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Exploring the mosaic of perceptions for water quality across watersheds in San Antonio, Texas

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Abstract

Past research on environmental perceptions has, for the most part, treated responses as independently distributed across a given study area. However, a random sampling of respondents may not necessarily produce a randomly distributed pattern of views on the natural environment. This article explores the degree to which perceptions of water quality are spatially correlated across two watersheds in San Antonio, Texas. Using spatial analysis techniques, we describe and map the mosaic of perceptions of water quality in Salado and Leon creeks running through the heart of the metropolitan area. Specifically, we test the degree to which responses are spatially autocorrelated across the watersheds, and then provide explanation as to why clustering of perceptions occurs in specific locations. Results demonstrate that environmental perceptions are in fact spatially dependent across the landscape and that geographic networks of issue-based activism contribute to the formation of localized "hot spots" of similar responses. Finally, we discuss how the results provide direction for more effective approaches to watershed planning and policy.

Keywords: Spatial autocorrelation; Environmental perceptions; Watershed planning; Geographic information systems

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1. Introduction

Studies on perceptions of the natural environment traditionally have been conducted with the assumption that responses are independently distributed across the landscape. However, recent findings suggest that perceptions and beliefs about specific natural features are, in fact, related across space. The influence of social networks, location, proximity, and other geographic factors causes environmental perceptions to unfold as a clustered pattern across regions, rather than one that is randomly dispersed. These "hot spots" of spatially correlated perceptions have important implications not only for statistical modeling of responses, but also for understanding why and where perceptions occur within a policy or plan-making context.

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We build on previous studies explaining the influence of socio-demographic and location-based factors on environmental perceptions by examining the mosaic of environmental responses across watersheds in San Antonio, Texas. Using spatial analysis techniques, we describe and map perceptions of water quality in two creeks based on the results of a random survey of residents in two San Antonio watersheds. We empirically test the degree to which responses are spatially autocorrelated across the study area and attempt to explain why there is a clustering of perceptions in specific locations. Results show that responses are indeed spatially related across the geographic landscape and certain factors contribute to the formation of localized 'hot spots' of similar answers. Identifying geographic areas where residents have similar perceptions about local water quality may help planners and policy makers strategically target environmental management programs in neighborhoods where initial support for these programs is likely.

The following section reviews the past literature explaining environmental attitudes and perceptions through socio-demographic and geographic variables. We then introduce the concept of spatial autocorrelation and discuss its applications for understanding human perceptions and behavior. Next, we describe sample selection, variable measurement using Geographic Information Systems (GIS), and data analysis procedures. Our findings are reported in four phases. First, we determine if spatial dependence among views of water pollution exists for the entire sample. Second, we identify geographic "hot spots" of similar responses. Third, we test the degree to which the clusters differ from the rest of the sample in terms of socio-economic and geographic variables. Finally, we use density calculations to examine spatial overlap between the LISA "hot spots" of similar views and areas of issue-based environmental activism. Based on the results, we discuss the policy and planning implications of being able to pinpoint areas of similar environmental views across a watershed.

2. Explaining environmental perceptions

There is a long tradition of scholarly research using socio-economic and demographic variables to explain environmental perceptions (i.e., attitudes, views, awareness, and concerns). Generally, these studies conclude that young, wealthy, educated women with liberal political views are the most likely to consider environmental protection as a priority. In their summary of over a decade of previous research, Van Liere and Dunlap (1980, p. 192) found that, "age, education and political ideology are consistently (albeit moderately) associated with environmental concern, and thus we have confidence in concluding that younger, well-educated, and politically liberal persons tend to be more concerned about environmental quality than their older, less educated and politically conservative counterparts." Jones and Dunlap (1992) and Scott and Willits (1994) found the same results: young, highly educated, liberal-minded individuals demonstrate greater recognition of and concern for environmental problems. Other more recent studies focusing on the role of demographic and socio-economic factors find evidence that younger age (Fransson and Garling, 1999; Nord et al., 1998) and higher levels of education (Guagano and Markee, 1995; Howell and Laska, 1992; Raudsepp, 2001) are significant drivers of environmental attitudes and concern. Income is another variable shown to explain environmental perceptions and attitudes (Fransson and Garling, 1999; Van Liere and Dunlap, 1980). For example, Scott and Willits (1994) found that respondents with higher income levels were more likely to demonstrate pro-environmental concerns.

Geographic factors, such as urban or rural environments, have long been recognized as important in explaining environmental perceptions (Tremblay and Dunlap, 1978). More recently, with the development of computer aided spatial analytical techniques, researchers have begun to examine factors, such as proximity and location to explain the underpinnings of environmental perceptions. The interaction between physical location and environmental values is most often conceptualized as "sense of place." The way in which an individual relates to and perceives the natural environment is manifested in his or her "sense of place." Sense of place is defined by the collection of beliefs, attitudes, and perceptions individuals associate with a particular locality (Tuan, 1977; Williams, 1995; Agnew, 1996). Sense of place thus marks the intersection of geographic setting and personal experience and helps to shape one's attitude toward the natural environment (Cantrill, 1998). Such a place-based theory is a first step in considering location and spatial issues when explaining perceptions of the natural environment.

Research in environmental psychology lays a strong foundation for understanding place-based perceptions by examining the difference in views among urban and rural residents. For example, Tremblay and Dunlap (1978) found that rural residents were less concerned with environmental problems than those living in urban settings, and that rural farmers were particularly uninterested in protecting the environment. Lowe and Pinhey (1982) confirmed these rural anti-environmental conclusions in a national study focusing on a respondent's place of socialization. However, more recent empirical research disputes the rural anti-environment hypothesis and instead suggests increasing environmental concern in non-metropolitan areas (Alm and Witt, 1994; Fortmann and Kusel, 1990). Regardless of the findings, using place-based measurements to examine environmental perceptions indicates a trend towards grouping individual beliefs by geography or physical space.

Hannon (1994) and Norton and Hannon (1997) are among the first to directly link environmental attitudes to geography. These authors propose that the intensity of environmental valuation is discounted across time and space. In other words, proximity factors play a critical role in determining individuals' view of physical place. Examinations of the importance of proximity also include research into attitudes toward and decisions about environmental risk. For example, Gawande and Jenkins-Smith (2001) found that distance from transportation routes for nuclear waste drove perception of risk and influenced property values. Elliot et al. (1999) found that proximity to adverse air quality locations affected community cohesiveness over air pollution issues. Brown et al. (2002, p. 63) used straight-line distance to test a place-based theory of environmental evaluation. These authors found that environmental values are "not randomly distributed across the landscape, but tend toward spatial clustering." Identifying a spatial pattern of community values adds an important insight into how locational factors influence attitudes and beliefs. Finally, Brody et al. (2004) found that proximity to water bodies based on driving distance is a significant factor in explaining perceptions of water quality, particularly compared to socio-economic variables.

3. Spatial dependence and spatial autocorrelation

Spatial clustering is often identified statistically through measures of spatial autocorrelation, which is defined as the phenomenon that occurs when the spatial distribution of a variable of interest (e.g., crime, housing, income, etc.) displays a systematic or non-random pattern in geographic space (Cliff and Ord, 1981; Anselin and Griffith, 1988). Positive spatial autocorrelation indicates clustering of similar responses, while negative spatial autocorrelation represents significantly dissimilar responses across a geographic area. The presence of spatial autocorrelation means that the response variable is not distributed randomly or independently, but rather forms a pattern across space. The impacts of this phenomenon when, in the multivariate case, the residuals are spatially autocorrelated include the potential for biased parameter estimates and misleading significance levels (Can, 1990; Ding, 2001).

Spatial autocorrelation measures have been applied most commonly in the natural sciences. Examples of this use include measures of spatial autocorrelation to aid in the prediction and modeling of non-indigenous riparian weed distributions at various spatial scales (Collingham et al., 2000), modeling savannah landscape structures (Pearson, 2002) and the distribution and effects of habitat fragmentation on bird species (Koenig, 1998). However, social scientists are also using this analytical technique to improve understanding of socio-economic trends. For example, spatial autocorrelation has been employed to model housing price variation and neighborhood quality (Dubin, 1992; Dubin and Robin, 1998), investments on adjacent property values (Ding et al., 2000), neighborhood crime characteristics (Dubin and Goodman, 1982), and transportation demand (You et al., 1997).

4. Modeling environmental perceptions using spatial autocorrelation

We used measures of spatial autocorrelation to analyze the geographic pattern of environmental perceptions of Salado and Leon creeks in San Antonio, Texas. Salado and Leon creeks stretch from Northern Bexar

County southeast to the confluences of the San Antonio River and Medina River, respectively. Salado creek runs for 44 miles through the eastern portion of the city, while Leon creek flows for approximately 57 miles through the western portions. Both watercourses traverse a variety of land uses ranging from rural/agricultural to urban/commercial. Currently, both creeks are recognized as "impaired waters" by the U.S. Environmental protection agency (EPA) due to high levels of pollution.

Our goal is to describe the spatial pattern of water pollution views across the study area and to explain why clustered responses occur in specific locations. Specifically, we pose the following research questions and test the corresponding hypotheses:

H1. Perceptions of water quality for Salado and Leon creeks are spatially correlated across the entire study area.

H2. Perceptions of water quality for Salado and Leon creeks cluster in geographically specific, positively spatially autocorrelated locations within the study area.

H3. Characteristics of respondents with clustered responses are significantly different than the rest of the sample population.

5. Data and methods

5.1. Sample selection

We selected the sample of respondents from a random household telephone survey of residents in San Antonio, Texas that over-sampled the area within the two major watersheds for Salado and Leon creeks. The sample was stratified into three groups: Salado creek watershed, Leon creek watershed, and Bexar County as a whole. In order to make sure the households were in the targeted areas, we used only listed numbers with addresses. This approach made certain that the correct strata could be determined for every household. We randomly selected 4000 listed households within each stratum. A sample of 2400 households was sampled from Bexar County and 800 from each of the over-sampled areas. The overall response rate was 25.4%, which generated a sample of 1017 for analysis. Of the 1017 respondents selected, 1005 were geocoded (placed in their true location on earth using X and Y coordinates) by tying their reported addresses to a 2000 U.S. Census Bureau TIGER line file (Fig. 1). Once each respondent was located in geographic space, we could effectively employ geographic factors and spatial analytical techniques to examine environmental perceptions within the study area.

5.2. Measurement of variables

Respondents' perceptions of water quality (the dependent variable for the study) in Salado and Leon creeks were measured by self-reports from the survey. Views of the creeks' safety for drinking, swimming, consumption of fish, and drinking for livestock were measured on a scale from 1–4, where 1 is very safe and 4 very unsafe. By combining these four perception variables, a single water safety variable was formed on a scale of 4–16.[1]

Socio-economic and demographic variables were also measured from survey responses. Party identification (PID), age, income, education, and gender were registered based on the methods used most widely throughout the environmental behavior literature (see Appendix A for more detail). Tenure (the length of time a resident has lived in a neighborhood) was measured based on the number of months a respondent has resided in a specific neighborhood. General Environmental viewpoints were measured based on questions initially used by Van Liere and Dunlap (1980). Responses were summed and ranged 4 (strongly agreeing humans are abusing the natural environment) to 16 (strongly disagree).[2] Finally, population density was measured using GIS along with census data to determine the population per square mile within the study area (see Appendix A for more detail).

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[1] Four separate questions regarding the safety of the Salado and Leon creeks (for drinking, swimming, eating fish, and drinking for livestock) on a scale from 1–4 were combined into a single variable. Cronbach's Alpha for the final scale is 0.91 and 0.95, respectively. Due to the increased range of values (4–16) this variable is approximately continuous.

[2] Eight separate questions regarding the degree to which humans are impacting the environment on a scale from 1–4 were combined into a single variable. Cronbach's Alpha for the final scale is 0.96.

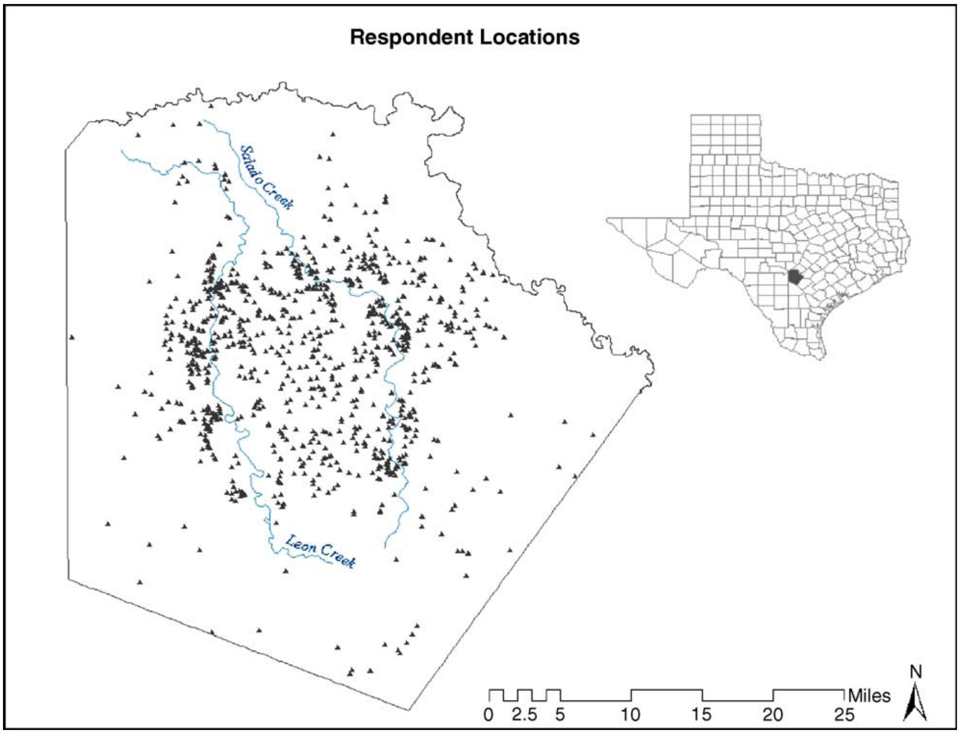

Fig. 1. Study area and respondent locations.

The majority of geographic variables in the model were measured through GIS analysis techniques. Driving distance was measured by tying the geocoded survey respondents to a 2000 U.S. Census Bureau TIGER line file product, which contains the road network for San Antonio.[3] Through network analysis, we determined the shortest driving distance in meters from a respondent's residence to the nearest intersection with Salado and Leon creeks. Land use for each respondent's location was measured using the Texas Natural Resource Conservation Commission (TNRCC) Land Use/Land Cover GIS coverage.[4] From this data layer, we formed the following three major land use categories: urban, rural, and residential. No overlap existed in the labeling, as each respondent fell into only one of the above land-cover classes. The variable, issue-activism density was determined by the weight of the respondents' locations combined with the weights based on the ranked responses to four selected survey questions. The density calculation used area established by a moving, point-based search radius of 1 km, creating a continuous surface layer for each question. The mean of these four layers was derived using a GIS, resulting in one final density layer.

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[3] Previous studies correlating distance with perceptions use Euclidian (straight line) measures. We improved upon these methods using the most recent GIS technology for the following reasons: (a) people tend to perceive distance not "as the crow flies" but how they gain access to natural resources, which is usually by automobiles. Driving distance is therefore a more accurate measure since it takes into account a respondent who lives close to a creek, but must drive a comparatively long distance to gain access; (b) as noted by a recent study examining the relationship between distance and environmental values (Brown et al., 2002), "barriers" are important issues when considering a person's location in relation to a natural resource. By using driving distance, we take into account urban barriers, such as buildings, watercourses, or neighborhood districts that a respondent would need to traverse to access Salado or Leon creeks.

[4] The TNRCC data layer was originally generated through the EPA by interpreting a series of Landsat satellite images into a raster format. This raster-based layer was then converted to a vectors format to analyze with respondent data.

5.3. Data analysis

We analyzed the data in four major phases. First, we used a global Moran's I to test for significant levels of spatial autocorrelation among views of water quality in Salado and Leon creeks. The Moran's I statistic (Moran, 1948) is one of the oldest measures of spatial autocorrelation that can be applied to points which have attribute values associated with them. This statistic, formally defined as:

$$I = \frac{N\sum_i\sum_j W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\left(\sum_i\sum_j W_{ij}\right)\sum_i(X_i - \bar{X})^2}$$

Where N is the number of cases, X_i the variable value at a particular location, i, X_j the variable value at another location (where $i \neq j$), $\bar{X}$ the mean of the variable and W_{ij} is a weight applied to the comparison between location i and location j.

The results from this test statistic provide an overall picture of the degree of spatial dependency across the study area. Second, we employed a local indicator of spatial autocorrelation (LISA) (Anselin, 1995) to identify and map the statistically significant similar responses (where $P \leq 0.05$) related to the creeks. LISAs detect significant spatial clustering around individual locations and pinpoint areas that contribute most to an overall pattern of spatial dependence. We were interested in identifying positively associated responses, i.e. positive, significant LISAs located near other positive significant LISAs ("hot spots" or "clusters"). This technique offered a finer lens of focus that may uncover important features or characteristics in explaining environmental perceptions of the creeks. The local Moran's I statistic is given by:

$$I_i = \frac{(Z_i - \bar{Z})}{S_Z^2}\sum_{j=i}^{N}[W_{ij}(Z_j - \bar{Z})]$$

Where $\bar{Z}$is the mean intensity over all observations, Z_i is the intensity of observation i, Z_j is intensity for all other observations, j (where $j \neq i$), S_z^2 is the variance over all observations, and W_{ij} is a distance weight for the interaction between observations i and j.

Third, we conducted two sample independent t-tests between these "hot spots" of clustered responses and the rest of the sample to obtain initial information on the distinguishing characteristics of spatially autocorrelated responses. Finally, we used moving, point density calculations to examine the spatial overlap between local geographic "hot spots" of similar views and areas of concentrated environmental activism.

6. Results

Global Morans I values indicate statistically significant positive spatial autocorrelation of views on water quality for both creeks (Table 1). Views associated with Salado creek show the strongest levels of spatial dependency with a Z-score of 18.01 ($P < 0.01$). The same responses for Leon creek reveal a lower level of spatial clustering with a Z-score of 10.17 ($P < 0.01$). These results suggest that perceptions of water quality for both creeks in the study area are not dispersed randomly, but instead are spatially correlated somewhere within their watersheds.

Once we established the presence of significant positive spatial autocorrelation among all respondents' views, we used a local Moran's I (LISA) to identify "hot spots" of locally clustered responses. Analysis of the top 5% (or 95th percentile) of Moran's I values for the entire sample provides further insight into the nature of perceptual spatial dependency by helping explain why views across the study area tend to cluster. Based on a test of means, respondents with locally clustered views of the creeks live significantly closer to the water

Table 1
Global Moran's I statistics for views of Salado and Leon creeks

Salado views	
Moran's "I"	0.03
Spatially random (expected) "I"	−0.00
Standard deviation of "I"	0.00
Normality significance (Z)	18.02
Randomization significance (Z)	18.01
P-value	<0.01
Leon views	
Moran's "I"	0.01
Spatially random (expected) "I"	−0.00
Standard deviation of "I"	0.00
Normality significance (Z)	10.18
Randomization significance (Z)	10.17
P-value	<0.01

An I value which is high indicates more spatial autocorrelation than an I which is low. Values of I above the theoretical mean, $E(I)$, indicate positive spatial autocorrelation while values of I below the theoretical mean indicate negative spatial autocorrelation.

Table 2
Comparison of locally clustered views and the remainder of the sample

	Salado creek			Leon creek		
	Cluster mean ($n = 30$)	Remaining mean ($n = 954$)	T-statistic	Cluster mean ($n = 29$)	Remaining mean ($n = 955$)	T-statistic
Tenure in San Antonio	370.20	301.90	1.66*	286.26	304.49	−0.48
Tenure in neighborhood	232.40	158.65	2.43**	133.50	161.71	−1.83
Population Density	8.07	7.84	3.64***	55.70	55.49	2.06*
Network distance	2191.63	9866.57	−30.34***	2408.45	12795.26	−12.63***
creek view	14.97	6.84	25.03***	12.93	3.78	13.39***
Political identification	2.17	2.24	−0.32	2.06	2.24	−1.03
Environmental views	13.73	15.22	−1.85	15.03	15.18	−0.17
Education	13.64	14.49	1.45*	14.72	14.16	−2.16
Age	55.03	47.95	1.89*	42.37	47.69	−2.00*
Income	7.15	8.65	−2.36	9.74	7.36	4.03***
Gender	0.05	0.53	−0.32	0.55	0.53	0.24
Urban land use	0.1	0.09	0.18	0.07	0.91	−0.45
Rural land use	0.03	0.41	−10.30***	0.76	0.39	4.45***
Residential land use	0.87	0.50	5.69	0.17	0.52	−4.71***

Results are based on a two sample independent *t*-test between the mean values for significant locally clustered responses and the remainder of the sample for each watershed.

* $P < 0.05$.

** $P < 0.01$.

*** $P < 0.001$.

bodies, believe they are highly polluted and unsafe for human activities, and live in areas with high population densities (Table 2). High population density may contribute to this pattern of local spatial autocorrelation because people living close to each other are more likely to share information, social and environmental values, and form neighborhood coalitions around specific issues. With high population densities, residents thus may be more likely to share similar views on the natural environment.

Other factors chosen for analysis based on the literature on environmental perceptions do not illustrate as clear a trend in distinguishing the clustered responses (Table 2). For example, neighborhood tenure is significantly longer for respondents with spatially autocorrelated views of Salado creek ($P < 0.01$), but not for Leon creek. We would expect tenure to play a more important role in explaining clustered responses for both creeks, since residents will be more likely to form personal relationships and share their views the longer they reside in a specific neighborhood. Also, residents forming spatial clusters of similar views of Salado creek have significantly lower levels of education than the rest of the sample, but this is not the case for respondents with clustered views of Leon creek.

Another divergence occurs regarding age. Respondents with spatially correlated views of Salado creek are significantly older, while those viewing Leon creek are significantly younger. Similarly, the clustered sample associated with views of Salado creek has lower family income levels, while in contrast the residents with clustered perceptions of water quality in Leon creek are significantly wealthier. Finally, those with clustered views of Leon creek reside in more rural areas, while those sharing perceptions of Salado creek are located in more residential settings. These differences in socio-economic and demographic characteristics between the 95th percentiles of clustered responses for each creek make it difficult to form more general conclusions about the data and demonstrate a need for further investigation to explain why perceptions cluster locally.

Mapping the local “hot spots” of clustered views of water quality in the creeks provides further insights into the nature of spatial autocorrelation within the study area. Highly clustered responses occur spatially in two separate groups for each creek. In other words, the clustered responses themselves are clustered. Each grouping, identified by ellipses in Fig. 2, crosses both sides of the creeks. Views of Salado creek congregate in an

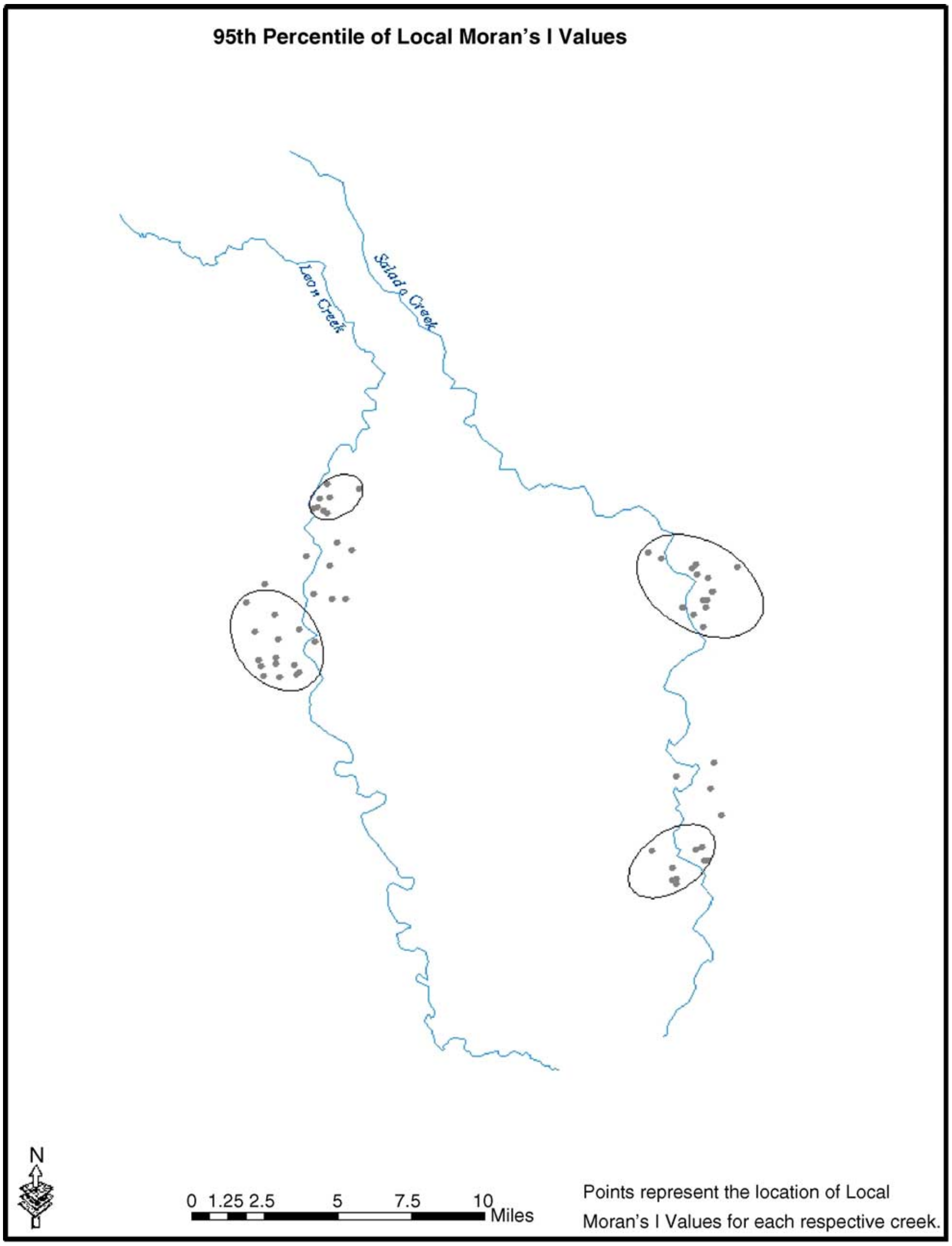

Fig. 2. Geographic clustering of local Moran's *I* hotspots.

area to the north and south of the city. Views of Leon creek seem to be concentrated in the northern reaches of the watercourse.

We used a moving point density analysis with respondents' views as a weighting variable to help further identify why grouping occurs in specific geographic areas in addition to the variables discussed above. The presence of tightly packed, spatially-defined groups of respondents with similar views of Salado and Leon creeks suggests that perceptions and behaviors may be linked by social networks operating in specific neighborhoods. Dense social networks have long been believed to facilitate collective thought and corresponding action (Oberschall, 1973; Tilly, 1978; Fireman and Gamson, 1979). More specifically, with increasing density, individuals are more likely to communicate, share information, and develop similar views and a shared identity (Kim and Bearman, 1997). Density in the sociological context is usually defined by the extent to which actors are tied to each other (Gerald and Prahl, 1988). We apply social network and network density theory to our spatially oriented data to help further explain the locations of clustered views. Thus, an alternative explanation for local "hot spots" of similar views on the water quality in Salado and Leon creeks is that respondents with highly clustered perceptions most likely contribute to or are influenced by a social or community issue network. In our case, the clusters of local Moran's *I*'s may be expressions of a broader social network on environmental issues related to the creeks.

We investigate the influence of a spatially defined social network by mapping the density of several variables representing environmental issue-based activity. These variables include whether a respondent: (1) discusses local issues with other people; (2) contributes money to an environmental group; (3) belongs to a group in San Antonio that is interested in clean water; (4) is willing to act as a community leader on the topic of clean water in Salado or Leon creek. Together, these variables help determine if a resident is a community activist operating within a social network. These four variables were combined and mapped as a single density surface area in Fig. 3. We spatially identify the presence of issue networks, where density refers to the concentration of similar views in a given area (1 km), yielding various intensities of issue-activism. The goal of this stage of analysis is to determine if the local Moran's *I* clusters are geographically aligned with areas of active environmental issue networks. Such a finding will provide additional insight on why the clusters identified in Fig. 2 occur in those specific locations.

Results shown in Fig. 4 indeed confirm that the clusters of local Moran's *I*'s overlap areas with the highest density of environmental issue activity responses. Individuals within the clusters may not only be issue activists themselves, but also be influenced by residents living in close proximity that possess the four issue activist traits. The overlap is particularly distinct for the groups along Salado creek, where the local Moran's *I* values almost coincide with the highest density areas of collective environmental activism. For Leon creek, the spatial overlap is consistent, but slightly less well defined. Here, we notice an area of dense issue-based activism toward the southern portion of the creek where there is no local Moran's *I* "hot spots." Overall, mapping perceptions and activities provides spatial evidence that communication and discussion of local issues, sharing of information, common group membership, and individual leaders may result in geographic areas where views of the environment are very similar. Demonstrating the overlap in spatial extent of responses may not provide the only explanation for why concentrated groups of views occur where they do. However, these exploratory findings lend initial support for the theory that environmental community activists are associated with "hot spots" of similar views on the importance of environmental protection.

Through spatial analysis and GIS techniques, we are able to identify the spatial extent of environmental activism and social networks. Site visits to each of the four issue-based activism areas identified in Fig. 4 provided additional support for the existence of and explanation for spatially defined social networks. By exploring the influence of spatial structure and urban form characteristics on the spatial extent of our issue networks, we could provide further explanation of why clustered responses and activities may occur in those specific locations. We found that the underlying development patterns of all four areas facilitate intense social interaction and the existence of tight-knit communities concerned for the surrounding natural environment.

For example, all areas are comprised of well-defined middle/lower income neighborhoods bounded by sharp human boundaries, such as major streets, culverts, and utility corridors. Each neighborhood is very insulated, with one or two primary entrances and multiple cul-de-sacs and dead end streets. Surrounding commercial and/or industrial zones further define each area as islands of residential development. The urban form of each area is characterized by high-density single-family dwellings with shallow setbacks from the road. Sidewalks and pedestrian access points were observed in all sites. Low levels of through traffic enable basketball nets to face into the streets, creating common play areas for children. Lack of privacy fences indicates

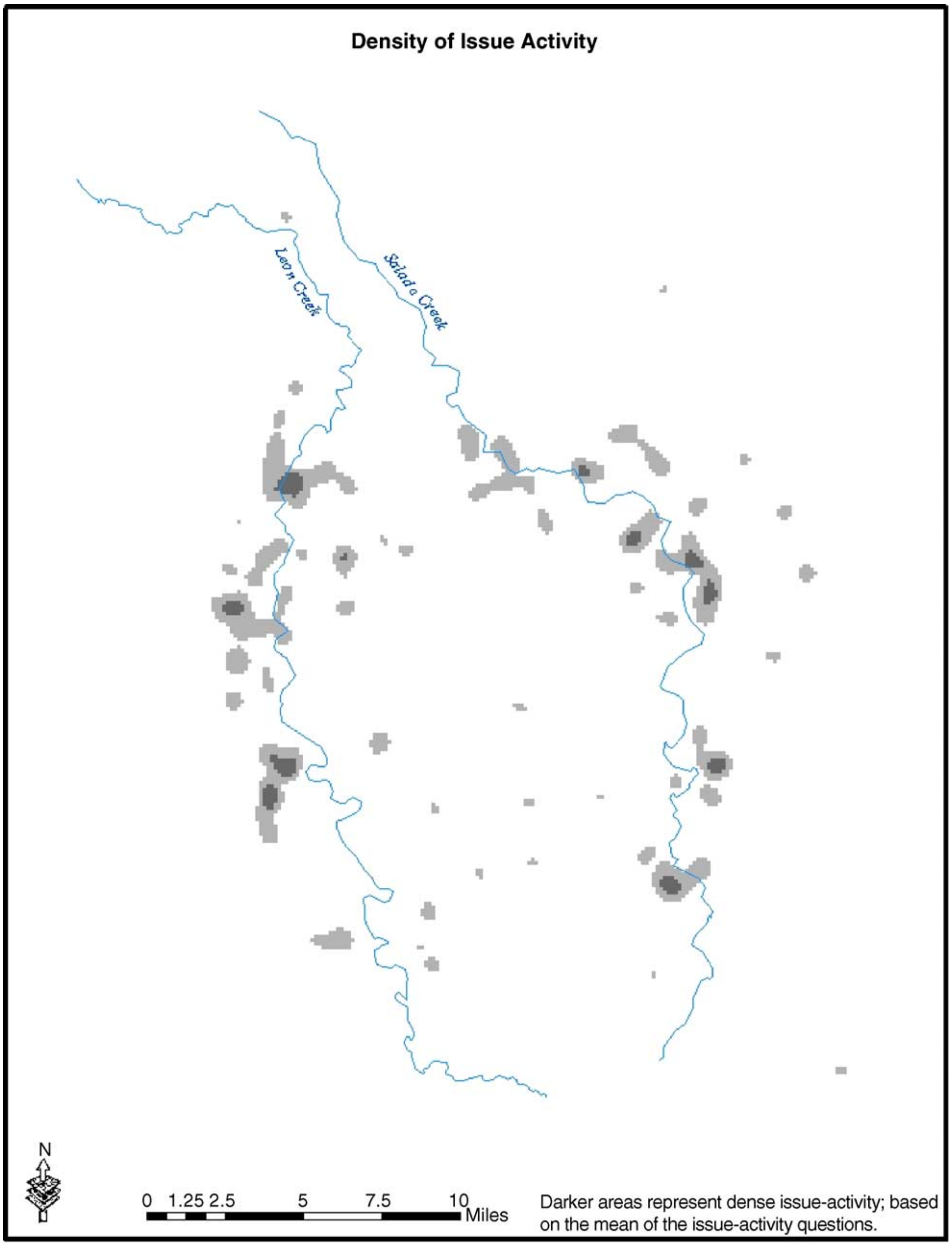

Fig. 3. Geographic density of issue activism responses.

willingness to share space and increases the likelihood of communication. Furthermore, all areas are adjacent to or surround a community church where families can meet, share information, and develop common interests. Two of the four areas have neighborhood parks, which provide additional space for communal gatherings. Community identity and solidarity is further emphasized by the presence of crime-watch postings in all sites. Overall, each neighborhood is tightly packed, well maintained, and child oriented with ample shared spaces. This residential spatial structure is well suited for community interaction, the formation of social net-

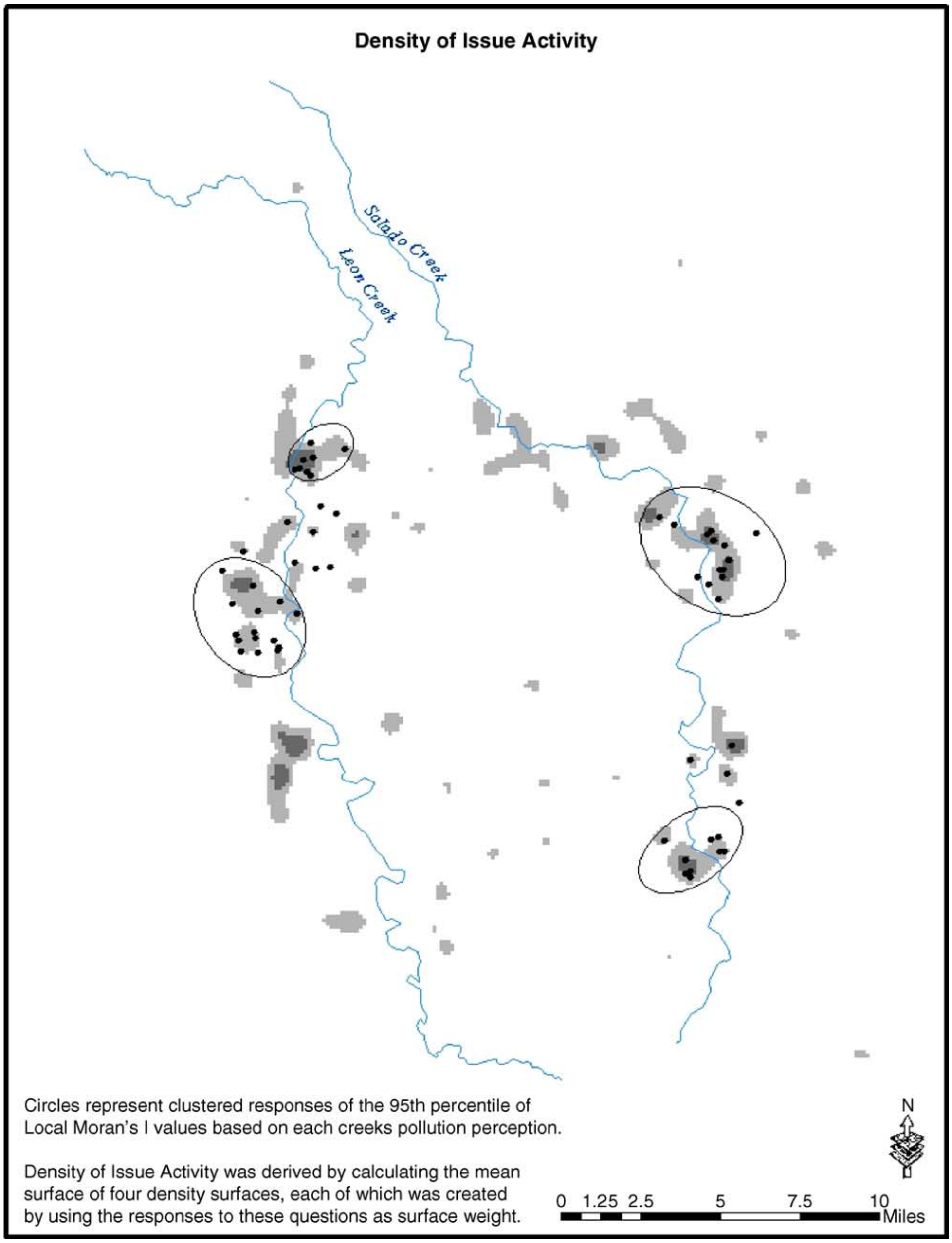

Fig. 4. Locally clustered views on water quality in creeks and density of issue activism responses.

works, and the development of similar perceptions and activities related to protecting the natural environment.

Evidence of spatial structure influencing the formation of social networks and environmental activism is particularly strong for areas along Leon creek. In addition to the above characteristics, the two neighborhoods associated with clustered views on this creek contain communal mailboxes, community bulletin boards placed in median areas announcing community events and issues that should be addressed, and gateways identifying the neighborhood as a single residential unit. In addition, houses in one area have garages attached to their neighbor's, creating large amounts of shared space where social interaction and community activism may be facilitated.

Site visits to each of the four areas containing similar views of Salado and Leon creeks confirm spatial analyses and provide important information as to why these clustered views and activities occur where they do. The spatial structure and urban form of each neighborhood clearly support community solidarity, communication and information sharing, family gatherings, a strong sense of place, and a concern for the safety and quality of their neighborhoods. These settings are ideal places for environmental issue activist traits to emerge, resulting in a strong social network defined by neighborhood boundaries. It is this social network structure that we believe contributes to local "hot spots" of similar responses regarding water quality in the creeks.

7. Conclusions and policy implications

The findings of this study suggest that a randomly selected sample of residents will not necessarily yield a randomly distributed pattern of results. We found that perceptions of water quality in Salado and Leon creeks are spatially correlated across Bexar County. Local measures of spatial autocorrelation determined that "hot spots" of similar views are more likely to occur close to the creeks, in densely populated areas, and that respondents in these clusters believe the watercourses are highly polluted. Mapping local clusters of similar perceptions reveals that local "hot spots" are themselves clustered in four distinct groups. The spatial extent of these areas coincides with density-based clusters of respondents who are active community agents for environmental issues. We suggest that community activism and involvement drives the formation of issue-based networks where neighbors hold similar environmental perceptions. These networks are facilitated by the spatial structure and form of each residential development.

While the findings of this study are exploratory in nature, they have important implications for policy making and plan implementation. Given the fact that environmental perceptions of water quality are clustered across watersheds in Bexar County, a targeted strategy of policy making and planning may be more effective than an approach that casts a broad regulatory net. Policies to protect the water quality of creeks should first be presented to groups of residents in specific locations who will most likely be the strongest supporters. In this regard, engaging community activists first so that issue-based networks evolve and spread to remaining parts of the watersheds may be the most effective way to gain involvement and commitment in generating local environmental policies. Community support for these policies will invariably increase the likelihood of their implementation.

There are thus two types of targeted watershed planning strategies that emerge from the results of this study. First, focusing planning initiatives on residents with specific socio-economic and demographic characteristics (in this case, people living in densely populated urban areas who are in favor of environmental protection, belong to clean water groups, give money to environmental groups, discuss local issues, and are potential community leaders). Second, aiming planning efforts at specific geographic areas where clustered views of poor water quality emerge (in this case, the four groups identified close to the creeks). It should be noted however, that while watershed planning should begin by targeting those likely to be most supportive of the initiative, ultimately, policies must be accepted in areas and by residents contributing most to the decline of water quality.

While this study offers some initial insights into the spatial pattern of environmental perceptions in Bexar County, TX, additional work is needed to more fully explain the presence of spatial autocorrelation. First, residents in local clusters should be re-surveyed followed by interviews to more thoroughly investigate the influence of issue-based activism networks. Because the original survey design for this study was intended to measure general environmental perceptions, not the effects of environmental activists on the clustering of views, pertinent data on activism was not collected. Our investigation of why clustered views occur in specific locations is exploratory in nature. Further study will help explain the relationship between spatially defined social networks, similar views on the environment, and corresponding collective action. Second, other variables should be controlled for when explaining spatial patterns of environmental perceptions across the study area. The bivariate relationships examined in this study should only be considered a starting point for a more detailed explanatory, multivariate analysis. This approach involves measuring and correcting for the presence of spatial autocorrelation that may bias parameter estimates when using multiple regression analysis. Both these types of additional research will improve understanding of where and why environmental views of specific natural features cluster in specific geographic settings. The cause of such a pattern or mosaic of responses can provide insights into how we view the natural environment and how we can target environmental policies for specific geographic areas.

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Appendix A. Concept measurement

Name	Type	Measurement	Scale	Source	Statistical measure
Water safety	Dependent	Views of water pollution in creeks from very safe to very unsafe	1–16	Survey	*t*-Test, global Morans, local Morans
Driving distance	Independent	Distance in meters from residence to nearest intersection with creeks	Continuous	GIS Analysis	*t*-Test
Population density	Independent	Population per square mile in study area	Continuous	U.S. Census	*t*-Test
Party ID	Independent	Association with specific party	1–4	Survey	*t*-Test
Education	Independent	Number of school grades completed	Continuous	Survey	*t*-Test
Age	Independent	Reported age in years	Continuous	Survey	*t*-Test
Income	Independent	Reported annual income	Continuous	Survey	*t*-Test

Appendix A (*Continued*)

Name	Type	Measurement	Scale	Source	Statistical measure
Gender	Independent	Reported gender	Dichotomous	Survey	*t*-Test
Environmental views	Independent	Range of views on the level of human impacts on the natural environment	1–32	Survey	*t*-Test
Neighborhood tenure	Independent	Number of months living in neighborhood	Continuous	Survey	*t*-Test
Land use	Independent	Type of land use for residence	Dichotomous	GIS analysis	*t*-Test
Discusses local issues	Independent	How often respondent discusses local issues	1–9	Survey	Density
Money to environmental group	Independent	Respondent contributes money to an environmental group.	Dichotomous, 0–1	Survey	Density
Water group	Independent	Respondent belongs to a group in San Antonio that is interested in clean water.	Dichotomous, 0–1	Survey	Density
Community leader	Independent	Respondent is willing to act as a community leader on the topic of clean water in Salado or Leon creek.	Dichotomous, 0–1	Survey	Density

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