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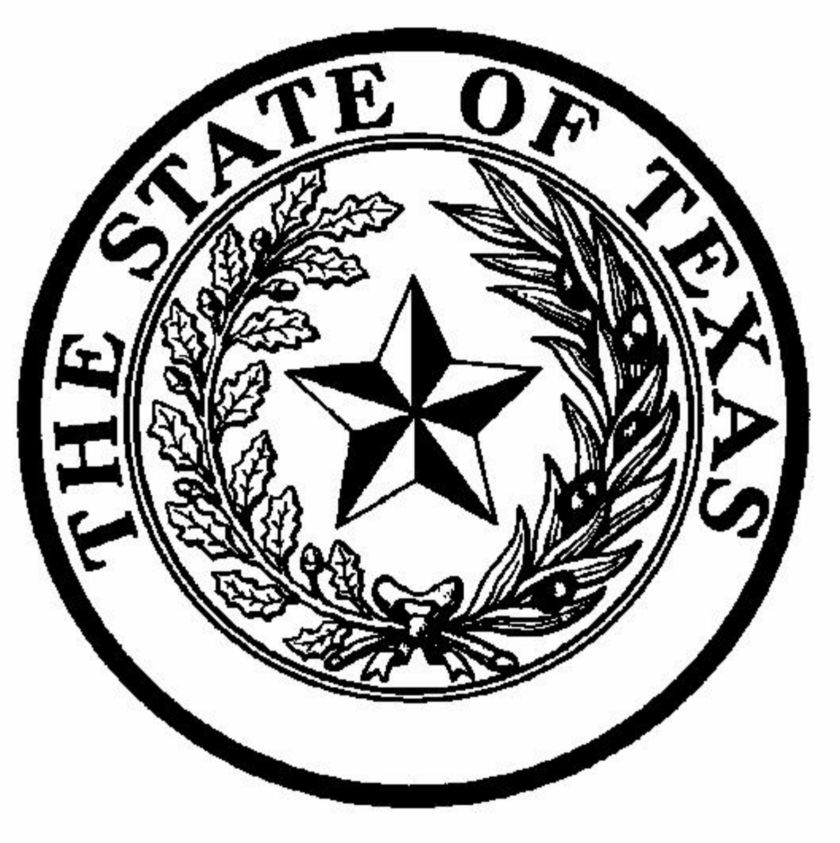

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Table of Contents

The Texas Journal of Agriculture and Natural Resource 18:1-14 (2005)

SPATIAL DISTRIBUTION of PLAYA BASINS on the TEXAS HIGH PLAINS

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ABSTRACT

There are approximately 20,500 playa basins on the Texas High Plains. The position, distribution, and alignment of playa basins can be observed on maps or aerial photographs. Latitude and longitude coordinates, in degrees, for the center of mass of each playa were the inputs used to quantify the spatial distribution. Point-to-point and origin-to-point functions were analyzed to quantify the spatial distribution of playa basins. Counties north of the Canadian river and along the Caprock escarpment have clustered playa basin distributions. Counties southwest of this region have high playa density and regular spatial distribution. The counties in the far southwestern portion of the Texas High Plains have low playa density and clustered spatial distribution patterns.

KEY WORDS: Texas High Plains, Playa basins, Spatial distribution

INTRODUCTION

Playas, ephemerally flooded basins with a veneer of fine-textured sediments, dot the surface of the Texas High Plains. Generally the playa bottoms are associated with the Randall clay soil (Fine, smectitic, thermic Ustic Epiaquert). Other soils that have historically been mapped within the playas are the Ness clay (Fine, smectitic, mesic Udic Haplustert) or the Lipan clay (Fine, smectitic, thermic Chromic Haplustert). All these soils are Vertisols, meaning that they swell when wet and shrink when dry (Soil Survey Staff 2003). Many of the playa soils have been remapped throughout the Texas High Plains into one of several playa depressionial soils.

There are approximately 20,500 playa basins on the High Plains. This count varies depending on whether the playas in New Mexico are included with those in Texas and whether playas north of the Canadian River into Oklahoma are included. Estimated playa numbers are as high as 37,000 (Walker, 1978), but Sabin and Holiday (1995) estimate the number to be closer to 20,000 in Texas. Fish et al. (1998) determined the number of Texas playas to be 20,557 while Howard et al. (2003) stated there are 19,226 playa basins on the Texas High Plains.

The distribution of playa basins as a topographic landscape feature on the Texas High Plains can be observed as a spatial point pattern. A spatial point pattern is defined as data in the form of a set of points, distributed within a region of space. There are three types of point patterns: random, regular or clustered (Diggle 1983; Davis 2002). A pattern is random if a point is as likely to occur at one area as any other area on a plane. In a regular pattern, the spacing between points is regularly repeated. In contrast, the spacing between points varies with the distance from other preexisting points in a clustered pattern (Davis 2002).

The first step in analyzing a point pattern is to either accept or reject the hypothesis of complete spatial randomness (Cressie 1993). A pattern for which complete spatial randomness is not rejected does not "merit any further formal statistical analysis" (Diggle 1983). If the analysis of the pattern does not indicate complete spatial randomness, the points need to be analyzed using additional tests. A pair of empirical distribution functions, $\hat{G}$ (Ghat) and $\hat{F}$ (Fhat), are used to evaluate patterns for randomness, clustering and regularity (Diggle 1983).

According to Cressie (1993), the empirical probability distribution function of $\hat{G}$ is as follows:

$$\hat{G}\,(\mathrm{r}) \equiv \sum_{i=1}^{n} \mathrm{I}(\mathrm{r}_{\mathrm{i,A}} \leq \mathrm{r})/\mathrm{n},\ \mathrm{r} > 0$$

where $\hat{G}$(r) is the point-to-point nearest neighbor distance probability estimator for points less than or equal to distance r from another point, n is the number of events in A, and I(A) is the indicator function of the event A (Cressie 1993).

The empirical probability distribution function $\hat{F}$ uses origin-to-point nearest neighbor distances as follows:

$$\hat{F}\,(\mathrm{r}) \equiv \sum_{i=1}^{n} \mathrm{I}(\mathrm{r}_{\mathrm{i}}^{*}{}_{,\mathrm{A}} \leq \mathrm{r})/\mathrm{n},\ \mathrm{d}_{\mathrm{i}}^{*} > \mathrm{r}$$

where the nearest-event distance is $\mathrm{r}_{\mathrm{i}}^{*}$ and nearest-arbitrary point distance is $\mathrm{d}_{\mathrm{i}}^{*}$, n is the number of events in A, I(A) is the indicator function of the event A (Cressie 1993).

If there is an excess of short distances, the $\hat{G}$ function will show the data to be clustered and the $\hat{F}$ function will show regularity. An excess of long distance neighbors will show regularity for $\hat{G}$ and clustering for $\hat{F}$. If the points are clustered, $\hat{G}$ would lead to an empirical distribution function that increases very rapidly. Conversely, if the pattern is regular, there will be few short distances and an excess of long distances. For a regular pattern, $\hat{G}$ would rise slowly at first and rapidly for the larger values of distance. If the points are random, then the distribution of nearest neighbor values will tend to be uniform and the empirical distribution function should be close to a straight line. Also, if $\hat{G}$ and $\hat{F}$ are equal, then complete spatial randomness holds true.

It is important to understand the spatial characteristics of playas on the Texas High Plains because they play such a vital role in the fate of water. Playas are important because they are thought to be the focus areas of recharge for the High Plains Aquifer. Additionally, playas benefit the migration and over wintering of water fowl and other bird species. Knowing the spatial arrangement and density of playas will help in understanding water use and management of the Texas High Plains. The objective of the study was to determine and categorize the spatial grouping of playa basins on the Texas High Plains.

MATERIALS AND METHODS

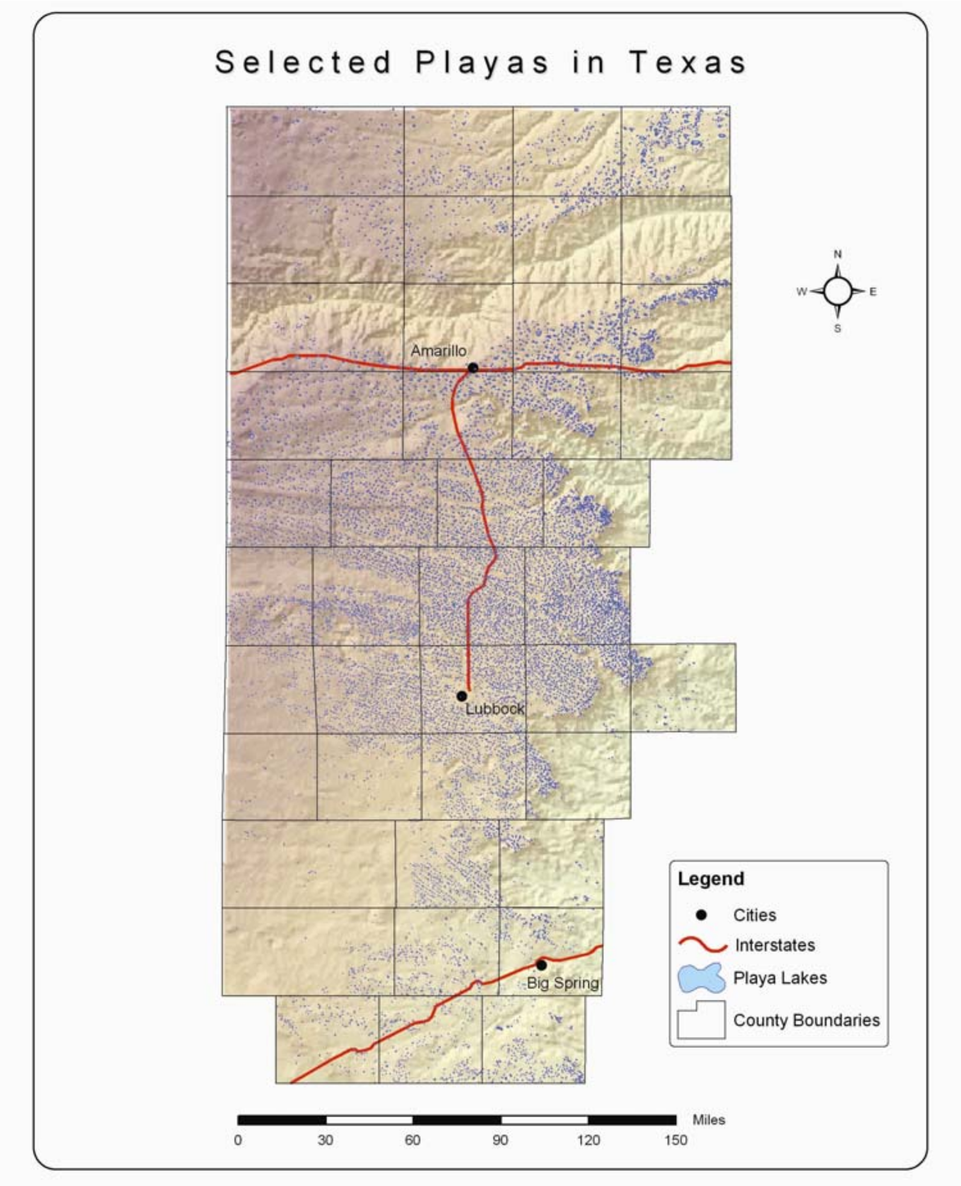
The data set used in this analysis was obtained from the Playa Lakes Digital Database (PLDD) for the Texas Portion of the Playa Lakes Joint Venture Region (Fish et al. 1998). The PLDD encompasses 65 Texas counties and contains 20,557 playa basins. Data from counties that did not occur on the Texas High Plains (i.e. east of the Caprock escarpment) contained in the PLDD CD were omitted from this study. The remaining 42 counties on the Texas High Plains contain 20,057 playa basins (Fig. 1).

For this study, computer software was used to analyze the data with point-to-point, $\hat{G}$, and origin-to-point, $\hat{F}$, analyses. S-Plus version 6.2 with a spatial add-on toolbox, S+ Spatial Stats was used to perform the density counts (Insightful Corp. Seattle, WA, 1998). This program computed and graphed the $\hat{G}$ and $\hat{F}$ as a function of distance (degrees latitude and longitude) between playas.

$\hat{G}$ and $\hat{F}$ values to determine the spatial analyses were plotted as a function of distance between the playa basins. The locations of the playa basins came from the PLDD data set (Fish et al. 1998) expressed in latitude and longitude coordinates. Therefore, distance between the playa locations has the somewhat unconventional unit of degrees. To determine the spatial arrangement of regular versus clustering, the $\hat{G}$ and $\hat{F}$ values were compared to the theoretical distribution of the playas within the region. The theoretical distribution was determined using the maximum and minimum latitude and longitude for a particular land area of interest. The length and width of the area was determined using the appropriate longitude and latitude in degrees. The northern edge of a particular area would be slightly shorter as measured in conventional lengths (feet, miles) than the southern edge of the area when the same longitude was used. While this was realized, it was not considered to have a significant impact on the outcome for this analysis. Once the area was determined in degrees squared, that value was divided by the number of playas within that region. The assumption was made that the area of influence for each playa was approximately a square-shaped area if the playas were uniform in distribution. Therefore, the square root of the area of influence for each playa would be the theoretical distance between each playa. The spatial analysis that leads to the assumption of clustering is when the $\hat{G}$ values are smaller than the theoretical value (i.e. large number of short distances) and the $\hat{F}$ values exceed the theoretical value for playa distribution. For the regular distribution of playas within the landscape, the $\hat{G}$ and $\hat{F}$ values as a function of distance are similar.

An example of these calculations for Lubbock County, Texas follows. The minimum longitude is -102.082 degrees and the maximum longitude is -101.556 degrees.

Figure 1. Geographical map of selected Texas counties and playas on the Southern High Plains.



The difference is 0.526 degrees. The maximum latitude is 33.8282 degrees and the minimum latitude is 33.3902 degrees for a difference of 0.438 degrees. The area of Lubbock County would be 0.23 degrees squared (0.526 *0.438). From the PLDD data set, there are 1068 playas in Lubbock County (Fish et al. 1998). The theoretical area of influence for each playa in Lubbock County would be 0.0002 degrees squared (0.23/1068). Assuming that this is a square shaped region, the square root of the theoretical area of influence for each playa in Lubbock County would be a distance value of 0.014 degrees ($0.0002^{0.5}$). This value of 0.014 degrees would be used to determine whether or not the $\hat{G}$ and $\hat{F}$ values are greater or less that the expected critical value.

Another playa characteristic evaluated was playa density. Playa density for each county was computed using the number of playas per county and the county latitude and longitude. County area in degrees squared was computed as above and the playa numbers published in PLDD were used. Playa density was the number of playas divided by the area of the county in degrees squared.

RESULTS AND DISCUSSION

Preliminary data analysis showed that the spatial distribution of playa basins was not completely random. There are 20,557 playa basins listed in the Playa Lakes Digital Database for Texas (Fish et al. 1998) that are distributed throughout 65 Texas counties. Using the empirical distribution function $\hat{G}$ on the entire playa basin data set shows apparent clustering of the playa basins in the region (Fig. 2). The critical value for $\hat{G}$ and $\hat{F}$ is 0.03 degrees. There is an excess of short distance (<0.03) neighbors and the line rises very rapidly. The empirical distribution function of $\hat{F}$ also implies clustering of the data by displaying an excess of long distance (>0.03) neighbors (Fig. 3).

Figure 2. Point-to-point nearest neighbor ($\hat{G}$) for all Texas High Plains playas. The distance is in degrees

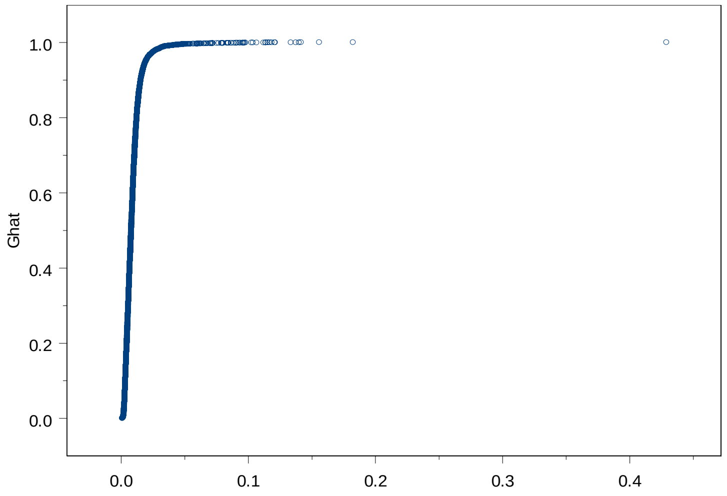
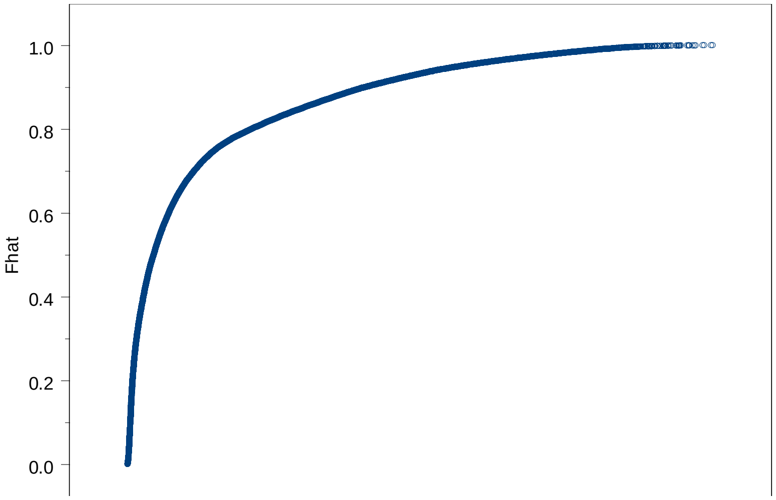


Figure 3. Origin-to-point ($\hat{F}$) for all Texas High Plains playas. The distance is in degrees.



When smaller areas such as individual counties are observed the results can change dramatically. Figure 4 shows the distribution of playa basins in Lubbock County. When $\hat{G}$ (Fig. 5) and $\hat{F}$ (Fig. 6) are plotted for Lubbock County, the distribution of the playas is indicated to be regular. There is limited clustering of the playas in Lubbock County, Texas. Figure 4, however, indicates there are areas of infrequent playas in Lubbock County. The void area running northwest to the center is Yellowhouse Draw. The void area running from the center to the southeast is Yellowhouse Canyon and the North Fork of the Double Mountain Fork of the Brazos River that runs along it. The void area running to the north is the Blackwater Draw.

Lubbock County was individually analyzed to obtain a better understanding of the pattern of playa basins on the Texas High Plains. The density of playas in Lubbock County varies across the county (Fig. 5). The regression equation for the playa density in Lubbock County, Texas is as follows:

$$Pd = 254909 + 2458*L$$

where the Pd is playa density (Number of playas /degree^2) and L is longitude in degrees west (note these are expressed as negative numbers in the PLDD) with an R^2 value of 0.35. This R^2 value is low for Lubbock County because of Yellowhouse Canyon and Blackwater Draw.

Figure 4. Playa distribution in Lubbock County, Texas from Fish et al. (1998).

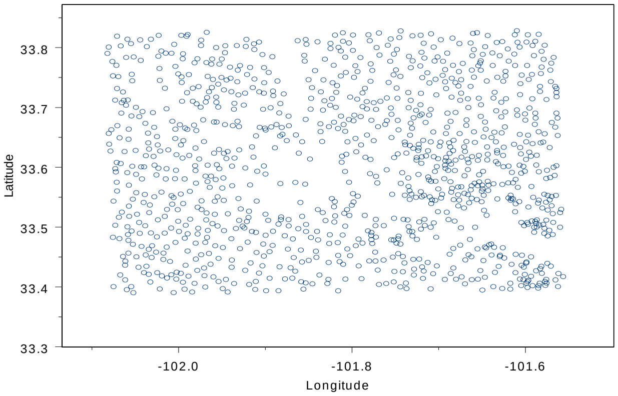


Figure 5. Point-to-point ($\hat{G}$) distribution for the Lubbock County, Texas playas. The distance is in degrees.

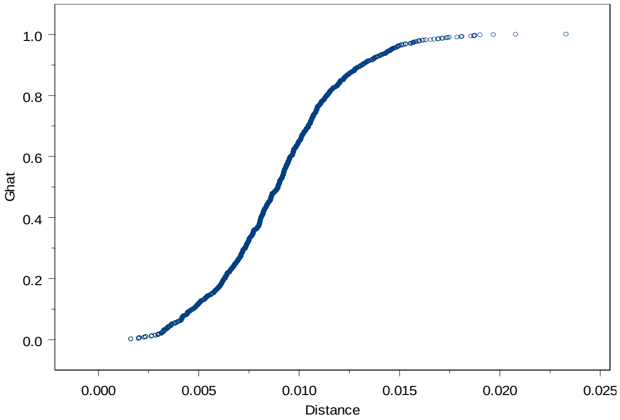
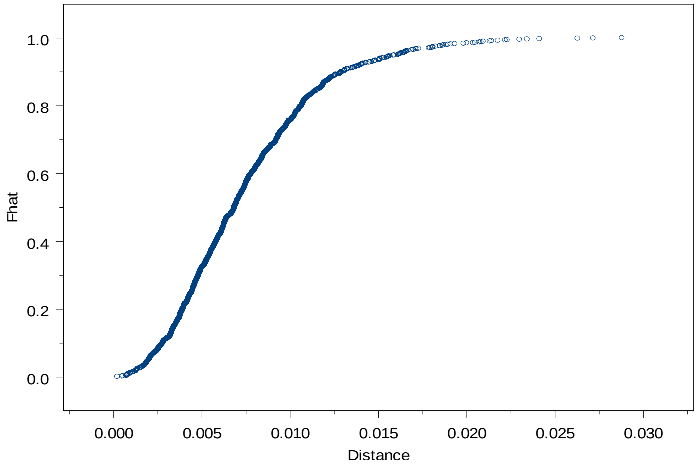


Figure 6. Origin-to-point ($\hat{F}$) spatial analysis for all playas in Lubbock County, Texas. The distance is in degrees.



Floyd County increase in density towards the edge of the Caprock (Fig. 7). Playa depressions northeast of the Caprock escarpment and not on the Texas High plains were omitted (Lat = -2.42* L -210.42: where Lat is north latitude and L is west longitude). The regression equation for playa density in Floyd County, Texas is as follows:

$$Pd = 798090 + 7813*L$$

where the Pd is playa density (Number of playas /degree^2) and L is longitude in degrees west (note these are negative numbers) with an R^2 value of 0.89. This R^2 value is much higher than for Lubbock County. The increased value is thought to be due to the absence major playa void areas in Floyd County. Had the whole county data been used, the regression value would have been much lower because the lack of playas past the edge of the Caprock.

The playa distribution pattern of Floyd County was analyzed on a whole county and near the edge of the Caprock escarpment. As a whole county, Floyd County has a regular playa distribution pattern as indicated by $\hat{G}$ (Fig. 8) and $\hat{F}$ (Fig. 9). For sub-county analysis, playas in Floyd County that occurred northeast of the Caprock escarpment and not on the Texas High plains and southwest of the line Lat = -2.35* L -204.087 were deleted. The remaining Floyd County playas at the edge of the Caprock were analyzed using $\hat{G}$ and $\hat{F}$ (Figs. 10 and 11). These remaining playas in Floyd County had a clustered playa pattern.

Figure 1 displays the playas on the Texas High Plains and the topography of the area. Areas north of the Canadian River valley have very few playas. Counties that are partially within the Canadian River valley are Hartley, Oldham, Potter, Carson, Hutchinson, and Roberts. These counties have a clustered pattern of playas due to the void areas in or at the edge of the Canadian River valley (Fig. 12). Counties that are positioned at the edge of the Caprock escarpment, such as Crosby, Ochiltree, Gray,

Figure 7. Playa distribution for Floyd County, Texas from the data of Fish et al. (1998).

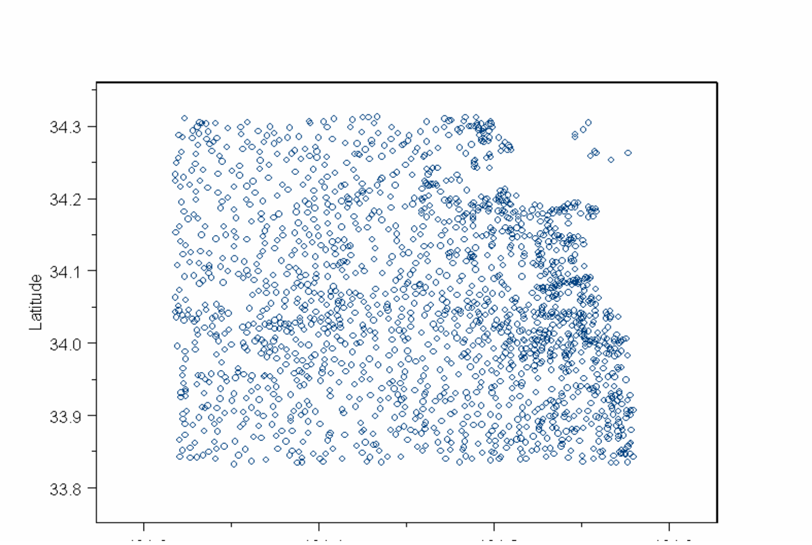


Figure 8. Point-to-point ($\hat{G}$) spatial analysis for all playas in Floyd County, Texas. The distance is in degrees.

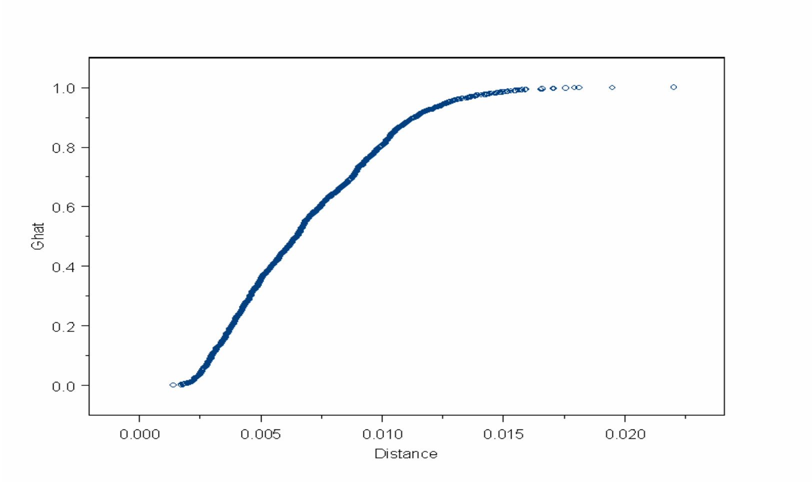


Figure 9. Origin-to-point ($\hat{F}$) spatial analysis for all playas in Floyd County, Texas. The distance is in degrees.

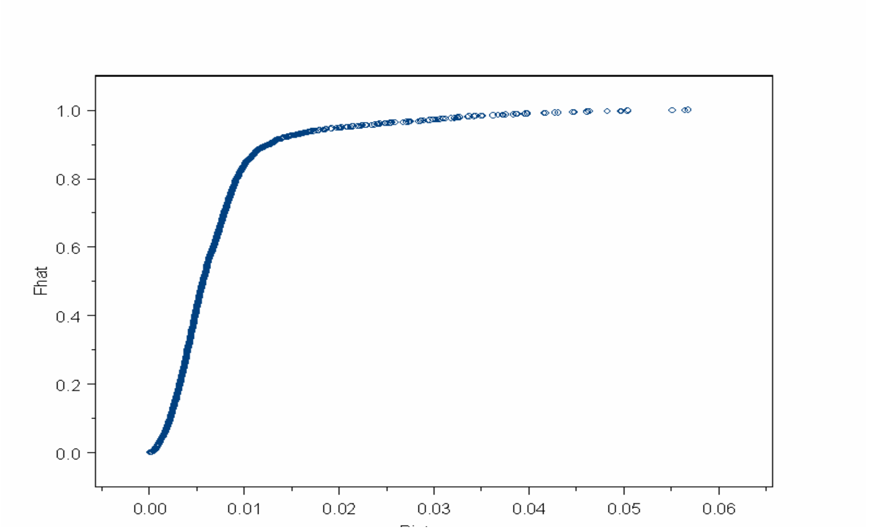


Figure 10. Point-to-point ($\hat{G}$) spatial analysis for playas on the Caprock escarpment with the subset (southwestern portion) of Floyd County, Texas omitted. The distance is in degrees.

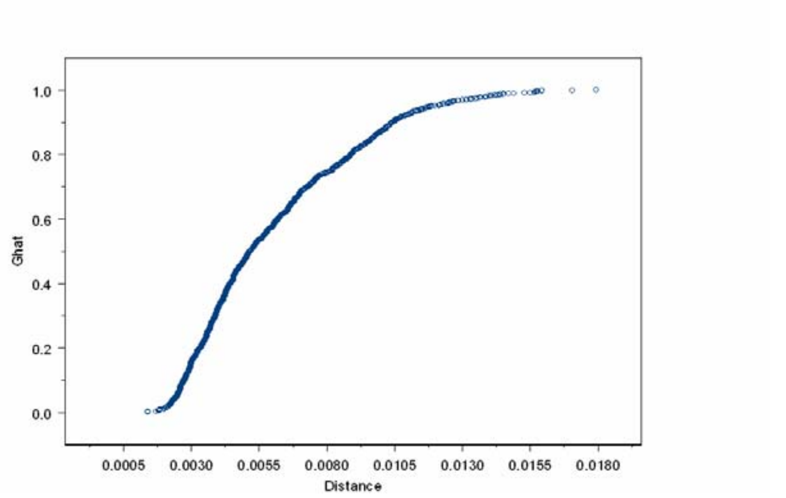
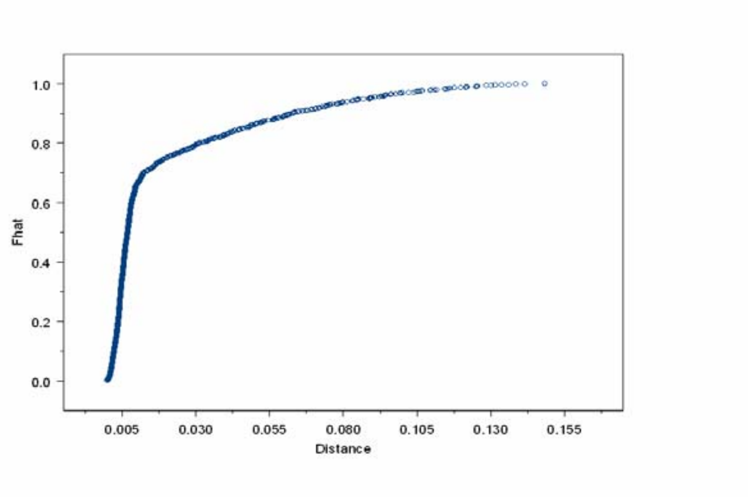


Figure 11. Origin-to-point ($\hat{F}$) spatial analysis for playas on the Caprock escarpment with the subset (southwestern portion) of Floyd County, Texas omitted. The distance is in degrees.

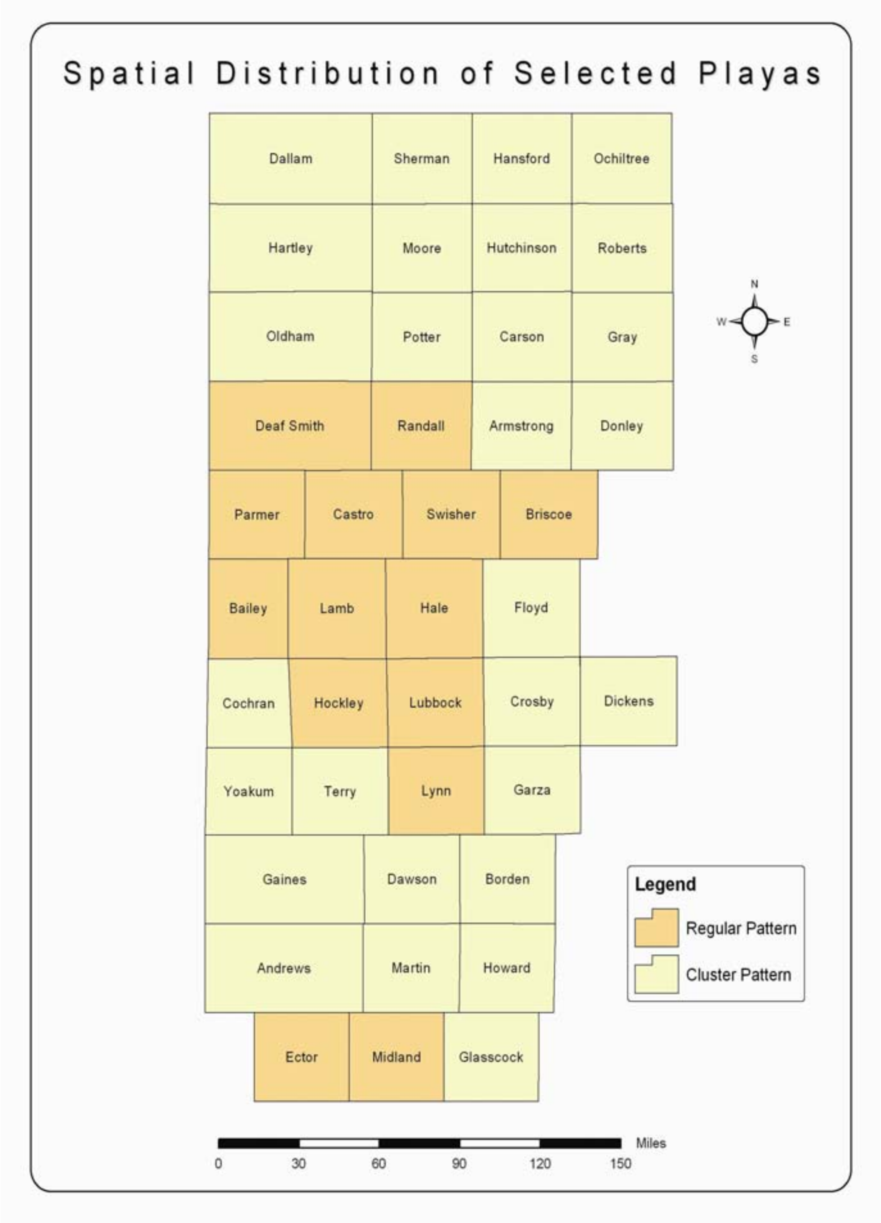


Donley, Briscoe, Garza, Borden, Glasscock, and Howard; tend to have a clustered pattern of playa basins due to the large void areas along the escarpment. Dallam and Hartley Counties located in the northwestern corner of the Texas panhandle have a clustered pattern probably because of large draws and "broken" land. Counties with very few playas, such as Gaines, Martin and Andrews County, also have a clustered pattern. Two additional counties east of the Caprock escarpment, Kent and Motley, also showed clustered playa distribution. A list of counties by the spatial distribution pattern they represent using $\hat{G}$ and $\hat{F}$ are presented in Table 1.

Table 1. List of Southern High Plains counties in Texas having either a regular or clustered pattern of playas.

Cluster				
Andrews	Crosby	Garza	Hutchinson	Roberts
Armstrong	Dallam	Glasscock	Martin	Sherman
Borden	Dawson	Gray	Moore	Terry
Briscoe	Dickens	Hansford	Ochiltree	Yoakum
Carson	Donley	Hartley	Oldham	
Cochran	Gaines	Howard	Potter	
Regular				
Bailey	Ector	Hockley	Lynn	Randall
Castro	Floyd	Lamb	Midland	Swisher
Deaf Smith	Hale	Lubbock	Parmer	

Figure 12. A graphical representation of Southern High Plains counties exhibiting a regular or clustered spatial distribution pattern.



The counties that have the regular spatial distribution (Fig. 12) are generally in the central region of the Texas High Plains. These counties have high playa density (>1,900 /degree^2). Two southern tier counties, Ector and Midland, also have a regular distribution, but have low playa densities (<1,800/degree^2).

In summary, when evaluating the playa spatial distribution on the Texas High Plains, playas exhibit either a clustered or regular pattern. Playas presented clustering patterns north of the Canadian River, at the eastern Caprock escarpment and in the southwestern High Plains. The Texas High Plains region south of the Canadian River and west of the Caprock escarpment had a regular distribution of playa depressions. Playa density numbers were high (>1,900 /degree^2) in the regular distribution region. Counties that are partially on the Caprock escarpment exhibited clustered pattern arrangement due to the infrequency of the playas beyond the Caprock escarpment. Counties in the southwestern portion of the Texas High Plains also had low playa density (<1,800/degree^2) and a clustered playa distribution pattern.

The spatial distribution and density of playas are critical to the understanding of water recharge and water use on the Texas High Plains. With playas thought to be the areas of focused water recharge to the High Plains Aquifer, knowing the spatial distribution patterns will aid in the understanding of potential recharge areas. Understanding of the distribution of playas additionally will aid in water fowl management.

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Impact of Alternative Property and Sales Tax Policies on Texas Representative Farms

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ABSTRACT

The call for school finance reform has threatened to modify or possibly remove the current property and sales and use tax exemptions currently benefiting Texas agricultural producers. This study utilizes a whole farm simulation model to evaluate the economic and financial impact of three alternative sales and/or property tax policy changes on Texas farms, dairies, and ranches along with their respective landowners. Results indicate that removing sales tax exemptions would most adversely impact producers, while removing property tax exemptions has a more negative effect on landowners.

Keywords: property tax, sales and use tax, school finance

Agricultural producers in Texas benefit from several tax exemptions, however, recent State budget difficulties in Texas have led to calls for changes in tax policies that may reduce, or possibly eliminate the benefits farmers and ranchers currently enjoy as a result of these exemptions. Currently, producers do not pay sales tax on purchases of inputs or services. In addition, they benefit from a special "agricultural" valuation of productive land resulting in a reduction in the amount of property tax they must pay (Texas Property Tax Code 2000).

A Special Session of the Texas State Legislature has been called to discuss alternative school finance issues put forth in Senate Bill 2. Senate Bill 2 proposes to reduce the local maintenance and operating expense (M&O) portion of school property tax from its current maximum of $15.00 per $1,000 of assessed property value to $7.50, however, the bill proposes to levy a sales tax on services not taxed under the current law (78(R) SB2 2003). The sales tax is intended to offset the lost revenue resulting from lower property taxes.

The primary objective of this research is to evaluate the economic and financial impacts of sales and/or property tax changes on farms and ranches in Texas. A secondary objective would be to determine if the tax policy changes will have different regional or commodity impacts.

Review of Literature

Most of the tax studies in the agricultural economics literature have focused on Federal Income Tax (FIT) legislation. Only a few have examined procedures for valuing productive land and at the impact of shifting property tax burden (Boisvert and Bills 1984, Drummond 1975). Doye and Boehlje (1985) investigated the firm-level effects of two flat rate tax alternative policies for three different sizes of representative hog and grain farms in Iowa. They found that most farms experienced an increasing tax burden over time, and the largest increases were with the current (Economic Recovery Tax Act of 1981) program since progressive rates result in a larger share of income paid in taxes.

A study by Perry and Nixon (2002) looked at the complete tax burden upon agricultural producers in America. Using a sample data set of IRS Federal Income Tax returns and the Commerce Clearing House summary of state tax law, they analyzed taxes levied on farms including real and personal property taxes, sales and excise taxes, federal and state income taxes, and self-employment taxes. They found Alaska to have the highest taxes for agriculture and found a strong connection between the property tax rate and the tax burden that producers within a particular state must endure.

Lowenberg-DeBoer and Boehlje (1987) simulated Iowa Farm Business Association data to estimate the impacts of alternative FIT policies. They found that all of the simulated farms exhibited a larger increase in net worth and total assets under the Economic Recovery Tax Act of 1981 (ERTA) and Tax Equity and Fiscal Responsibility Act of 1982 (TEFRA) provisions than under pre-reform conditions.

Richardson and Nixon (1984) utilized a whole farm simulation model (FLIPSIM-TAX) to study the effects of the 1980, 1981, and 1982 Federal Income Tax laws on a representative Texas Gulf Coast rice farm, finding that the 1981 (ERTA) law resulted in the most favorable financial position for the farm. Like Nixon and Richardson, this study will utilize representative farm data collected from panels of farms across Texas to evaluate the impacts of State tax policy changes. The representative farm data will be analyzed using a whole farm simulation model (FLIPSIM) developed by Richardson and Nixon (1986).

Methodology

This study will utilize primary representative farm data coupled with a whole farm simulation model to examine the effects of modifying state tax policies on Texas agricultural producers. Twenty-four Texas representative farms, dairies, and ranches created through a focus group interview process were analyzed assuming each of the alternative policies using the farm level simulation model (FLIPSIM) developed by Richardson and Nixon (1986) at Texas A&M University. These farms are representative of the major agricultural production regions of Texas. A description of each representative farm is included in the appendix. Included in the representative set are nine cotton farms, four feed grain farms, four rice farms, five dairies, and two cow/calf operations. These representative operations display a wide variety of land tenure ranging from 100 percent ownership to 100 percent leasing, and lease arrangements include both cash lease and sharecropping (Table 1).

Table 1. Land Tenure Arrangements for Texas Representative Farms

	Acres Owned	Acres Leased	Cash Lease	Share Lease
			--%--	--%--
TXNP1750	160	1590	0	100
TXNP7000	1150	5850	0	100
TXHG2000	230	2070	13	87
TXWG1400	180	1460	14	86
TXSP2239	670	1569	0	100
TXSP3745	1650	2095	0	100
TXRP2500	400	2600	19	81
TXCB1850	360	1490	0	100
TXCB5500	225	5275	0	100
TXVC4500	900	3600	6	94
TXPC2500	1250	1250	50	50
TXMC3500	350	3150	50	50
TXEC5000	640	4360	0	100
TXR1553	129	1424	60	40
TXR3774	0	3774	42	58
TXBR1650	110	1540	50	50
TXER3200	320	2880	0	100
TXCD1300	460	0	0	0
TXCD500	325	0	0	0
TXED550	150	150	100	0
TXED1000	450	600	17	83
TXND2400	260	0	0	0
TXBB150	400	2000	100	0
TXSB250	900	775	100	0

The FLIPSIM model draws random crop yields, livestock production variables, and prices from a multivariate empirical probability distribution for these variables, thus allowing projections to incorporate production and price risk. A complete description of FLIPSIM is provided in Richardson and Nixon (1986). Each tax alternative was simulated 500 times (iterations) for a five-year (2004 to 2008) projection period using random prices, yields, and production. Annual mean crop and livestock prices, inflation rates for input prices, national average interest rates, and inflation rates for land were obtained from the January 2004 Baseline reported by FAPRI (Tables 2 and 3) (FAPRI 2004). State and local sales tax rates and local property tax rates were obtained from the Texas State Comptroller of Public Accounts (Table 4) (Local Sales and Use Tax 2000, Texas Property Tax Rates by County 2000).

Three general assumptions were made in this analysis: (1) long term and intermediate debt beginning in 2001 is 20 percent for crop farms, 30 percent for dairies, and 1 percent for long-term and 5 percent for intermediate debt for beef cattle operations, (2) the provisions of the 2002 Farm Bill are assumed to continue throughout the projection period, and (3) cash rents and share lease arrangements remain constant throughout the study period.

The following potential tax policies will be analyzed relative to the **Base,** or current tax policy situation:

- **SB2** - Senate Bill 2 provisions including reduction of the mil rate for school taxes from the current average level of $15.00 to $7.50 while levying an 8.25 percent sales tax on services (custom applications and harvesting, veterinary services, custom feeding, insurance, utilities, transportation, repairs, and other services);

Table 2. FAPRI January 2004 Baseline Projections of Crop, Livestock, and Milk Prices, 2001-2008

	2002	2003	2004	2005	2006	2007	2008
Crop Prices							
Corn ($/bu.)	2.32	2.31	2.35	2.32	2.31	2.35	2.37
Wheat ($/bu.)	3.56	3.36	3.27	3.23	3.17	3.23	3.26
Cotton ($/lb.)	0.4450	0.6303	0.5737	0.5546	0.5460	0.5415	0.5418
Sorghum ($/bu.)	2.32	2.33	2.16	2.17	2.15	2.18	2.19
Soybeans ($/bu.)	5.53	7.24	5.63	5.06	5.19	5.21	5.23
Barley ($/bu.)	2.72	2.81	2.57	2.60	2.59	2.60	2.60
Oats ($/bu.)	1.81	1.43	1.49	1.44	1.40	1.40	1.40
Rice ($/cwt.)	4.22	7.21	6.12	5.67	5.81	6.20	6.15
Soybean Meal ($/ton)	173.19	219.58	178.01	168.44	173.57	176.47	177.75
All Hay ($/ton)	92.40	86.40	84.86	84.66	84.21	84.65	85.54
Peanuts ($/ton)	364.00	375.95	384.54	384.34	383.97	385.18	384.78
Cattle Prices							
Feeder Cattle ($/cwt)	86.11	94.99	85.81	98.17	103.59	97.50	92.94
Fat Cattle ($/cwt)	67.04	84.69	75.46	80.44	83.55	82.03	79.19
Culled Cows ($/cwt)	39.23	46.48	41.18	47.81	49.11	47.27	45.58
Milk Prices -- National and Texas							
All Milk Price ($/cwt)	12.11	12.51	12.71	12.62	12.81	12.92	13.05
Texas ($/cwt)	12.90	13.13	13.32	13.25	13.45	13.59	13.74

Source: FAPRI 2004 U.S. and World Agricultural Outlook

Table 3. FAPRI January 2004 Baseline Assumed Rates of Change in Input Prices, Annual Interest Rates, and Annual Changes in Land Values, 2002-2008

	2002	2003	2004	2005	2006	2007	2008
Annual Rate of Change for Input Prices Paid							
Seed Prices (%)	1.30	7.12	1.21	0.45	0.74	1.00	0.89
Fertilizer Prices (%)	0.07	20.60	-8.83	-4.84	-1.17	2.02	1.56
Chemical Prices (%)	1.64	6.36	-0.16	2.90	2.03	1.09	0.77
Machinery Prices (%)	1.95	0.30	0.39	0.40	0.31	0.34	0.34
Fuel and Lube Prices (%)	0.14	20.60	-8.83	-4.84	-1.17	2.02	1.56
Labor (%)	4.38	0.76	0.73	0.73	0.68	0.69	0.67
Other Input Prices (%)	2.31	1.51	1.78	2.17	2.15	2.19	2.24
Non-Feed Dairy Costs (%)	0.56	4.86	-0.76	0.12	0.56	0.96	0.82
Non-Feed Beef Costs (%)	0.56	4.86	-0.76	0.12	0.56	0.96	0.82
Non-Feed Hog Costs (%)	0.56	4.86	-0.76	0.12	0.56	0.96	0.82
Annual Change in Consumer Price Index (%)	2.32	1.51	1.78	2.17	2.15	2.19	2.24
Annual Interest Rates							
Long-Term (%)	5.40	4.99	5.47	5.85	5.71	5.71	5.98
Intermediate-Term (%)	4.53	3.65	4.34	5.10	5.24	5.36	5.84
Savings Account (%)	1.70	1.11	1.11	1.80	2.17	2.44	3.18
Annual Rate of Change for U.S. Land Prices (%)	5.22	4.96	5.83	3.28	1.76	2.76	4.00

Source: FAPRI 2004 U.S. and World Agricultural Outlook

Table 4. County, School District, and City Property Tax Rates for Texas Representative Farms, 2000

	City	County	County Tax Rate	School Tax Rate	City Tax Rate
			--%--	--%--	--%--
TXNP1750	Sunray	Moore	0.37	1.54	0.22
TXNP7000	Sunray	Moore	0.37	1.54	0.22
TXHG2000	Hillsboro	Hill	0.44	1.60	0.61
TXWG1400	Taylor	Williamson	0.40	1.58	0.69
TXSP2239	Lamesa	Dawson	0.68	1.40	0.69
TXSP3745	Lamesa	Dawson	0.68	1.40	0.69
TXRP2500	Anson	Jones	0.63	1.36	1.04
TXCB1850	Sinton	San Patricio	0.54	1.47	0.62
TXCB5500	Robstown	Nueces	0.36	1.61	1.08
TXVC4500	Lyford	Willacy	0.54	1.50	0.90
TXPC2500	Hereford	Deaf Smith	0.57	1.50	0.41
TXMC3500	Edna	Jackson	0.55	1.52	0.39
TXEC5000	Ralls	Crosby	0.78	1.33	0.73
TXR1553	Eagle Lake	Colorado	0.39	1.48	0.64
TXR3774	Eagle Lake	Colorado	0.39	1.48	0.64
TXBR1650	Bay City	Matagorda	0.31	1.53	0.51
TXER3200	El Campo	Wharton	0.69	1.49	0.60
TXCD1300	Stephenville	Erath	0.48	1.75	0.47
TXCD500	Stephenville	Erath	0.48	1.75	0.47
TXED550	Sulphur Springs	Hopkins	0.50	1.42	0.41
TXED1000	Paris	Lamar	0.35	1.53	0.61
TXND2400	Muleshoe	Bailey	0.52	1.35	0.66
TXBB150	McGregor	McLennan	0.46	1.51	0.55
TXSB250	Gonzales	Gonzales	0.71	1.38	0.33

Source: 2000 Texas Property Tax Rates by County, Texas Comptroller of Public Accounts

- **NoSTexempt** - Remove the sales tax exemption, charging an 8.25 percent sales tax on all inputs and services;

- **NoAgUseVal** - Eliminate agricultural-use valuation for productive land, resulting in increased property taxes paid (the agricultural use valuations for each county in which representative farms are located were used to determine the size of the current exemption for each of the representative farms, and that exemption was subsequently removed).

The following key assumptions were made in the analysis of the individual scenarios:

- The maintenance and operating expense (M&O) school district portion of all local property taxes is assumed to be at the current maximum allowed level of \$15.00. The average school district portion of total property tax for the combined maintenance and operating expense (M&O) and expense associated with interest and sinking fund (I&S) debt service for building projects was 1.5057 percent for communities in which representative farms are located according to the 2000 Texas Property Tax Rates by County report published by the Texas Comptroller of Public Accounts.
- The state, city, and county sales taxes sum to 8.25 percent for all representative farm locations.

Preference for each alternative will be evaluated based on the projected average net cash farm income (NCFI) for each operation[1]. Net cash farm income is defined as total cash receipts minus all cash expenses. It does not reflect profit, as family living expenses, principal payments on loans, income taxes, self- employment taxes, and machinery replacement costs must be paid from this sum.

Policies that shift more emphasis toward sales tax are expected to increase total cash costs, thus adversely impacting farmers who own little land or those who engage in more intensive production. Policies that shift emphasis to property taxes are expected to have a more adverse impact on producers who own a large portion of their land, thus significantly reducing their NCFI. This would mean that landowners and their tenants would not necessarily rank their preferred options in the same order due to the shifting tax burdens, and the preferred options will likely differ across type of operation (e.g., crop farms, dairies, or ranches).

Results

With respect to net cash farm income, 23 of the 24 representative farms analyzed prefer the **Base** situation in which they have lower taxes and higher NCFI via special use valuation of land and no sales and use taxes on goods or services (Table 5). The only exception is TXR3774, a rice farm in the Eagle Lake area. This farm is indifferent between the **Base** situation and the situation in which special use valuations are eliminated (**NoAgUseVal**) because it leases all of its planted acres.

The **SB2** option is the second choice for 15 of the 24 representative farms. Of the crop farms, the two central Texas feed grain farms (TXHG2000 and TXWG1400), five of the nine cotton farms (TXRP2500, TXCB1850, TXVC4500, TXPC2500, and TXMC3500), and one of the four rice farms (TXR1553) prefer the **SB2** option over other policy options. All of the representative livestock operations analyzed including five dairies and two ranches prefer the **SB2** option.

Removal of special use valuations and property tax exemptions **(NoAgUseVal)** is the second choice for 9 of the 24 representative farms, including the two Northern Plains feed grain farms (TXNP1750 and TXNP7000), four of the nine cotton farms (TXSP2239, TXSP 3745, TXCB5500, and TXEC5000), and three of the four rice farms (TXR3774, TXBR1650, and TXER3200).

The levying of an 8.25 percent sales and use tax **(NoSTexempt)** on all goods and services is the last choice for 22 of the 24 representative farms. The Williamson County feed grain farm (TXWG1400) and the South Texas Ranch (TXSB250) would prefer the **NoSTexempt** option to the **NoAgUseVal** option. The TXWG1400 farm owns 180 acres of high-value cropland in Williamson County (near Austin), and TXSB250 owns 900 acres while purchasing relatively few inputs.

All 16 of the landlords for the representative farms analyzed prefer either the **Base** situation or the **SB2** option with respect to net cash farm income (Table 6). Three of the nine cotton farms (TXSP2239, TXSP3745, and TXEC5000) prefer the **Base** situation. The feed grain farms and the three rice farms analyzed prefer the **SB2** option over the **Base** situation. Six of the nine cotton farms prefer the **SB2** option to the **Base** situation. Similarly, all of the landowners analyzed ranked levying an 8.25 percent sales and use tax on all goods and services **(NoSTexempt)** their third choice and the removal

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of special use land valuations **(NoAgUseVal)** their least preferred choice. The large Eagle Lake rice farm (TXR3774) was not analyzed as it is in a 50 percent crop share lease arrangement where the landlord pays for all of the seed and irrigation costs and pays for half of the fertilizer, chemicals, drying costs, and other miscellaneous costs. The significant risk that this landowner bears tends to make it behave more like a tenant than a typical landowner.

Table 5. Average Net Cash Farm Income for Texas Representative Farm Tenants Under Current and Alternative Tax Policies, 2004-2008

	Base[1]	SB2[2]	NoSTexempt[3]	NoAgUseVal[4]
	--$1000--	--$1000--	--$1000--	--$1000--
TXNP1750	137.1	131.4	93.3	135.8
TXNP7000	458.4	443.2	325.3	449.6
TXHG2000	93.6	88.5	69.1	85.5
TXWG1400	84.2	82.2	66.3	55.5
TXSP2239	103.8	85.5	41.8	99.3
TXSP3745	147.6	120.2	62.2	132.1
TXRP2500	86.6	81.8	70.5	79.3
TXCB1850	155.8	147.8	120.4	140.4
TXCB5500	191.5	175.0	103.0	184.0
TXVC4500	319.4	306.2	233.8	269.6
TXPC2500	184.9	174.3	130.0	164.0
TXEC5000	169.7	139.4	55.9	164.7
TXMC3500	305.2	293.0	230.3	285.1
TXR1553	93.0	86.3	63.8	82.8
TXR3774	362.7	349.9	305.5	362.7
TXBR1650	130.8	123.2	92.2	125.0
TXER3200	139.9	127.6	59.4	132.0
TXCD500	-62.6	-65.4	-180.8	-145.1
TXCD1300	447.4	403.9	165.5	210.9
TXED550	197.9	192.7	107.7	174.3
TXED1000	541.5	534.9	370.7	500.5
TXND2400	359.2	345.1	-161.8	339.5
TXBB150	76.1	74.2	57.8	64.4
TXSB250	60.8	60.6	57.8	17.4

[1] Base: Current situation

[2] SB2: Reduction of the mil rate for school property taxes from $15.00 to $7.50 while levying an 8.25 percent sales tax on services

[3] NoSTexempt: Removal of the sales tax exemption, charging an 8.25 percent sales tax on all inputs and services

[4] NoAgUseVal: Elimination of agricultural-use valuation for productive land

Table 6. Average Net Cash Farm Income for Texas Representative Farm Land Owners Under Current and Alternative Tax Policies, 2004-2008

	Base[1]	SB2[2]	NoSTexempt[3]	NoAgUseVal[4]
	--$1000--	--$1000--	--$1000--	--$1000--
TXNP1750	126.5	130.2	126.3	114.8
TXNP7000	433.6	443.8	409.0	392.6
TXHG2000	101.1	104.2	98.7	39.1
TXWG1400	76.4	78.4	74.7	-144.4
TXSP2239	66.9	66.4	64.3	58.0
TXSP3745	75.7	75.5	69.7	59.2
TXRP2500	40.6	42.5	38.3	2.4
TXCB1850	111.9	116.7	109.2	55.1
TXCB5500	304.4	315.7	293.6	139.8
TXVC4500	169.3	189.6	161.6	-21.5
TXPC2500	58.0	59.5	55.7	38.2
TXEC5000	221.1	220.8	209.6	190.1
TXMC3500	124.8	134.4	116.8	-53.6
TXR1553	30.4	33.3	30.3	-75.0
TXR3774	277.2	274.9	257.4	277.2
TXBR1650	22.8	28.7	22.4	-54.9
TXER3200	120.9	125.6	119.7	57.4

[1] Base: Current situation

[2] SB2: Reduction of the mil rate for school property taxes from $15.00 to $7.50 while levying an 8.25 percent sales tax on services

[3] NoSTexempt: Removal of the sales tax exemption, charging an 8.25 percent sales tax on all inputs and services

[4] NoAgUseVal: Elimination of agricultural-use valuation for productive land

The seven livestock operations were not analyzed as landowners because they are generally owner-operators. As expected, landlords prefer plans that result in lower property taxes. Most share lease arrangements provide for sharing of a relatively small portion of costs, so landlords would generally prefer to pay taxes on those inputs versus increasing their property taxes.

Conclusions and Implications

Most operations in this study rent at least some land; therefore, they are generally less affected by increasing property taxes than by removing sales tax exemptions. As landowners begin to pay higher property tax rates, pressure will arise to increase cash rents or to modify share lease arrangements; however, agricultural lease arrangements are traditionally resistant to change. Conversely, most of the farms own some land, so cutting the school district portion of property taxes in half while levying a 8.25 percent sales tax on services generally hurts the farms less than removing the special use valuation altogether. Completely removing the sales tax exemption has the most adverse impact on NCFI for the representative farms.

For landowners, no significant changes are generally observed when **SB2** and **NoSTexempt** policies are implemented; however, removing special use valuation for productive land is detrimental to their survival if rents or arrangements are not adjusted upward.

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Appendix: Characteristics of Texas Representative Farms, Dairies, and Ranches, 2003

TXNP1750	This is a 1,750-acre grain farm located on the northern High Plains of Texas (Moore County). This 100 percent irrigated farm is moderate-sized for the region and plants 640 acres of corn, 240 acres of sorghum, and 870 acres of wheat annually. Seventy percent of total receipts are generated from feedgrain sales.
TXNP7000	TXNP7000 is a large-sized, 80 percent irrigated, grain farm located in the northern Texas Panhandle (Moore County). This farm annually

	plants 3,350 acres of irrigated corn, 930 acres of sorghum (350 irrigated and 580 dryland), and 2,130 acres of wheat (1,550 irrigated and 580 acres dryland). Dryland wheat is planted on the corners of all pivot-irrigated fields. Eighty-four percent of 2003 cash receipts were derived from feedgrain sales.
TXHG2000	This 2,000-acre grain farm is located on the Blackland Prairie of Texas (Hill County). On this farm, 600 acres of corn, 750 acres of sorghum, 400 acres of cotton, and 250 acres of wheat are planted annually. Feedgrain sales accounted for 57 percent of 2003 receipts with cotton accounting for 31 percent of sales. Forty beef cows live on 150 acres of improved pasture and contribute approximately five percent of total receipts.
TXWG1400	This 1,400-acre farm is located on the Blackland Prairie of Texas (Williamson County). TXWG1400 plants 900 acres of corn, 250 acres of sorghum, 150 acres of cotton, and 100 acres of winter wheat annually. Additionally, this farm has a 50-head beef cow herd that is pastured on rented ground that cannot be farmed. Feedgrain sales accounted for 70 percent of 2003 receipts with cotton accounting for 18 percent of sales.
TXSP2239	A 2,239-acre Texas South Plains (Dawson County) cotton farm that is moderate-sized for the area. TXSP2239 plants 1,616 acres of cotton (1,250 dryland, 366 irrigated), 270 acres of peanuts, and has 183 acres in CRP. For 2003, 59 percent of receipts came from cotton.
TXSP3745	The Texas South Plains (Dawson County) is home to this 3,745-acre, large-sized cotton farm that grows 2,625 acres of cotton (2,120 dryland, 505 irrigated), 245 acres of peanuts, and has 288 acres in CRP. Cotton sales comprised 74 percent of 2003 receipts.
TXRP2500	TXRP2500 is a 2,500-acre cotton farm located in the Rolling Plains of Texas (Jones County). This farm plants 1,122 acres of cotton and 825 acres of winter wheat each year. Seventy-nine percent of 2003 farm receipts came from cotton sales. Twelve head of beef cows generated approximately two percent of farm receipts.
TXCB1850	A 1,850-acre cotton farm located on the Texas Coastal Bend (San Patricio County) that farms 925 acres of cotton, 775 acres of sorghum, and 150 acres of corn annually. Seventy-three percent of 2003 cash receipts were generated by cotton.
TXCB5500	Nueces County, Texas is home to this 5,500-acre farm. Annually, 2,750 acres are planted to cotton and 2,750 acres to sorghum. Cotton sales accounted for 75 percent of 2003 receipts.

TXVC4500	This 4,500-acre farm is located in the lower Rio Grande Valley of Texas (Willacy County) and plants 2,388 acres to cotton (500 irrigated and 1,888 acres dryland), 1,887 acres to sorghum, and 225 acres of sugarcane. In 2003, 72 percent of TXVC4500's cash receipts were generated by cotton sales.
TXPC2500	The Texas Panhandle is home to this 2,500-acre farm (Deaf Smith County). Annually, cotton is planted on 1,184 acres (1,000 irrigated and 184 dryland), 308 acres to sorghum (125 irrigated and 183 dryland), 883 acres planted to wheat (700 irrigated and 183 dryland), and 125 irrigated acres are planted to corn. Sixty-four percent of 2003 cash receipts were generated by cotton sales.
TXMC3500	A 3,500-acre cotton farm located on the middle Texas Gulf Coast (Jackson County) that farms 1,750 acres of cotton and 875 acres each of sorghum and corn. In 2003, cotton sales comprised 72 percent of total cash receipts on this operation.
TXEC5000	This 5,000-acre farm is located on the Eastern Caprock of the Texas South Plains (Crosby County). Annually, 4,300 acres are planted to cotton (2,800 irrigated and 1,500 dryland), 400 acres of wheat (100 irrigated and 300 dryland), and 300 acres of dryland sorghum. In 2003, cotton sales accounted for 96 percent of gross receipts.
TXR1553	This 1,553-acre rice farm located west of Houston, Texas (Colorado County) is moderate-sized for the region. TXR1553 harvests 450 acres of first-crop rice and 405 acres of ratoon rice. The farm generated 98 percent of its receipts from rice during 2003.
TXR3774	TXR3774 is a 3,774-acre, large-sized rice farm located west of Houston, Texas (Colorado County). This farm harvests 1,589 acres of first-crop rice and 1,351 acres of ratoon rice annually. TXR3774 realized 98 percent of 2003 gross receipts from rice sales.
TXBR1650	The Texas Gulf Coast (Matagorda County) is home to this 1,650-acre rice farm. TXBR1650 harvests 550 acres of rice annually (550 acres of first-crop rice and 475 acres of ratoon rice) and realized 100 percent of 2003 farm receipts from sales of rice.
TXER3200	This 3,200-acre rice farm is large for the Texas Gulf Coast (Wharton County). TXER3200 harvests 1,280 acres of first-crop rice and 1,024 acres of ratoon rice each year. The farm also grows 160 acres each of soybeans and grain sorghum annually. Ninety-six percent of 2003 receipts came from rice sales.
TXCD1300	A 1,300-cow, large-sized central Texas (Erath County) dairy. TXCD1300 plants 215 acres of silage annually. During 2003, milk sales accounted for 92 percent of receipts.

TXCD500	A 500-cow, moderate-sized central Texas (Erath County) dairy. TXCD500 plants 500 acres of hay each year. Milk sales represented 90 percent of this farm's 2003 gross receipts.
TXED550	A 550-cow, moderate-sized northeast Texas (Hopkins County) dairy. This farm has 300 acres of improved pasture and 50 acres of hay. During 2003, milk sales represented 88 percent of annual receipts.
TXED1000	A 1,000-cow, large-sized northeast Texas (Hopkins County) dairy. This farm plants 825 acres of hay/silage. This farm generated 87 percent of 2003 receipts from milk sales.
TXND2400	A 2,400-cow, large-sized diary located in the South Plains of Texas (Bailey County). This farm plants 360 acres for silage annually. Milk sales account for 90 percent of 2003 gross receipts.
TXBB150	TXBB150 runs 150 mother cows and 2,000 stockers annually in the Blackland Prairie of central Texas (McLennan County). The ranch operates on 3,000 acres (400 owned and 2,600 leased) of improved pasture and oat pasture. Additionally, 100 acres of coastal Bermuda hay is harvested for use on the ranch. In 2003, 96 percent of gross receipts were generated by the cow-calf and stocker cattle sales.
TXSB250	A 250-head cow-calf operation is the central focus of this full-time agricultural operation in south central Texas (Gonzales County). High-intensity best describes the grazing philosophy of the region, with cows deriving most of their forage needs from improved coastal Bermuda pasture. Native pasture serves as fallback pasturage and is host to this operation's fledgling lease hunting program. Contract broiler production is an important source of agricultural revenue for this ranch; even so, cattle sales accounted for 82 percent of 2003 gross receipts.

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Germination of Redberry Juniper (*Juniperus pinchotii*) Seed in Western Texas

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ABSTRACT

We investigated germination/seedling emergencecharacteristics of redberry juniper (*Juniperus pinchotii* Sudw.) seeds harvested in December 1993 from 20 trees in the central Edwards Plateau and in December 1996 from 21 trees. Germination of seeds collected from raccoon (*Procyon lotor*) and bird (American robin [*Turdus migratorius*] and cedar waxwing [*Bombycilla cedrorum*]) feces in the northwestern Edwards Plateau in December 1996 were also tested. Seedling emergence from the 1993 seeds planted in soil in a greenhouse averaged 5.7% and emergence ceased after one year. Seedling emergence occurred primarily in winter (3.53%) and autumn (1.51%). Average laboratory germination at 68º F of the 1996 seeds was 8.8% at 3 and 52 mo after seed harvest. Scarification and stratifications treatments produced evidence of impermeable seed coats, embryo dormancy, and/or germination inhibitors, but these constraints seem of little biological or ecological significance. Redberry juniper seed germination is relatively low, but a single tree can produce thousands of seed in a favorable year and the seeds can potentially survive for one to several years. Long-range redberry juniper management plans should consider controlling trees before they reach reproductive maturity and using prescribed fire to control seedlings soon after years when climatic conditions favor juniper seed production, germination, and establishment.

KEYWORDS: after-ripening, birds, dormancy, ingestion, longevity, raccoons, scarification, stratification, sulfuric acid, temperature

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INTRODUCTION

Redberry juniper (*Juniperus pinchotii* Sudw.) is a dioecious or sometimes monoecious, basal-sprouting, evergreen conifer native to the southwestern United States and northern Mexico (Adams and Zanoni 1979). It occurs on about 11.7 million acres of Texas rangeland, primarily in the Edwards Plateau and Rolling Plains resource areas (Soil Conservation Service 1985). Redberry juniper was primarily restricted to rocky outcrops, canyons, and shallow range sites, but since the late 1800's, it has increased in density and spread into adjacent grasslands (Ellis and Schuster 1968). Its distribution increased about 60% during the period from1948 to 1982 in a 65-county region in northwestern Texas by seedling recruitment (Ansley et al. 1995). Dense stands of redberry juniper suppress the growth of forage plants and threaten species biodiversity, rangeland watersheds, livestock production and wildlife habitat quality (Steuter and Wright 1983, McPherson and Wright 1990a, Dye et al. 1995). The conversion of grassland to shrubland has been attributed to the interactions of overgrazing, reduced fire frequency and intensity, drought, and perhaps climate change that favors woody plants (Smeins 1983, Archer et al. 1988).

Seeds of most *Juniperus* spp. are characterized as long-lived because germination can be delayed for several years by embryo dormancy, a pericarp covering the seed, an impermeable seed coat that interferes with imbibition, and/or the presence of germination inhibitor(s) (Johnsen and Alexander 1974). However, the germination requirements of redberry juniper seeds have not been thoroughly studied. Smith et al. (1975) reported greatest germination of redberry juniper cones at 64E F in distilled water. Warren (2001) reported only 0.07% seedling emergence from 1500 depulped redberry juniper seeds planted on tilled soil surfaces in 1997 at a site in the Rolling Plains of Texas.

Several monoterpenes are present in redberry juniper cones (Erica Campbell; Texas Agricultural Experiment Station, San Angelo, Texas, personal communication, December 2004). Volatile monoterpenes inhibit seed germination and seedling growth in some plants (Vaughn and Spencer 1993). Germination rates of several juniper species have been increased by dormancy-breaking treatments such as stratification, scarification, or an after-ripening period (Johnson and Alexander 1974, Fisher et al. 1987, Young et at. 1988, Chambers 1999). Removal of the pericarp increased germination of one-seed juniper (*J. monosperma* [Engelm.] Sarg.) seeds in northern Arizona (Johnsen 1962).

Knowledge of the population dynamics of redberry juniper is essential for developing ecologically and economically sound integrated management systems, aids in understanding historical patterns of invasion, and provides information to guide management decisions and predict their consequences. Whisenant (1991) described the potential of population modeling to direct research efforts and improve management strategies. Sensitivity analysis of an Ashe juniper *(J. ashei* Buchholz) population model identified seedling mortality as the most critical transition impacting Ashe juniper populations.

The berrylike cones of most juniper species are well adapted for dispersal by vertebrates. Frugivorous mammals and birds, and heteromyid rodents have likely accelerated the rate of juniper expansion (Chavez-Ramirez and Slack 1993, 1994, Chambers et al. 1999). Large numbers of redberry juniper seeds have been observed in the feces of frugivorous birds and mammals, however, little information is available regarding their post-digestive effect on seed germination and seedling recruitment

The objectives of this study were to investigate the germination ecology of redberry juniper, specifically the variability in seed germination among trees within a population, the effects of stratification, scarification, after-ripening, ingestion of seed by birds and small mammals, seasonality of germination, and seed embryo longevity. Understanding germination requirements provides information about the environmental conditions required for seedling recruitment and the conversion of grasslands to juniper woodlands.

MATERIALS AND METHODS

Greenhouse Seedling Emergence Experiment

One experiment was conducted at the Texas Agricultural Experiment Station 28 miles southeast of Sonora (Edwards County), TX (lat 30E17'N; long 100E32'W) in the central Edwards Plateau to evaluate seasonality of seed germination/seedling emergence and seed embryo longevity under greenhouse conditions. Elevation at the seed collection site is about 2075 ft and mean annual precipitation is 22.6 in. More than 10,000 cones were hand harvested from 20 randomly selected, mature, redberry juniper trees with heavy cone production growing during December 1993 to January 1994 on Tarrant silty clay and Tarrant stony clay soils (clayey-skeletal, montmorillonitic, thermic, Lithic Haplustalls) (Wiedenfeld and McAndrew 1968). Cones were harvested from different parts of the trees to randomize any positional effects. Cones collected from the 20 trees were composited, air dried, and pericarp was removed from the seeds by rolling a 4-in. polyvinyl chloride (PVC) pipe over the cones. Seeds were stored in a refrigerator at 37E F until planting. Two hundred 1-qt (4.5- ×5.0-in.) pots were filled with soil from the seed harvest site and placed in a greenhouse. Fifty fully developed seeds were planted about 0.5 in. deep in each pot on 8 March 1994. Pots were hand-watered as needed to keep the soil moist for the duration of the trial. The greenhouse was heated with a natural gas heater and cooled with an exhaust fan and evaporative cooler as needed during temperature extremes. Seedling emergence was recorded biweekly and emerged seedlings were marked with 24-gauge colored telephone wire to prevent multiple counts of the same seedling. Data were composited seasonally (spring = March through April; summer = May through September; fall = October through November; and winter = December through February).

Laboratory Germination Study

About 1000 cones were hand harvested from each of 21 mature redberry juniper trees in December 1996 on an undulating Kimbrough soil (loamy, mixed, thermic, shallow Petrocalcic Calciustolls) (lat 31E38'N; long 100E32'W) (Wiedenfeld and Flores 1976) about 10 miles northwest of San Angelo in Tom Green County, Texas. Elevation of the site is about 2165 ft and mean annual rainfall is 21 in. with peak periods generally in late spring and early fall. The trees were arbitrarily selected from plants 12- to 18-ft tall with a heavy cone crop. Cones were collected from different parts of the trees to randomize any positional effects and the 21 trees were permanently marked to facilitate resampling in subsequent years. Cones from each tree were bagged separately and dried in a forced-air oven at 100E F. Pericarps were removed by rubbing the cones between two wooden boards. Fresh raccoon (*Procyon lotor*) and bird (probably American robin

[*Turdus migratorius*] and cedar waxwing [*Bombycilla cedrorum*]) feces containing redberry juniper cones were collected at the same time and site. Bird feces were generally concentrated around watering areas and under perch sites, whereas raccoon feces were collected in interspaces between juniper trees, along trails and roads, and near watering areas. The feces were air dried at 68Eto 75E F (drying the seed in a forced-air oven at 100° was not necessary because the animals' digestive processes had removed most of the pericarp). Pericarp not removed by passage through the digestive track of the animal was removed as described above. Seeds were stored in the laboratory at room temperature in cloth bags.

Three replications of 50 seeds from each tree were placed on double layers of #2 blotter paper in 3.9-in. diameter petri dishes on 13 March 1997 (3 mo postharvest) to determine early post-harvest germinability and to quantify variability of seed germination among trees. Captan (cis-N-[trichloromethyl]thio-4-cyclohexene-1,2-dicarboximide) fungicide was applied to the seeds and 0.27 oz of distilled water were applied to each dish. Seeds were placed in an environmental chamber at alternating temperatures of 81E F; 12 h light/54E F; 12 h dark. These temperatures approximate average daily maximums and minimums, respectively, for spring and fall in the study area. Three 50-seed replications from each tree were placed in another environmental chamber at a constant 68E F (intermediate between the alternating temperature regime) and12 h light/12 h dark at the same time. Distilled water was added as necessary to keep the blotter paper saturated. Seeds were examined at 7-d intervals for 56 d and were considered germinated when radical length was ∃ seed length. Six 50-seed replications from each tree were used in a germination trial at constant 68E F (12 h light/12 h dark) initiated on 29 March 2001 (52 mo postharvest) to test seed embryo longevity.

Equal numbers of seed from each of the 21 trees were composited, thoroughly mixed, and separated into three equal groups (weight basis) on 13 March 1997 for stratification treatments. Seeds collected from the raccoon and bird feces were treated similarly. Seeds were spread between two layers of cheesecloth within dampened vermiculite at 39E F for 30 d (cool-moist stratification), placed in dry cloth bags at 39E F for 30 d (cool/dry stratification), or stored in cloth bags at room temperature (no stratification). Scarification treatments were superimposed on these three composited, hand-harvested seed lots after stratification and immediately before the germination trials. Seeds not used in germination trials conducted 4 mo after harvest were stored in cloth bags at room temperature until additional germination trials were conducted 10 mo postharvest. Seed scarification treatments applied to hand-harvested seeds included: 1) 45 min in concentrated sulfuric acid; 2) boiling water for 10 s; 3) rubbing between coarse-grit emery paper attached to boards; and 4) no treatment. No scarification treatments were applied to seeds ingested by raccoons or birds. Six 50-seed replications from each treatment combination were subjected to 56-d germination trials at 68E F (12 h light/12 h dark) in mid April 1997 (4 mo postharvest) and late October 1997 (10 mo postharvest) by the same methods described above.

Analysis of variance (ANOVA) was conducted on final percent germination data for the laboratory study. Data were square root or arc sine transformed to meet assumptions of normality and homogeneity of variances. The observed means are presented for ease of interpretation. Analyses for the seed stratification/scarification study were conducted using a split-split-plot design with postharvest interval (4 mo vs. 10 mo) as the whole plot, stratification as the subplot, and seed scarification as the sub-subplot effect. ANOVAs were performed similarly but separately on data from raccoon-and bird-ingested seeds because these free-ranging animals did not likely ingest cones from the same trees or those from which cones were hand harvested. Means were separated by Fisher's Protected LSD tests at the 5% level where appropriate, and 95% confidence intervals (CI) were calculated for each treatment mean (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Greenhouse Seedling Emergence Experiment

Ambient internal greenhouse temperatures varied from 32º to 100º F during the greenhouse experiment and were generally similar to external ambient temperatures. No seedlings emerged after the 1994-95 winter season. Seedling emergence by season averaged 0.68, 0.00, 1.51, and 3.53% for the spring, summer, fall, and winter seasons after the seeds ripened, respectively (Figure 1). Total redberry juniper seedling emergence was 5.7% from the 10,000 seeds planted. These results suggest the presence of a dormancy mechanism, an after-ripening requirement, the presence of a germination inhibitor, and/or that high summer temperatures in the Edwards Plateau inhibit germination. Owens and Schliesing (1995) reported 0% germination of Ashe juniper seed collected from a soil seed bank and 5% for seeds collected from trees in the southeastern Edwards Plateau. Smeins and Fuhlendorf (1997) suggested that bacteria and other degrading factors destroyed Ashe juniper seeds buried 0.5 in. below the soil surface under field conditions after 18 mo Smith et al. (1975) reported greatest germination of redberry juniper seed collected in the Texas High Plains (Garza County) at 64E F (range 3.3 to 15% in 3 experiments with one seed lot) and no or only limited germination at 50 and 81E F, respectively.

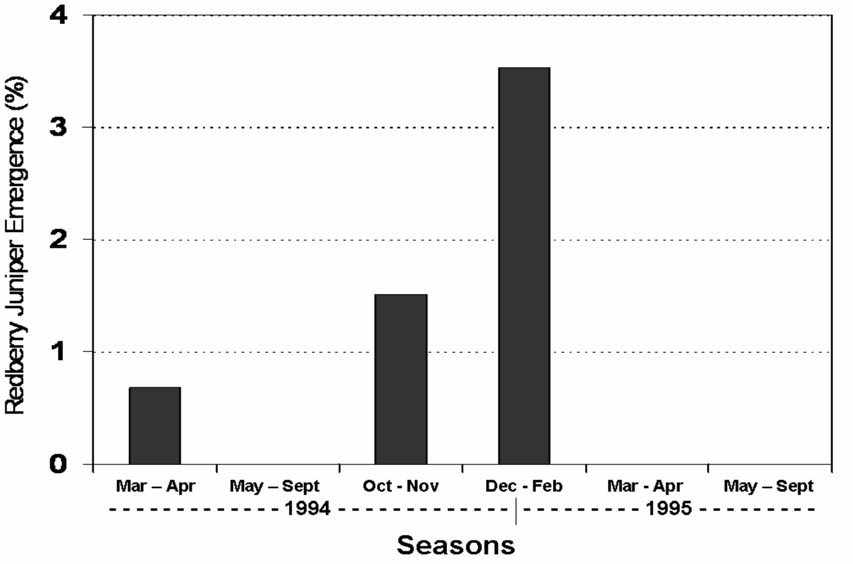

Figure 1. Seasonal percent (%) emergence of redberry juniper seedlings from 10,000 seeds harvested from 20 trees in December 1993 in Edwards County, TX and planted in pots in a greenhouse, 8 March 1994.

Laboratory Germination Study

Seeds were abundant on the female redberry juniper trees sampled at the site near San Angelo in December 1996, presumably because total rainfall during 1995 and 1996 was 10 and 8% above the long-term average, respectively, and seasonal distribution was favorable (data not shown). Cones were rare or not present on trees at the site during the drought of 1997 through 2001. All mature junipers at the study site were killed by mechanical grubbing during 2002, thus preventing any quantification of year-to-year variation in germination of seeds from the marked trees. Because this experiment was not repeated temporally or spatially, the inferences presented herein apply specifically to the study site, the population of redberry juniper trees sampled, and the environmental conditions that existed during this study.

Mean germination at 3 mo postharvest was 8.8 ∀ 4.8% (95% CI; n = 21) at a constant 68E F, but only 2.9 ∀ 1.6% (n = 21) at an alternating 81/54E F (data not shown). No seeds germinated for 23 and 36% of the trees at the constant and alternating temperatures, respectively. Mean germination at 68E F 52 mo after harvest (8.8 ∀ 3.8%) (range 0-24%; n = 21) was not different than that at the same temperature 3 mo (range 0-36%) postharvest. The variability in seed germination among juniper trees suggests that large numbers of trees should be sampled to obtain reliable estimates of germination for a tree population. Seed germination at 68E F varied from 0 to 36% among trees even though rainfall was above average during development and maturation of the fruits. Warren (2001) concluded from visual examination of x-ray film of seeds from four tree populations that redberry juniper, as a taxon, produces fully developed, empty seeds. Seed fill was only 17.0, 9.5, 18.1, and 9.9% for seed harvested from tree populations at Palo Duro Canyon State Park, Justiceburg, San Angelo, and Salt Flat, Texas, respectively in September 1999 during severe drought conditions (National Oceanic and Atmospheric Administration [NOAA 2004]). Smeins and Fuhlendorf (1997) reported significant tree to tree variation in germination (0 to 55%) of Ashe juniper seeds harvested in the central Edwards Plateau. Our finding that germination was greater at a constant 68E F than at an alternating 81/54E F temperature regime suggests that germination of redberry juniper seeds may be enhanced during warm-moist periods when diurnal temperature fluctuations in the surface soil are minimal. Low germination within the temperature regimen that included 81E F in our study was consistent with findings of Smith et al. (1975) and Owens and Schlieshing (1995).

Average germination of seeds in our laboratory study (8.8%) was somewhat greater than that reported from other studies with cones (Smith et al. 1975) or depulped seeds (Warren 2001). Similar germination (8.8%) at 3 and 52 mo postharvest suggests that the embryos were mature when cones were harvested in December, and that dormancy mechanisms or germination inhibitors (if present) are stable over time at room temperature, and that seeds kept in dry storage may remain viable for several years. Warren (2001) reported 44% seed fill and 100% viability of embryos (determined by tetrazolium tests) in redberry juniper seeds harvested in early September, but only 14.8% seed fill and 72% embryo viability after these seeds were left on the soil surface for 22 mo. Smeins and Fuhlendorf (1997) reported no germination of Ashe juniper seeds planted 0.5 cm below the soil surface after 18 mo, suggesting that seed longevity is limited under field conditions. Data from our greenhouse seedling emergence trial indicate that redberry seeds in the soil seedbank may lose their germinability after about one year.

A significant postharvest interval × scarification × stratification interaction for hand-harvested seeds (*F* = 3.0; *df* = 6,120; *P* = 0.010) precluded comparing the main effects, so analyses were conducted separately for each postharvest interval. The stratification × scarification interaction was significant (*F* = 4.2; *df* = 6,60 *P* = 0.001) at 4 mo postharvest, thus scarification effects were analyzed within each stratification treatment. The stratification × scarification interaction was not significant at 10 mo postharvest, thus the main effects were compared. The 45-min sulfuric acid treatment apparently damaged many of the embryos (Table 1). This finding was inconsistent with Johnson and Alexander (1974), who reported that seeds of redberry juniper soaked for 45 min in concentrated sulfuric acid had slightly higher germination than seeds subjected to warm and cold stratification, but these authors did not indicate if the pericarp was removed prior to the acid treatment. Mechanical scarification of seeds following a cool/moist stratification enhanced seed germination at 4 mo postharvest, but did not affect germination of unstratified seeds. No scarification treatment enhanced germination of unstratified seeds at 4 mo postharvest or that of seeds in all stratification treatments at 10 mo postharvest. Germination at 10 mo postharvest averaged about 4% greater for seeds subjected to cool/moist stratification compared to that for seeds that received a cool/dry or no stratification treatment (Table 1). Cool/moist stratification enhanced seedling emergence of western juniper (*Juniperus occidentalis* subsp. *occidentalis* Hook.) and Utah juniper [*J. osteosperma* (Torr.) Little] (Young et al. 1988). This suggests that cool-moist stratification might overcome physiological dormancy mechanisms and/or dilute or eliminate germination inhibitors in the seed coat. Substantial new seedling recruitment might be expected during wet spring seasons that follow a cold, wet winter. There was little evidence that the seed coats of redberry juniper seeds must be scarified to facilitate imbibition and germination, especially after the seeds are about 1 y old.

The postharvest interval × seed stratification interaction was not significant for germination of raccoon-ingested seeds, so the 4- and 10-mo postharvest data were pooled for analysis (Table 2). Mean seed germination was greater for cool/dry-stratified seeds than for unstratified seeds, with germination of cool/moist-stratified seeds being intermediate between these two treatments. Stratification treatments did not affect germination of bird-ingested seeds at 4 mo postharvest, but germination at 10 mo postharvest was greater for the cool/moist treatment compared to that for unstratified seeds (Table 2). Germination of bird-ingested seeds subjected to the cool/dry treatment was intermediate between that of unstratified and cool/moist stratified seeds. Germination of redberry juniper seeds ingested by raccoons and birds generally tended to be greater than that of untreated, hand-harvested seeds but similar to that of hand-harvested seeds that were cool/moist stratified and mechanically scarified (Tables 1,2). This indicates that ingestion by raccoons and birds may have removed germination inhibitors and provided a scarification treatment similar to our mechanical scarification. However, data from seeds harvested from trees were not compared statistically with that for ingested seeds for the reasons discussed above. Smith et al. (1975) reported that ingestion of redberry juniper seeds by small mammals did not affect germination, but they also collected seeds from the feces of free-ranging animals. Fuentes and Schupp (1998) reported that the seed-eating bird, plain titmouse (*Parus inornatus* Gambel*)* was more likely to prey on Utah juniper trees that had higher proportion of filled seeds. This may explain why redberry juniper seeds ingested by birds or raccoons in our study appeared more germinable than seeds we harvested from trees.

Table 1. Mean percent (%) germination (∀ 95% confidence interval) (68E F constant temperature) of redberry juniper seeds subjected to stratification and scarification treatments in 56-d trials at 4 and 10 mo postharvest in December 1996 from 21 trees near San Angelo, Texas.[1]

4 mo postharvest			
	Seed stratification		
Treatments	Cool/dry	Cool/moist	None
Scarification (*n* = 6)	%		
45 min in sulfuric	3.3 c ± 3.4	0.7 c ± 1.1	2.7 ± 1.1
10 s in 212° F water	5.3 bc ± 3.9	0.7 c ± 1.7	5.3 ± 3.4
Mechanical	10.3 a ± 4.1	13.3 a ± 5.4	5.7 ± 3.1
None	9.0 ab ± 3.2	6.7 b ± 4.3	6.7 ± 2.9

10 mo postharvest	
Stratification (*n* = 24)	Mean
	%
Cool/dry	7.4 b ± 1.4
Cool/moist	11.2 a ± 2.3
None	7.4 b ± 2.0
Scarification (*n* = 18)	
45 min in sulfuric	5.3 b ± 2.0
10 s in 212° F water	9.0 a ± 2.6
Mechanical	10.7 a ± 2.5
None	9.7 a ± 1.6

[1] Means within a column and treatment category followed by a similar lower case letter are not different according to LSD$_{0.05}$.

Table 2. Mean percent (%) germination (∀ 95% confidence interval) of stratified and unstratified redberry juniper seeds at 68E F constant temperature after collecting from raccoon (averaged over trials at 4 and 10 mo postharvest) and bird feces (at 4 and 10 mo postharvest) collected in December 1996 near San Angelo, Texas.[1]

	Raccoon (*n* = 12)	Bird (*n* = 6)	
		mo postharvest	
Seed stratification		4	10
	%		
Cool/dry	17.5 a ± 2.9	12.0 ± 5.8	9.7 ab ± 2.5
Cool/moist	15.2 ab ± 3.4	9.7 ± 4.7	14.5 a ± 4.4
None	12.4 b ± 2.6	14.0 ± 5.0	6.6 b ± 5.9

[1] Means within a column followed by a similar lower case letter are not different according to LSD$_{0.05}$.

Warren (2001) found that four populations of redberry juniper in western Texas differed in DNA polymorphisms. Because it is not known how or if these polymorphisms might affect life history, metabolism, or reproductive efforts, inferences from this study should not be extended to other redberry juniper populations or to environmental conditions that differ from those encountered during this study.

MANAGEMENT IMPLICATIONS

Our data and those of others are conclusive that average seed germination is relatively low for redberry juniper populations. However, a single tree can produce thousands of seed in a year of favorable growing conditions, so the deposition of viable seeds to the soil seedbank during these years would be significant. Data from our study did not reveal any major constraints to redberry seed germination after they ripen on the trees, but indicated that seeds in the soil may lose their ability to germinate in about one year. Seed dispersal to safe microsites during years of abundant cone production, combined with favorable climatic conditions (cool, wet spring or fall or mild, wet winter), provides the potential for invasion into new sites or re-establishment in areas where juniper populations have been controlled. McPherson and Wright (1990b) reported that redberry juniper seedlings established during the second year of a wet (above-average rainfall) 2-year period at two Rolling Plains sites in western Texas. Furthermore, above-average cool-season rainfall in successive years was not rare—occurring 10 times during the period 1950-1979 at the two study sites. The ability of certain species to respond to an episodic event, such as precipitation, or to treatments that remove conditions that inhibit germination/establishment is not uncommon and must be considered in long-term management strategies (Owens and Schliesing, 1995). Land managers should control redberry juniper plants before they reach reproductive maturity to minimize the deposition of viable seeds in the soil seed bank.

The Texas Journal of Agriculture and Natural Resource 18:15-27 (2005)

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