SPATIAL DISTRIBUTION of PLAYA BASINS on the TEXAS HIGH PLAINS

J. P. Quillin
R. E. Zartman
Department of Plant and Soil Science, Texas Tech University, Lubbock, TX 79409-2122
E. B. Fish
Department of Range, Wildlife, and Fisheries Management, Texas Tech University, Lubbock, TX 79409-2125.

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:

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

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:

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

where the nearest-event distance is r_i^* and nearest-arbitrary point distance is d_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

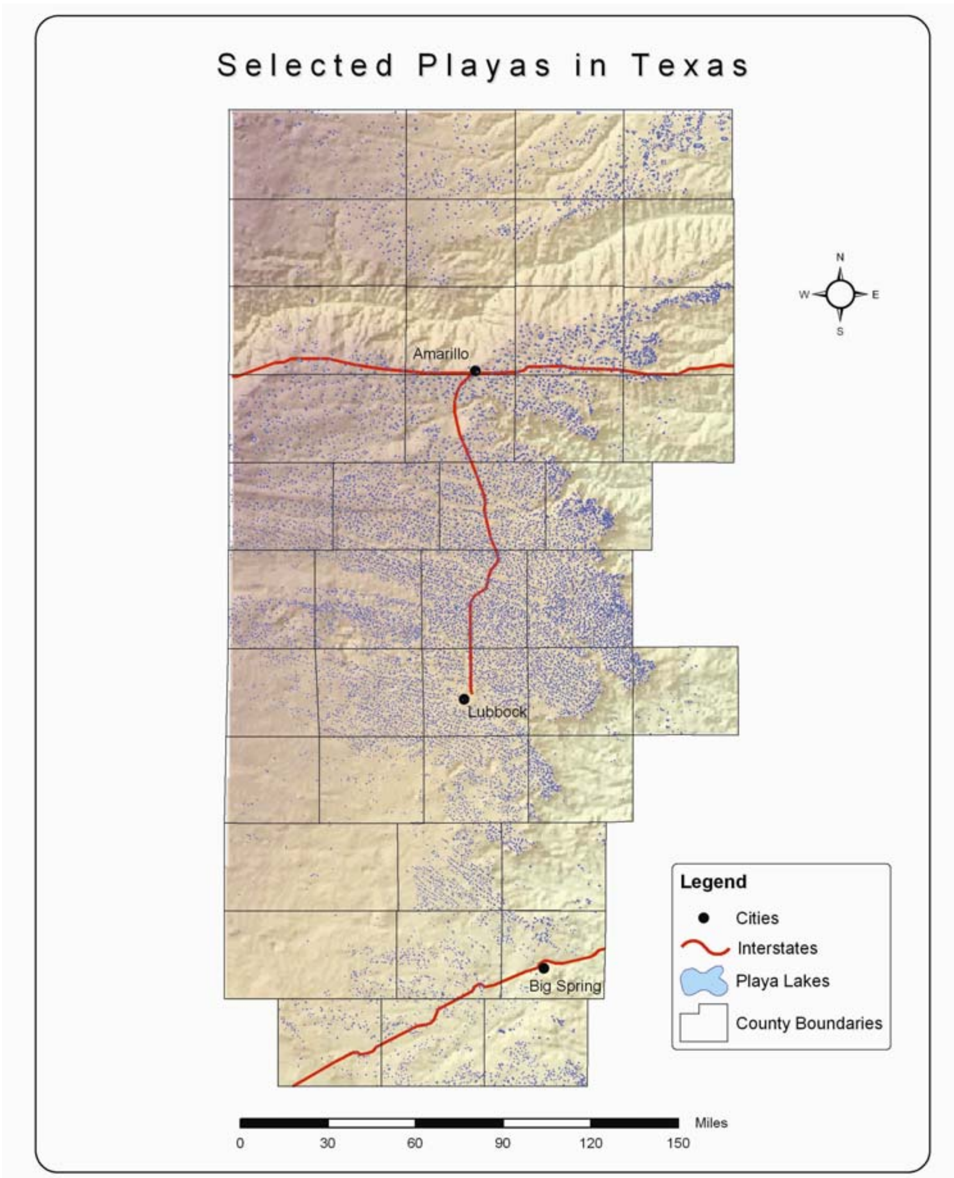
The data set used in this analysis was obtained from the Playa Lakes Digital Database (PLDD) for the Texas Portion of the Playa Lakes Joint Venture Region (Fish et al. 1998). The PLDD encompasses 65 Texas counties and contains 20,557 playa basins. Data from counties that did not occur on the Texas High 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

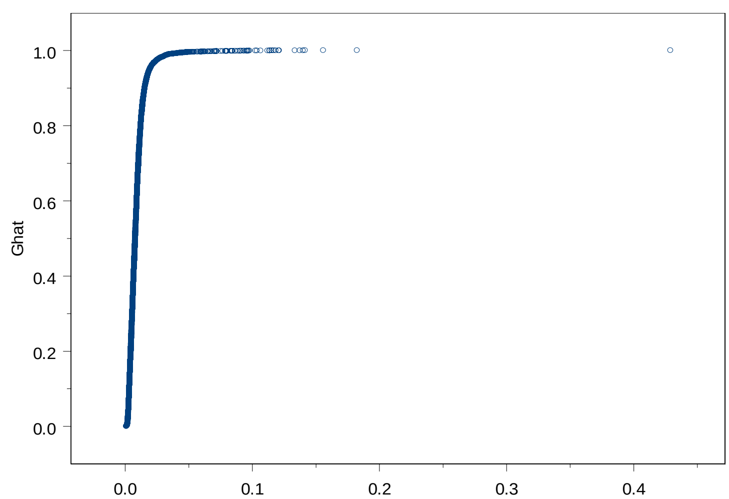
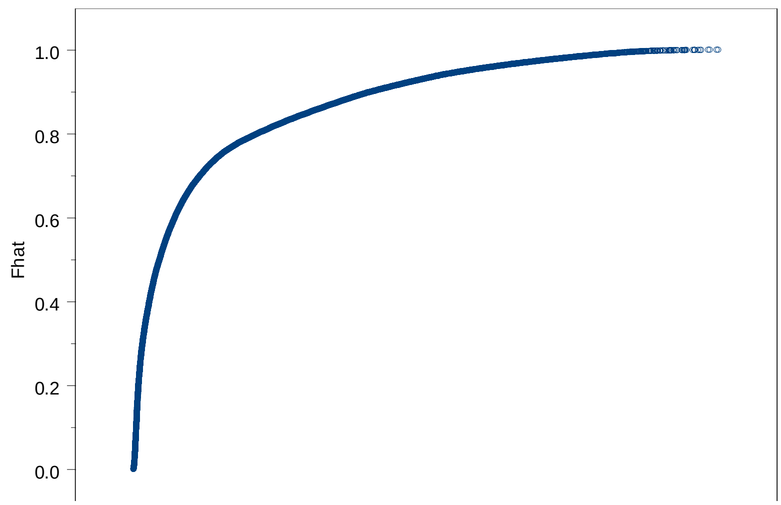


Figure 3. Origin-to-point ($\hat{F}$) for all Texas High Plains playas. The distance is in degrees.



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).

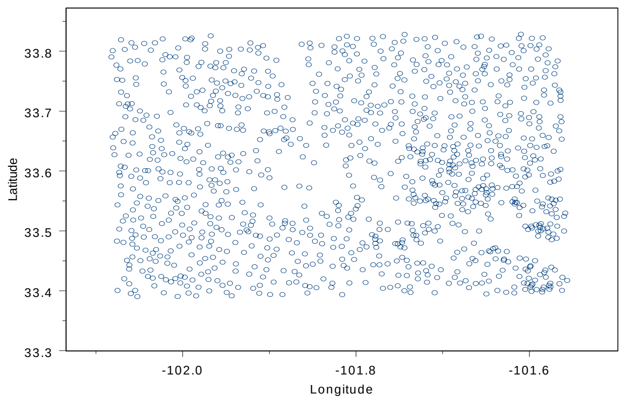


Figure 5. Point-to-point ($\hat{G}$) distribution for the Lubbock County, Texas playas. The distance is in degrees.

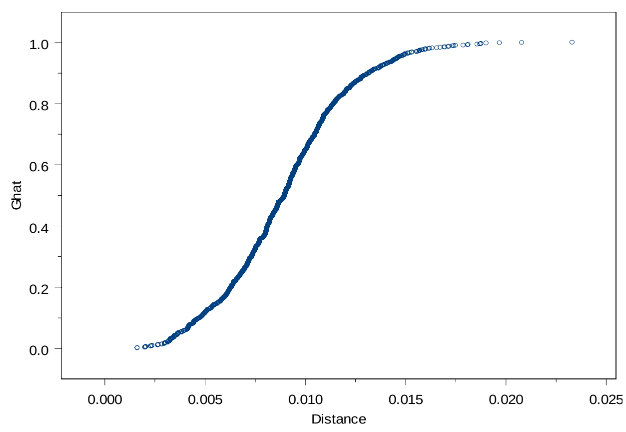
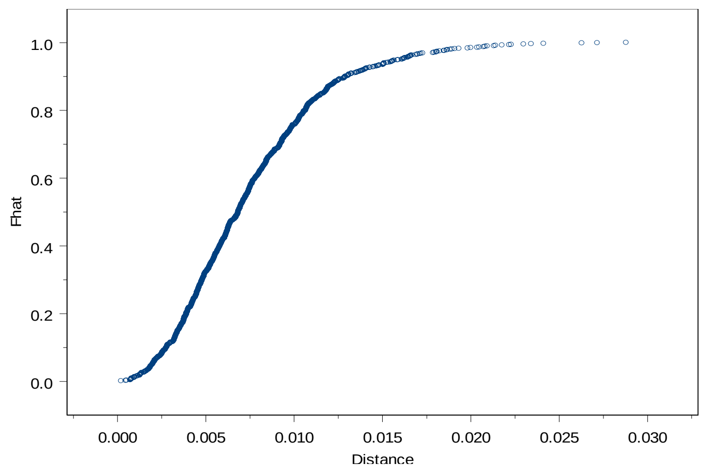


Figure 6. Origin-to-point ($\hat{F}$) spatial analysis for all playas in Lubbock County, Texas. The distance is in degrees.



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).

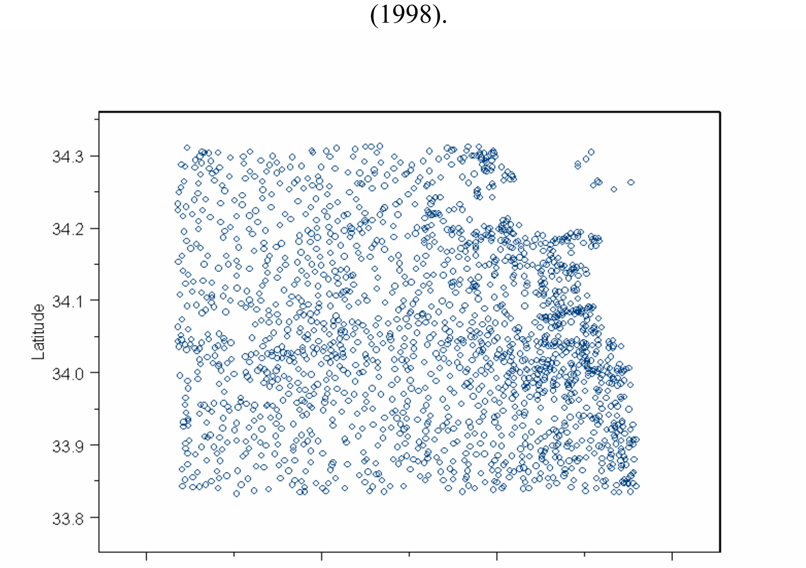


Figure 8. Point-to-point ($\hat{G}$) spatial analysis for all playas in Floyd County, Texas. The distance is in degrees.

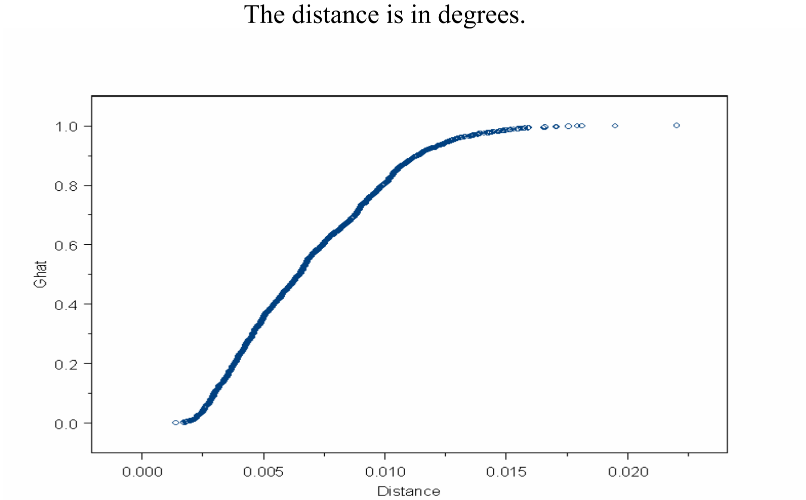


Figure 9. Origin-to-point ($\hat{F}$) spatial analysis for all playas in Floyd County, Texas. The distance is in degrees.

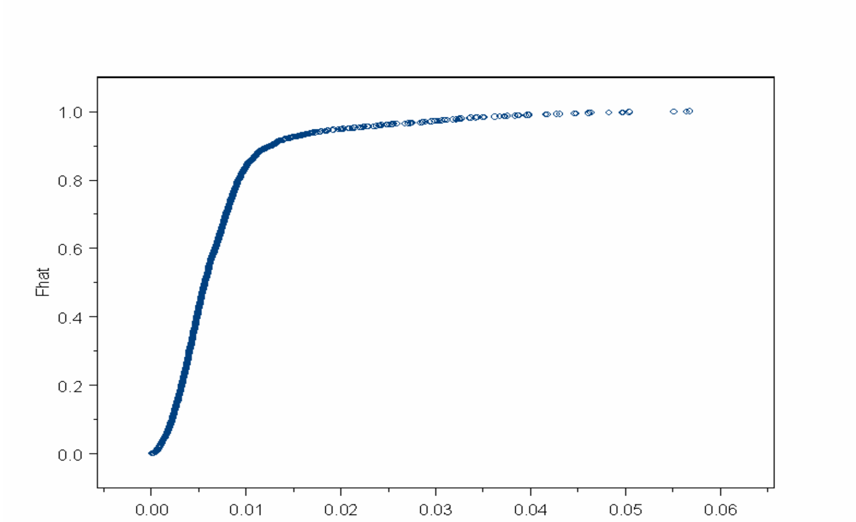


Figure 10. Point-to-point ($\hat{G}$) spatial analysis for playas on the Caprock escarpment with the subset (southwestern portion) of Floyd County, Texas omitted. The distance is in degrees.

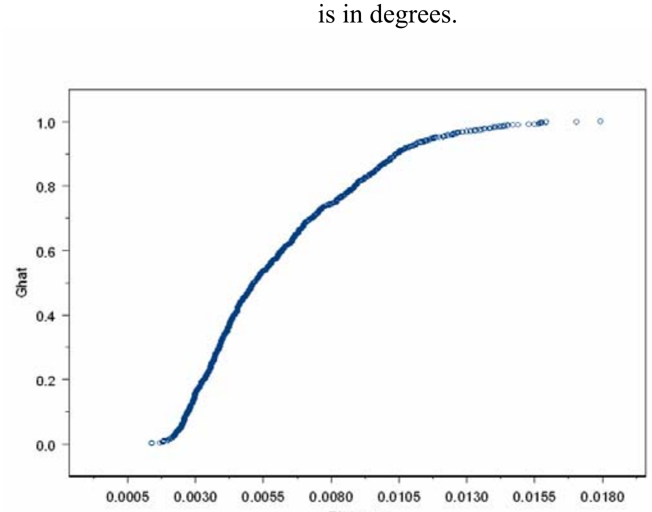
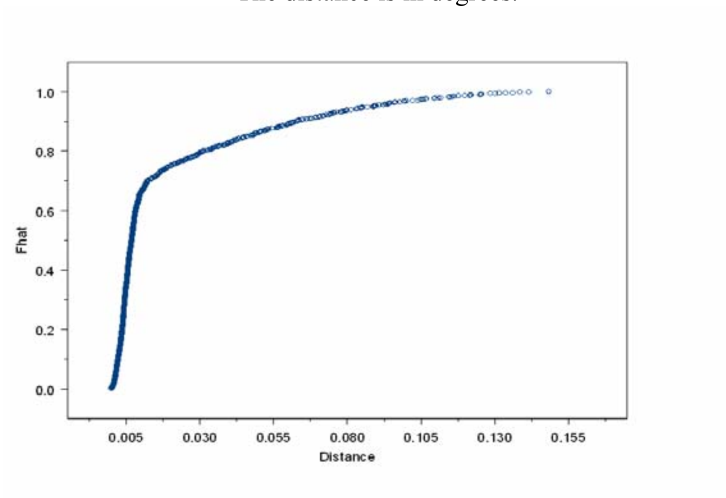


Figure 11. Origin-to-point ($\hat{F}$) spatial analysis for playas on the Caprock escarpment with the subset (southwestern portion) of Floyd County, Texas omitted. The distance is in degrees.

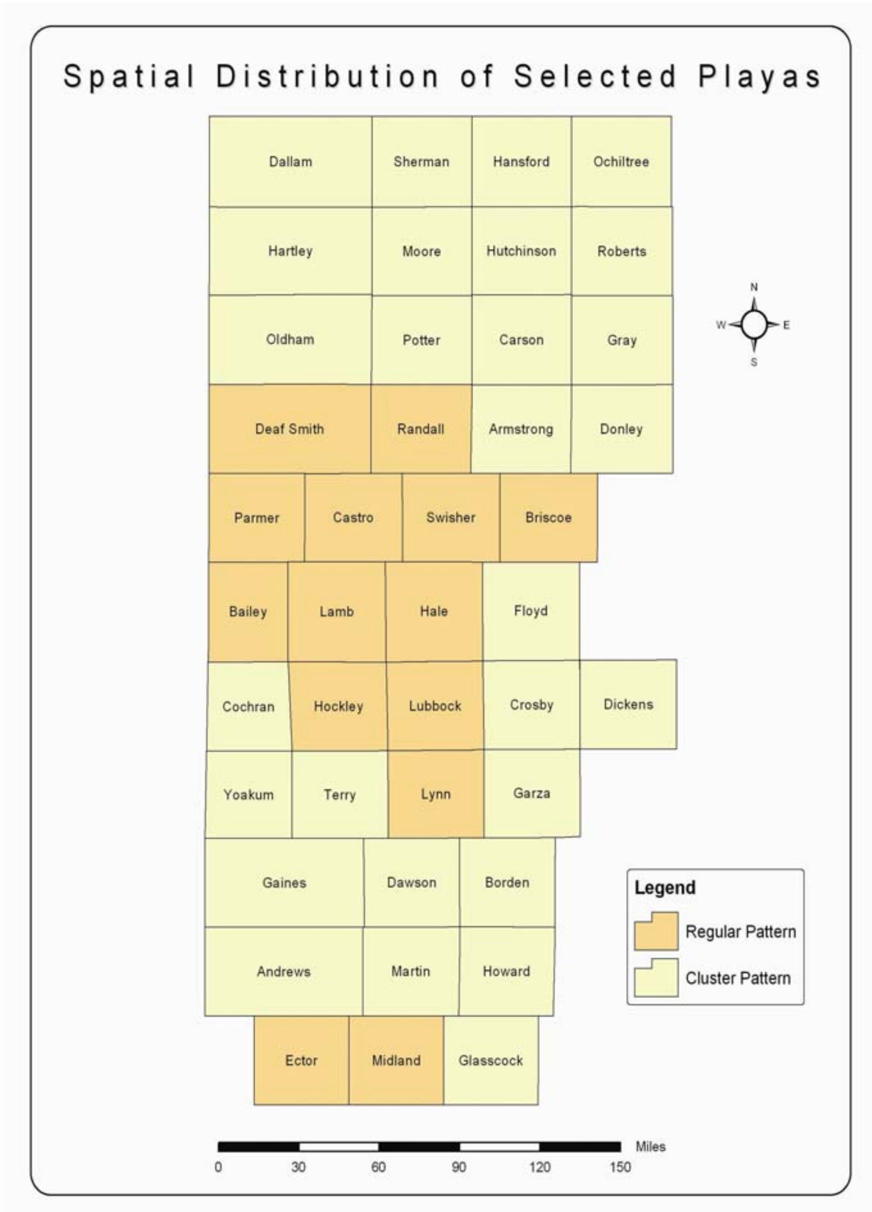


Donley, Briscoe, Garza, Borden, Glasscock, and Howard; tend to have a clustered pattern of playa basins due to the large void areas along the escarpment. Dallam and Hartley Counties located in the northwestern corner of the Texas panhandle have a clustered pattern probably because of large draws and “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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