowest growth (figure 4). The relative water content test showed that no surviving trees were water stressed; all were above 75% (figure 5). Site C deep had one tree heavily damaged by aphids bringing the average down.

There was much variation between trees so further analysis is needed to show stronger growth trends at and between sites. Some of the variability of tree growth may be due to insect damage on the trees, differing levels of solar radiation, and different growing substrates. Some of the mid-field trees were supplied with some unanticipated irrigation water on one side of the field which created unexpected results for the mid-field plots.

More data will be collected and further analyzed to make a more complete picture of the cottonwood growth trends along the acequia, river, and in the fields. This includes obtaining a leaf area for each tree to help further analyze the growth trends (Scott et al. 1999, Mahoney and Rood, 1992), and calibrating the soil moisture data to determine how closely the growth is correlated to the soil moisture levels and substrates at each site (Francis et al. 2005; Mahoney and Rood 1992). It has been shown by Willms et al. that water is the main determinant in the growth of riparian cottonwoods. The success of the trees planted by the acequia reveals that the acequias are a promising place to conduct riparian plantings with enough lateral seepage to support their growth.

Figures:

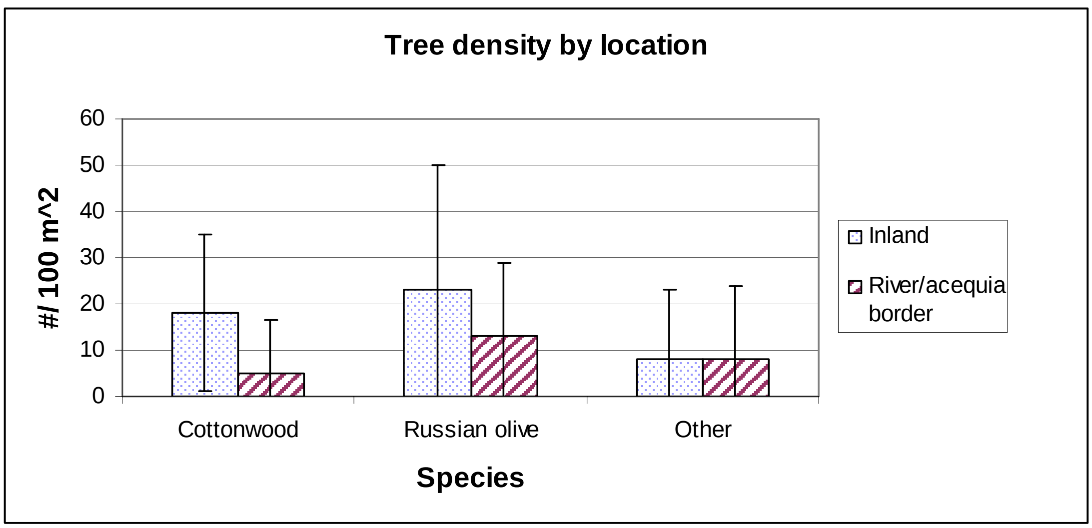

Figure 1. The density (in number per 100m²) of the various species of trees in the riparian area. Inland represents the riparian areas greater than 10m from the river's edge, and River/acequia border represents areas within 10m of the waters edge.

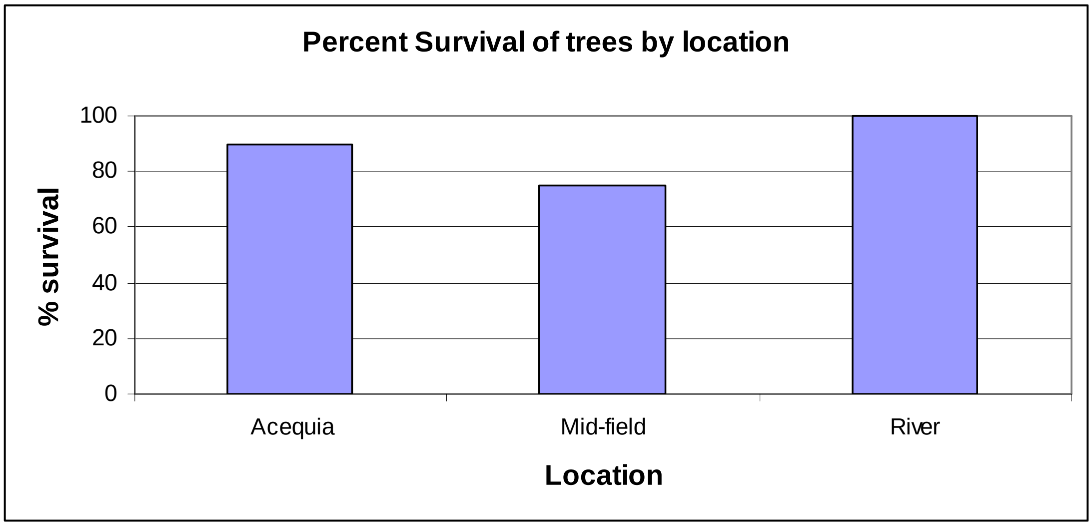

Figure 2. The percent survival of cottonwood pole cuttings planted at each site.

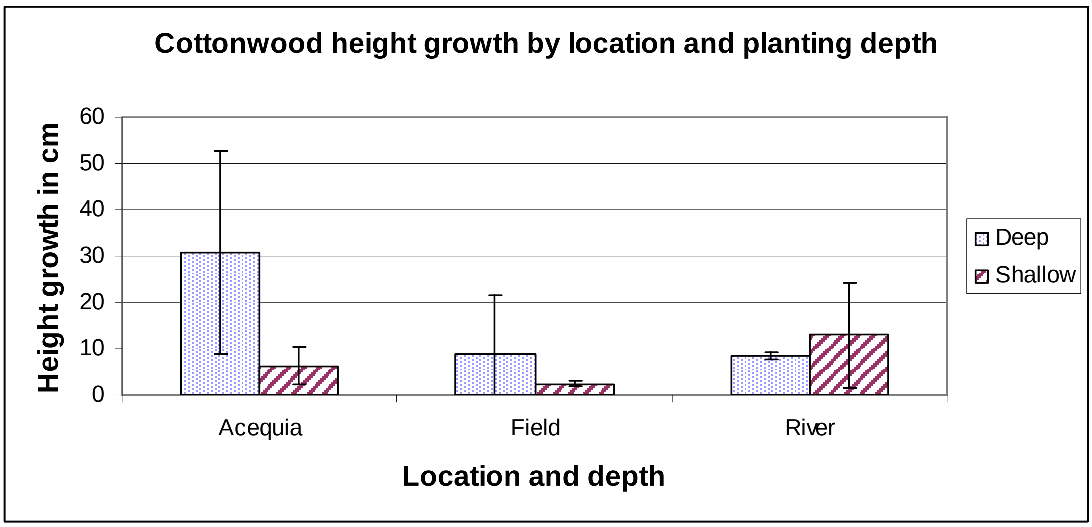

Figure 3. The cottonwood pole cuttings gain in height by planting depth, over the 2008 growing season. Deep signifies the trees planted approximately a meter below the shallow planting depths. The shallow depths were all at least a meter below the soil surface. The bars represent the mean gain in height in centimeters and the error bars represent the standard deviation.

Figure 4. The growth in centimeters of the longest new shoot on each tree averaged at each site over the 2008 growing season.

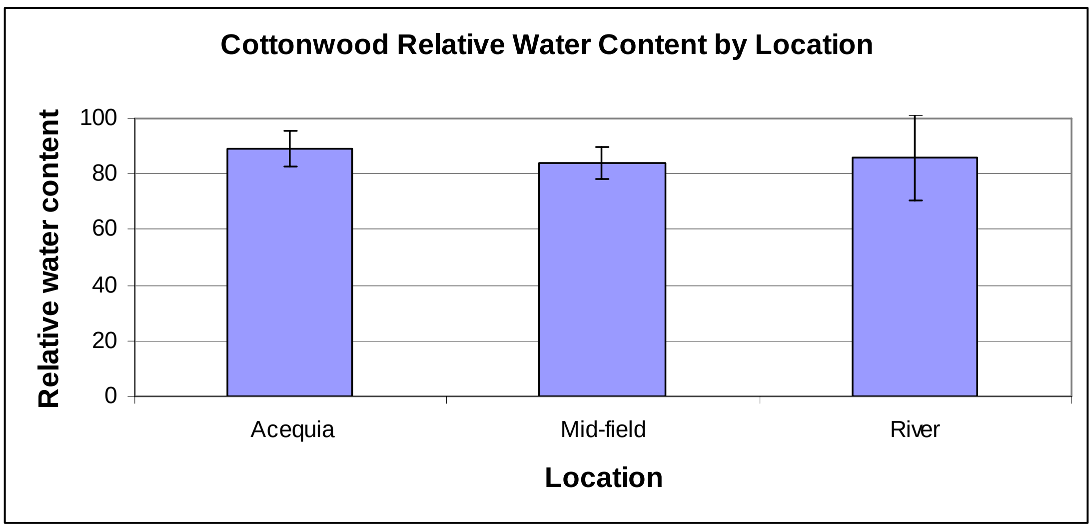

Figure 5. The relative water content of the cottonwood pole cuttings by planting location in September of 2008. The bars represent the mean percent water content and the error bars are the standard deviations.

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