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THE PROBLEM OF SCALE IN ENVIRONMENTAL EQUITY RESEARCH

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ABSTRACT: *There is a growing body of research that examines the spatial association of environmental hazards with low-income, urban and minority communities. However, these studies have been performed on many different environmental threats, at several geographic scales, on various subpopulations, and within different time frames, all with conflicting evidence. This research focuses on the correlation of socioeconomic variables with the number of solid waste sites at various scales within the state of New York. This paper demonstrates the inconsistency in outcomes that may result from using different geographical scales and concludes with suggestions for dealing with this problem.*

INTRODUCTION

Concern for the spatial-temporal distribution of pollution and other environmental problems, in the social sciences and geography in particular, date back to the 1970s (Burke, 1993). The impetus for much of the recent interest in environmental equity can be linked to studies by the US General Accounting Office (USGAO, 1983) and the United Church of Christ's Commission for Racial Justice (UCC, 1987) which document the disproportionate risk of environmental hazards to minority communities. In 1990 the Environmental Equity Workgroup was established by the US Environmental Protection Agency (USEPA) "... to evaluate the evidence that racial minority and low-income groups bore a disproportionate burden of environmental risks and to identify factors that contributed to different risk burdens and to suggest strategies for improvement" (Cutter, 1995). Two years after the EPA Workgroup Report was filed (USEPA, 1992), Executive Order 12898 was signed by President Clinton requiring all federal agencies to achieve the principle of environmental justice (Bullard, 1994). However, the change in public policy may be the result of political pressure rather than sound empirical research (Cutter, 1995).

The purpose of this study is to demonstrate the effect that scale has on environmental equity research and to suggest ways in which future research may deal with this problem. The number of inactive waste sites and the number of solid waste sites in New York State (the former being a subset of the latter) are used with 1990 US Bureau of Census data to examine the extent to which the number of sites is correlated with the socioeconomic characteristics of the surrounding residential communities. Assuming that environmental inequity exists, there would be differences between the socioeconomic characteristics of populations in areas with waste sites and in areas without waste sites. This paper asserts that a greater number of inactive/solid waste sites in residential communities will coincide with: 1) lower population densities; 2) higher vacancy rates; 3) lower housing values; 4) lower percentages of owner-occupied housing; 5) lower levels of income; 6) lower levels of educational attainment; and 7) higher percentages of nonwhite populations. The analysis is performed at the census blockgroup and census tract level for Erie County, New York, and at the county scale for New York State. For the county level analysis the number of inactive waste sites is used since the number of solid waste sites is unavailable.

LITERATURE REVIEW

There have been several terms used to describe the problem of environmental equity as outlined above, including environmental racism and environmental justice. The term environmental racism appeared in the early 1980s and refers to "... a historical system of discriminatory exploitation" (Cutter, 1995). However, the term implies that the inequities do in fact exist and are racially motivated (Burke, 1993). Environmental justice generally refers to grassroots political activism associated with environmental issues seeking to redress inequities, whether they are race, class, gender, or age based. The term environmental equity is used to describe a range of disproportionate effects, including social (class, race, gender, ethnicity, political power), generational, and procedural (governmental rules and regulations, enforcement) (Cutter, 1995). Often the researcher is concerned with the mechanism which brings about inequity (process equity) or the spatial and temporal distribution of inequity (outcome equity). The vast majority of environmental equity research focuses on outcome equity.

Environmental Equity

In one of the first equity studies, the USGAO (1983) focused on one region of the country, the South, choosing four of the largest hazardous waste facilities in the region. It examined the racial makeup of the surrounding communities and found three of the four had a majority of African-American residents. While this study is frequently cited, it is reasonable to question the statistical validity of the results for two reasons. First, small sample sizes contain too little information to be representative of the population, in this case, all hazardous waste facilities. Second, it is necessary that the observations be randomly selected in order for the inferences drawn to be valid. Other studies at the county scale have produced mixed results. Hird (1993) found no significant relationship between poorer counties and Superfund National Priority List (NPL) sites, but there was evidence that counties with NPL sites had higher percentages of minorities. However, Cutter's (1994) study of several risk factors for South Carolina found that the most at risk populations were in racially diverse, urbanized counties.

Both Zimmerman (1993) and Greenberg (1994) analyzed NPL sites at an urban scale. Zimmerman examined 800 national sites in the process of being remediated and found that among minor civil-divisions in large urban areas there were higher percentages of racial/ethnic minorities. In contrast, Greenberg found no relationship between the federal Hazard Ranking System and the percentage of minority residents for 90 municipalities in New Jersey. The UCC (1987) report found that race was the most significant variable associated with commercial hazardous waste facilities and uncontrolled waste sites. The study was based on a national sample of zip codes, which are in general a larger areal unit than census tracts, but smaller than minor civil-division or municipalities.

Burke (1993), Holm (1994), and Anderton et al. (1994) performed their analyses at the census tract level. Burke examined toxic release inventory (TRI) and found as the number of sites per census tract increased there were higher percentages of minorities, lower per capita incomes, and lower population densities. Holm examined hazards treatment, storage, and disposal (TSD) facilities and found similar results to Cutter (1994), that is, environmental risk was concentrated in areas of high population densities or urbanized areas. Anderton et al. (1994) sampled census tracts within standard metropolitan statistical areas (SMSAs) nationally and found no relationship between race and the siting of TSD facilities. However, when the data were aggregated to a larger spatial unit a significant relationship between race and TSD facilities was found.

Data Aggregation and Scale

Environmental equity research has two salient features, the different environmental risks under study and the corresponding geographical scale of the analysis. Use of various geographical scales is problematic since as the scale and specifically the areal unit changes, the data values and statistical inferences also change. Sensitivity of statistical results to the observational unit has been identified in the statistical and geographical

literature as the "Modifiable Area Unit Problem" (MAUP) (Openshaw and Taylor, 1979, 1981; Openshaw, 1984). "Modifiable" refers to two separate but related concerns. First, different levels of aggregation result in what is known as the scale problem and second, different geographical configurations, for a given number of subregions, result in the zone problem. The seminal work outlining the MAUP is the Openshaw and Taylor (1979) study of the correlation between percentages of elderly population and Republican voters in the 99 counties of Iowa. They found that by varying the scale and zonal configuration, correlations ranging from - 0.811 to + 0.979 could be generated.

The basis for the influence of scale is that as data are aggregated, a smoothing effect (by averaging or summing) occurs resulting in a reduction of variance. The correlation coefficient between two variables, x and y, is determined by ratio of the covariance of x and y, and the product of the standard deviations of x and y. Therefore, "... the correlation coefficient will increase if the covariance between x and y is relatively stable" (Fotheringham and Wong, 1991). Environmental equity research generally uses socioeconomic variables that have been aggregated to various administrative or political boundaries depending on the scale or scope of the analysis. Whenever areal data are used in this way the modifiable areal unit problem may occur.

DATA AND METHODOLOGY

The data employed in this study include a map of the known solid waste sites throughout the city of Buffalo and Erie County, New York, acquired from the Erie County Department of Environment and Planning (DEP). Information regarding inactive waste sites was obtained from the New York State Department of Environmental Conservation (DEC).

The US Bureau of Census TIGER/Line files provide a database from which maps of counties, census tracts, and census blockgroups are generated. Aggregate population, housing, and socioeconomic data for the three levels of areal units are obtained from the Bureau of Census Summary Tape File 3A for the 1990 census and defined in Table 1. The number of observations for the county, census tract and census blockgroup analyses are 62, 236 and 972 respectively. There are three counties that contain over 90 waste sites each; they include Erie, Niagara (the location of Love Canal) and Suffolk counties.

The primary hypothesis, that the variability in socioeconomic variables will be associated with variations in the number of solid/inactive waste sites, will be tested with a two-tailed t-test. Pearson's correlation coefficient assumes that the variables are normally distributed and are measured on an interval scale. However, the number of sites is not normally distributed and the number of sites is an ordinal approximation for the environmental risk in a given areal unit. A more detailed measure of environmental risk would take into consideration the geographical area of the waste site, the total quantity of waste, and its toxicity. Therefore an alternative test statistic is used. Spearman's rank correlation coefficient is a nonparametric test statistic based on the differences of ranks between the two variables, rather than the values themselves. A second and related hypothesis is that a significant difference in the socioeconomic variables will exist between regions with at least one waste site and regions with no waste sites. This hypothesis will be tested using a two-tailed difference of means test.

RESULTS AND ANALYSIS

The correlations between the socioeconomic variables and the number of waste sites for the three levels of analyses are presented in Table 2. Nine of the correlations between the socioeconomic variables and number of waste sites are statistically significant at the 0.05 level. Only the correlation coefficients for the percentage of non-white and black populations are consistent with the stated research hypotheses. Population density, percentage with a bachelor's degree and graduate degree, median family income, per capita income, vacancy rate, and median gross rent are statistically significant, but with signs opposite of those expected. The positive correlation between population density, income and university degrees

Table 1. Variable Description

Variable	Description
DENSITY	population per square mile
PNWHITE	percentage of nonwhite population
PBLACK	percentage of black population
PHISPANIC	percentage of hispanic population
PBACHELOR	percentage of population 25+ years of age with a baccalaureate degree
PGRADUATE	percentage of population 25+ years of age with a graduate or professional degree
MFAMILY	median family income
PERCAPITA	per capita income
PVACANT	percentage of vacant housing units
PRENTER	percentage of renter-occupied
MVALUE	median value of owner-occupied
MRENT	median gross rent of renter-occupied housing

with the number of waste sites may simply reflect the level of industrial and residential development. It is important to note, however, that the correlation values for median gross rent and the percentages of non-white and black populations are low and may be spurious. In other words, the variables may be influenced by an extraneous variable and therefore the correlations would not necessarily indicate a cause-and-effect relationship.

Only five of the correlations between the socioeconomic variables and number of waste sites are statistically significant at the 0.05 level for census tracts analysis and one additional variable is statistically significant for census blockgroups. The signs of the correlation coefficients for population density, percentages with a bachelor's degree and a graduate degree are consistent with the stated research hypotheses. The percentages of renter-occupied housing, non-white and black populations are statistically significant, but with signs opposite of those expected. Again, the values of the correlation coefficients are quite low, except for population density, indicating the possibility of spurious correlations. The five variables that are significant at the census tract level are also significant at the county scale, but in each case the correlation coefficients have the opposite sign.

The number of waste sites and the percentage of black population are mapped and displayed in Figures 1 and 2 (the maps of the remaining socioeconomic variables with statistically significant correlations are not included due to limited space). Each of the variables are arranged into four classes based on the quartiles of the distribution. The purpose of the first two maps is to demonstrate the similarity in the map pattern. In Figure 1, many of the counties with the largest number of waste sites (Niagara, Erie, Monroe, Onondaga, Oneida, Albany, Broome, and Orange) also contain the largest urbanized areas (Niagara Falls, Buffalo, Rochester, Syracuse, Utica, Albany, Binghamton, and Newburgh, respectively). Two noticeable exceptions are Dutchess and Suffolk counties. Dutchess county, however is the location of many IBM facilities and several light manufacturing companies; Suffolk county's large number of sites may be due to its proximity to the New York Metropolitan area.

The percentage of black population is displayed in Figure 2 and has a similar map pattern to Figure 1. Counties with the highest percentages of blacks also have a large number of waste sites, but more importantly blacks tend to reside in the more urbanized counties of the state. The only two non-urbanized counties with a relatively large percentage of blacks are Orleans county, between Niagara and Monroe counties on the shores of Lake Ontario, and Delaware county, northwest of the Catskill Mountains.

Table 2. Correlation with the Number of Waste Sites

Variable	County	Census Tract	Census Blockgroup
DENSITY	0.4988***	-0.4649***	-0.3958***
PNWHITE	0.2876**	-0.2304***	-0.0872***
PBLACK	0.2746**	-0.2546***	-0.1045***
PHISPANIC	0.0732	0.0708	0.0056
PBACHELOR	0.3901***	-0.2050***	-0.0771**
PGRADUATE	0.3667***	-0.1928***	-0.0825**
MFAMILY	0.5025***	0.0099	0.0154
PERCAPITA	0.4657***	-0.0762	-0.0265
PVACANT	-0.4421***	-0.0093	0.0112
PRENTER	0.1617	-0.0960	-0.0683**
MVALUE	0.2347*	-0.0225	-0.0011
MRENT	0.2852**	-0.0004	-0.0469

* Significant at 0.10 level
** Significant at the 0.05 level
*** Significant at the 0.01 level

Figures 3 and 4 display the number of waste sites and the percentage of black population for census tracts of Erie County, New York (the maps of the remaining socioeconomic variables with statistically significant correlations are not included due to limited space). As with the state maps, the variables are grouped into four classes based on quartiles.

In Figure 3, there are a number of sites in the northwestern region of the county, especially in Tonawanda along the Niagara River, which corresponds with the location of several oil refineries. South of downtown Buffalo along Lake Erie is where most of the steel production took place in the early part of this century and is also the location of many waste sites.

From Figure 4, a considerable amount of spatial clustering of the black population can be found east of the downtown area. Also, over 25% of the census tracts contain no black residents and over 10% of the census tracts have black population shares greater than fifty percent. It is clear that the census tracts with the greatest share of black population do not coincide with the location of tracts with the most numerous sites.

A difference of means test is utilized to address the second research hypothesis. All tracts with no waste sites are placed in group 1 and all tracts with at least one waste site are placed in group 2. The same variables which are significantly correlated with the number of waste sites also have significantly different values for the two groups of census tracts (the results are not included due to limited space). Similar results are found for the census blockgroups. The difference of means test is not performed at the county level since only two counties in New York State have no waste sites.

CONCLUSIONS

The findings at the county scale are consistent with other county level research by Hird (1993) and Cutter (1994), which found that environmental risk is positively associated with urbanized areas and minority communities. Other studies which used highly aggregate data, UCC (1987) using zip codes and Anderton et al. (1994) using SMSAs, also found a significant and positive relationship between race and environmental risk. At the census tract level Burke (1993) found that environmental risk was positively correlated with

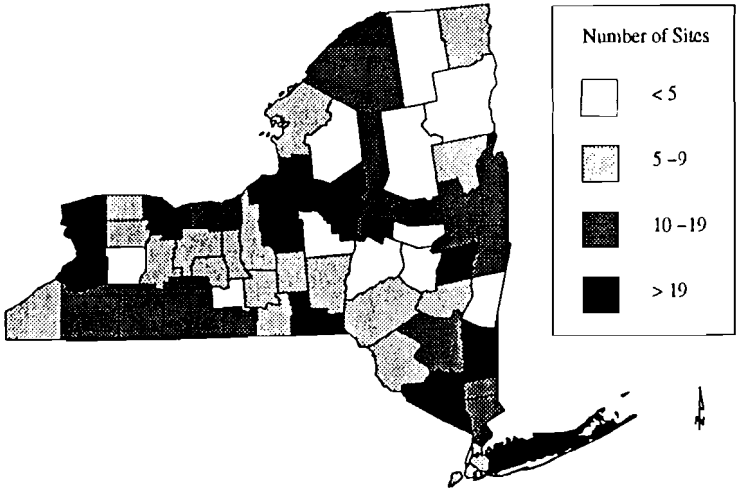

Figure 1. Inactive Waste Sites in New York State Counties.

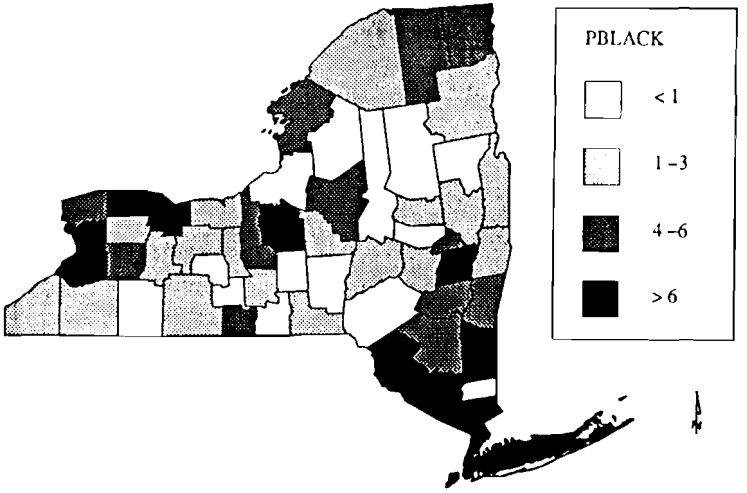

Figure 2. Percentage of Black Population in New York State Counties.

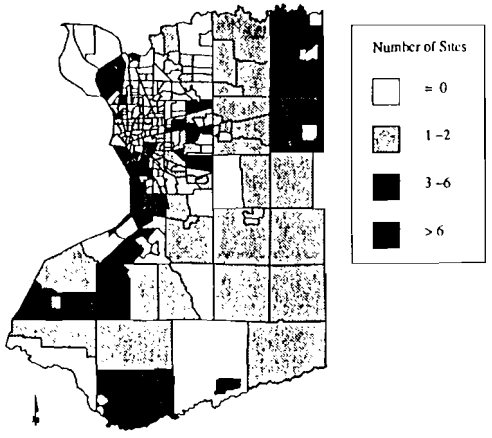

Figure 3. Solid Waste Sites per Census Tract in Erie County, New York.

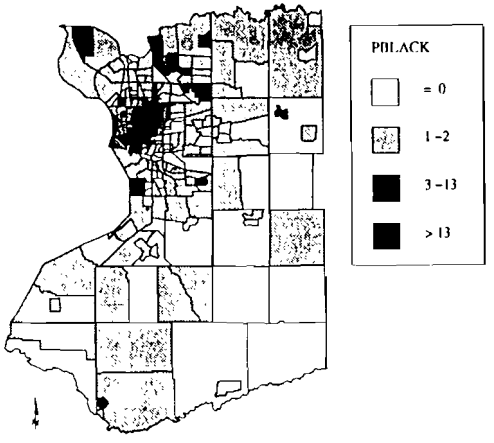

Figure 4. Percentage of Black Population for Census Tracts in Erie County, New York.

minority communities, while negatively correlated with income and population density. The findings of this analysis at the census tract level are mixed. The relationship with environmental risk is negative for minority communities and density, while there is no significant relationship with income.

This analysis clearly demonstrates the inconsistency of research findings as a result of changing scale. Generally, variables which have a statistically significant correlation coefficient with the number of sites at one scale are also significant at other scales. However, the correlation coefficients at the census tract and blockgroup scales have signs opposite those observed at the county scale. The above findings are congruous with those of Openshaw and Taylor (1977) and Anderton et al. (1994), who found that changing scale not only changes data values but also changes statistical inferences. Hence, county level analysis might be suitable for studying the link between the number of sites and urbanization or population density, but may be unsuitable for studying the links between sites and racial composition. The variation of racial composition and the specific location of sites within the county are critical to understanding the links between them.

SUGGESTIONS FOR FUTURE RESEARCH

Given the influence of scale on empirical studies in environmental equity research it is imperative that techniques be developed to address the problem. One approach would be to employ sensitivity analysis by modeling at several scales in order to examine and better understand the scope and extent of scale effects. Such an approach may also enable the researcher to determine the appropriate scale of analysis for particular variables. A second approach is to model the phenomenon under study at several scales simultaneously. Recent advances in statistical analysis enable researchers to model both micro and macro effects at once (Jones, 1991a, b). Finally, by using buffered zones around environmental risks at various scales and areal interpolation, the analysis can focus on the "affected population" surrounding risks independent of the underlying geography.

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