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A Case Study on Assessment of Environmental Justice using GIS in Franklin County, Ohio, USA

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ABSTRACT

Environmental justice is a growing concern in the United States. This study is an attempt to assess if fairness exists when it comes to the population of Franklin County concerning the location of industries based on environmental laws. Industries in Franklin County are taken into consideration and the areas surrounding it to assess the concern of environmental justice using tools in geographic information systems (GIS). This study concentrates on Franklin County as it is one of the most populated counties in Ohio as of 2019. Eleven major cities and industrial facilities are selected in Franklin County. A 4-mile buffer zone is considered around each city using ArcGIS to find the number of industries surrounding them. Pollution is gauged with the count of industries in the considered buffer zones. This study assumes that the number of industries is directly proportional to pollution. Minority and low-income data are extracted from the US Census Bureau. The number of minorities and low-income populations in the considered buffer zone is found using ArcMap. Minority population and income brackets of the population in a buffer zone are compared to the extent of industrial facilities in the same buffer zone. Statistical analysis is performed on the samples to find the correlation between the extent of industrial facilities and minorities to assess Environmental Justice. Another buffer is created using a 14-mile radius (with the centroid of the Franklin County as center) is created using EJSCREEN version 2019 to compare environmental indicators and demographic indicators with the NAAQS standard pollutants. A comparative analysis is performed to evaluate the results. The results indicate that there is no significant correlation between the minority population and industries in the selected 4-mile buffer zones. This approach can apply to any small geographic areas such as counties, zip codes, and census tracts to assess environmental justice.

1. Introduction

Securing the Earth is at times seen as an extravagance - something individuals care about just when they have a lot of recreation time and discretionary cash flow [1]. By and by, low-pay networks and minority ethnic groups regularly bear the most serious outcomes of natural corruption and contamination [2]. This issue influences both national and universal circles [3]. Dangerous waste dumps may frequently be situated in poorer areas, and poisonous squanders might be delivered to low-income countries where controls administering toxics are feeble or nonexistent [4]. Ecological contaminants may likewise be conveyed long separations, influencing networks a long way from their origin. Some may contend this is only how the market works since more economically developed countries can manage the cost of better natural assurance [5]. Others battle that the issue includes more extensive inquiries of human rights and major equity, requiring national approaches, or global understandings, to alter the activities of unregulated markets [6].

The environmental justice movement was started by individuals, primarily people of color, who sought to address the inequity of environmental protection in their communities [7]. The fight for environmental justice took off in 1982 when residents of warren county, North Carolina against a plan to dump contaminated soil in a landfill in their community [8]. In 1987, the United Church of Christ Racial justice commission found that around the country, hazardous waste facilities are most likely to be in mostly minority communities [9]. So, in 1992 President George H.W. Bush founded the office of environmental justice inside of EPA [10]. In 1994, President Bill Clinton signed an executive order requiring federal agencies to consider Environmental Justice in all their policies as well as extending civil rights protections to environmental discrimination [11]. Then in 2001, George W. Bush shifted the focus of the Office of Environmental Justice from protecting low-income and minority communities to 'all people' leaving vulnerable populations without a

federal environmental advocate [12], and in 2009, Barack Obama's administration recommitted to Environmental Justice and advanced a healthy, sustainable future [13]. Later in 2016, Lisa P. Jackson established environmental justice as an agency-wide priority [14, 15].

The current study is an attempt to assess environmental justice in Franklin County, Ohio. This method is usually applied to small geographic areas like counties, zip codes, census tracts, etc. The capital of the state of Ohio is situated in Franklin County, which is one of the most populated counties in Ohio according to the 2010 U.S. Census Bureau. GIS has a wide range of applications in the field of Environmental Justice. This study uses ArcMap tools and the JASP 0.12.2.0 version to perform the analysis.

2. Experimental Methods

GIS is a framework to perform operations like manipulation, summarize, query, edit, and visualize data with spatial and non-spatial information. In simple terms, GIS refers to information about a particular place/location on the surface of the earth. GIS has been utilized widely as of late for assessing ecological hazards and investigating natural equity. GIS considers the integration of different information sources, the geographic portrayal of affected areas, and the use of investigative systems for processing the statistic attributes of such regions. Thus, ArcGIS is especially appropriate for this category of research. Researchers have connected GIS and myriad spatial and factual techniques to examine imbalances in the spatial circulation of risks, for example, landfills [16].

2.1 Framework

The current study concentrates only on the assessment of Environmental Justice in Franklin County as it is one of the most populated counties in Ohio and so there is more scope for the results to be justified. In this paper, industries in Franklin County are taken into consideration, and the areas surrounding it to assess environmental justice. There are 11 major cities in Franklin County and for each city, a 4-mile buffer is drawn around it using GIS to find the number of industries surrounding them.

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With the number of industries, pollution is gauged. That means this study assumes that the number of industries in a particular area is directly proportional to the amount of pollution emitted. After the buffers for each city are created, the number of minorities and low-income populations in that buffer zone is found using tools in GIS, this data is extracted from the US Census Bureau. Minority population and income brackets of populations in a buffer zone are compared to the extent of industrial facilities in the zone. Later, a t-test is performed on the samples along with regression statistics to find the correlation between the extent of industrial facilities and minorities to assess Environmental Justice. The step-by-step procedure followed to complete the assessment of Environmental Justice is represented in Fig. 1.

Fig. 1 Flowchart representing method to complete the assessment of environmental justice

2.2 Data Collection

The demographics including population, ethnicity, race, minority, and low-income data are collected to assess environmental justice around industries in Franklin County. Demographics such as a total population, percentage minority in Franklin County are directly extracted as tiger line shapefiles from the United States Census Bureau website. The data on the number of industries in Franklin County is collected from the USEPA website in an excel file. From statistical atlas, data of population in different income brackets are shown as geospatial data so it is easy to compare it with results. Data collected from the sources are converted to CSV files and extracted so they could be used in ArcGIS readable format.

Fig. 2 Location of the study area (Franklin County) in USA map
<https://doi.org/10.30799/jespr.219.22080102>

2.3 Demographic Information

The basic demographic information of Franklin County as per 2020 Deloitte Datawheel [17] includes:

- Population - 1.31 Million (1.42% Growth)
- Median Age - 34.1
- Median household income - \$60,373 (1.93% Growth)
- Poverty rate- 16.7%
- Number of employees- 686,173 (1.68% Growth)
- Median property value - \$186,500 (8.05% Growth)

3. Results and Discussion

Franklin County map is extracted from the US map by selecting the county and creating a new layer out of the selected feature and naming it Franklin County, Ohio. The data collected is extracted and made into the ArcGIS readable format. The data tables are joined to the existing demographics data by using join and relates to the Franklin County layer. The industries situated in Franklin County are pointed out on the map. Industries in the county are pointed out as orange triangles (Fig. 3). Industrial clusters situated to a large extent can be identified using this process.

Fig. 3 Considered cities and industries represented on Franklin County map

3.1 Buffer Analysis

Buffer Analysis is used to identify the industries and demographics in the area surrounding the cities [18]. GIS software tools give buffer creation abilities. A buffer is a region of an indicated width that encompasses at least one map feature. Making buffers involves the production of new territories from a point, line, or territory which are included in a current GIS database [19]. Buffer zones empower us to look at regions influenced by exercises happening at or close to the map features. GIS-based investigations of natural equity have commonly depended on the utilization of circular buffer zones around point highlights employed in this paper to find the number of industries around the cities [20]. The steps involved in the buffer analysis are:

1. City-wise demographics in Franklin County are collected.
2. 11 cities in Franklin County and 776 industries are considered for analysis.
3. A 4-mile radius buffer zone is created around each city.
4. One city is selected at a time to perform the analysis.
5. Data required for statistical analysis were extracted.

3.2. Intersection

An Intersection tool is used to calculate the number of industries around the cities layer. The intersection tool figures the geometric convergence of any number of feature classes and feature layers. The features, or bits of features, that are regular to all data sources will remain in the output feature class [21,22].

1. Using an intersection tool in the geoprocessing from the toolbar is used to intersect the buffers created to intersect the industries' layer and city layer.

2. Creation of the attribute table which gives only the number of industries in that buffer zone and the demographics of the pertinent city.
3. Segregation allows us to compare the number of industries with the number of minorities in each area.

Figs. 4-6 represents the final output maps of the buffer zones created for 11 cities in Franklin County, Ohio. The 11 cities include Hillard, Upper Arlington, Dublin, Columbus, Worthington City, Gahanna, Reynoldsburg, Baxley, Westville, Whitehall and Grove City.

Fig. 4 Buffer zone of Hillard, Upper Arlington, Dublin and Columbus

Fig. 5 Buffer zone of Worthington City, Gahanna, Reynoldsburg and Baxley
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Fig. 6 Buffer zone of Westville, Whitehall and Grove City

3.3 Statistical Analysis

The major information necessary for this analysis includes the statistics of major minorities present in the cities considered and industries present within the considered 4-mile buffer zone (Table 1).

3.3.1 Using t-Test: Two-Sample Assuming Unequal Variances along with Regression Statistics

A T-test is performed on the data to find the P-value which tells us the calculated probability of finding if environmental injustice exists as in the questions, are more minorities living around the areas with more industries is answered. All the data is collected in excel and the t-test: two samples assuming unequal variances is performed. The percentages of industries and the percentage of minorities in a buffer zone are categorized into two tables.

The t-test is performed on these two tables to find the P-value. Information of the demographics and industries in the 4-mile buffer zones in the cities are represented in Table 1. Results of t-Test for Two-Sample Assuming Unequal Variances are represented in Table 2. The P-value is 0.3, which is not very significant and shows that the minority population in an area is not correlated to the number of industries in the selected buffer zones.

Table 1 Information of the demographics and industries in the 4-mile buffer zones in the cities

Cities	Black	Hispanic	Total Minority	Franklin Minority	% of Minority	Industries in 4-Mile Buffer	% of Industries
Upper Arlington	200	330	530	215475	0.25	179	23.07
Dublin	543	317	860	215475	0.40	10	1.29
Hilliard	357	426	783	215475	0.36	136	17.53
Columbus	174065	17471	191536	215475	88.89	99	12.76
Worthington	241	138	379	215475	0.18	46	5.93
Gahanna	2657	430	3087	215475	1.43	42	5.41
Reynoldsburg	3347	578	3925	215475	1.82	24	3.09
Bexley	592	121	713	215475	0.33	117	15.08
Westerville	1131	379	1510	215475	0.70	20	2.58
Whitehall	3678	566	4244	215475	1.97	71	9.15
Grove City	418	318	736	215475	0.34	32	4.12

Table 2 Results of t-Test for two-sample assuming unequal variances

	Total Minority	Industries in the 4-mile buffer
Mean	18936.64	70.55
Variance	3278953526	3030.47
Observations	11	11
Hypothesized Mean Difference	0	
df	10	
t Stat	1.09	
P(T<=t) one-tail	0.15	
t Critical one-tail	1.81	
P(T<=t) two-tail	0.30	
t Critical two-tail	2.22	

3.3.2 Correlation Analysis

The correlation plot between total minority and industries in the selected 4-mile buffer zone is represented in Fig. 7. The scatter plot indicates that the correlation is positive. However, the relation is not significantly correlated because the further the data are from the line of fit, the weaker the correlation. If the correlation is perfect, the data points lie directly on the line of fit. In order to identify the factors that are strongly or weakly correlated to the industries in the considered buffer zones Pearson's, Spearman's rho, and Kendall's tau B correlation coefficients are generated and compared. The results of these correlation coefficients and the respective probability values are presented in Table 3. All the correlation analysis results are generated using JASP Version 0.16.

Fig. 7 Correlation plot between total minority and industries in selected 4-mile buffer zone

3.3.3 EJSCREEN Analysis

The centroid of Franklin County is located on the map. Then a 14-mile radius buffer zone (Fig. 8) was drawn with the centroid of Franklin County as the center and considered 11 cities are inside the buffer zone. An EJ report was generated for comparison of the other environmental and demographic indicators to analyze the environmental justice in Franklin County using EJSCREEN, version 2019.

Fig. 8 The 14-mile buffer created EPA's EJSCREEN
<https://doi.org/10.30799/jespr.219.22080102>**Table 3** Correlation table of the NAAQ pollutants within the 4-mile buffer of 11 cities

Industries in 4-Mile Buffer	Pearson		Spearman		Kendall	
	r	p	rho	p	tau B	p
Particulate Matter (PM 2.5 in ug/m ³)	0.558	0.074	0.577	0.063	0.449	0.059
Ozone (ppb)	-0.304	0.363	-0.369	0.264	-0.256	0.295
NATA Diesel PM (ug/m ³)	0.514	0.106	0.473	0.146	0.382	0.121
NATA Air Toxics Cancer Risk (risk per MM)	0.350	0.292	0.411	0.210	0.366	0.143
NATA Respiratory Hazard Index	0.521	0.100	0.535	0.090	0.486	0.041
Traffic Proximity and Volume (daily traffic count/distance to the road)	0.133	0.697	0.311	0.353	0.278	0.240
Lead Paint Indicator (% pre-1960s housing)	0.646	0.032	0.691	0.023	0.636	0.006
Superfund Proximity (site count/km distance)	-0.006	0.987	0.219	0.518	0.147	0.532
RMP Proximity (facility count/km distance)	0.650	0.031	0.806	0.003	0.587	0.012
Hazardous Waste Proximity (facility count/km distance)	0.648	0.031	0.664	0.031	0.491	0.041
Wastewater Discharge Indicators (toxicity-weighted concentration/m distance)	-0.174	0.609	-0.173	0.614	-0.091	0.761

There are a total of 776 industries around 4-mile buffer zones near 11 cities in Franklin county, Ohio. The pollutants considered from the National Ambient Air Quality Standards according to USEPA for this analysis are includes Particulate Matter (PM 2.5 in ug/m³), Ozone (ppb), NATA Diesel PM (ug/m³), NATA Air Toxics Cancer Risk (risk per MM), NATA Respiratory Hazard Index, Traffic Proximity and Volume (daily traffic count/distance to the road), Lead Paint Indicator (% pre-1960s housing), Superfund Proximity (site count/km distance), RMP Proximity (facility count/km distance), Hazardous Waste Proximity (facility count/km distance) and Wastewater Discharge Indicators (toxicity-weighted concentration/m distance).

Some of these environmental indicators quantify proximity to and the numbers of certain types of potential sources of exposure to environmental pollutants, such as nearby hazardous waste sites or traffic. The lead paint indicator indicates the presence of older housing, which often, but not always, indicates the presence of lead paint, and therefore the possibility of exposure. In some cases, the term "exposure" is used very broadly here to refer to the potential for exposure. Other indicators in EJSCREEN are estimates of ambient levels of air pollutants, such as PM2.5, ozone, and diesel particulate matter. Still, others are actual estimates of air toxics-related cancer risk or a hazard index, which summarizes the ratios of ambient air toxics levels to health-based reference concentrations. In other words, these environmental indicators vary widely in what they indicate.

Figs. 9-11 represent Pearson's, Spearman's rho, and Kendall's tau B correlation analysis to compare the significance of the relation between the considered pollutants.

Fig. 9 The Pearson's correlation heat map of the NAAQ pollutants in the considered buffer zones

Fig. 10 The Spearman's rho correlation heat map of the NAAQ pollutants in the considered buffer zones

Fig. 11 The Kendall's tau B correlation heat map of the NAAQ pollutants in the considered buffer zones

As per the Pearson correlation results, the environmental indicators including ozone concentration, superfund proximity, and wastewater discharge indicators show a negative relationship to the industries within the 4-Mile buffer of each city in Franklin county. All the other environmental indicators show a moderately positive relationship. However, the Spearman and Kendall correlation results indicate that only ozone and the wastewater discharge indicators are the only two environmental indicators that show a negative correlation, and all the other environmental indicators show a moderately positive correlation to the industries within the 4-Mile buffer of each city in Franklin County. Overall, the lead paint indicator, RMP proximity, and hazardous waste proximity are the three environmental indicators that are on the upper boundary of a highly moderate positive relationship. These observations support the fact that higher-income people choose to live away from the industries as opposed to the lower-income population.

4. Conclusion

Assessment of environmental justice is performed on eleven cities in Franklin County using GIS tools in the current study. A 4-mile buffer zone is considered around the cities. Geographic and industrial data are plotted using ArcGIS. Demographic data is analyzed using t-Test: (Two-Sample Assuming Unequal Variances). The correlation is assessed based on the $P(T \leq t)$ two-tail. In the performed analysis alpha value is set at 0.05, if the p-value is less than 0.05, there is a statistically significant difference between the minority population and industries in the selected 4-mile buffer zone. In current study, $p = 0.3$, which is > 0.05 , so the difference is not significant. It can be concluded from the analysis that there is no significant correlation between the minority population and industries in the selected 4-mile buffer zones. One of the common observations includes that higher-income people choose to live away from the industries as opposed to the lower-income population. This method can be a simple approach to assess Environmental Justice in small geographic areas such as counties, zip codes, and census tracts.

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