Abby Primack, Caitlin Clark, Andrew Hood

Earlham College, 12/13

Identification and Prediction of Environmental Racism in Indiana

Introduction:

Environmental justice is defined as the fair and meaningful treatment under the law and enforcement of environmental laws and regulations without regards to race, ethnicity, gender, or socioeconomic circumstance (Chavis 2009, EPA 2013). Although it calls for all people to have an equal contribution and participation about the regulation of activities that may negatively affect their health and environment, entire communities and populations are often overlooked and underrepresented. The environmental racism movement calls for the recognition that minority communities and individuals are burdened with a disproportionate share of environmental risk while not having economic alternatives or political power to take an active part in environmental decision making (Chavis 2009, EPA 2013). Those who have the economic means and political power are able to enjoy protection from environmental health hazards while having access to the decision-making processes.

Environmental justice can be measured using three categories: procedural equity, geographic equity, and social equity (Bullard 2002). Procedural equity occurs with the uniform application and enforcement of laws in a nondiscriminatory manner, such as providing multi-lingual public hearings scheduled at easily accessible locations. Geographic equity occurs when the location and proximity of communities is evenly spread with regards to socioeconomic factors with proximity to noxious facilities and environmental hazards. Social equity refers to the role of socioeconomic factors in environmental decision-making and has strong ties to the environmental racism movement.

We used ArcGIS 10.1 to investigate the correlation between geographic equity and hazardous environmental exposure in Indiana. We chose to look at both of these factors in relation to health and disease. As our research team currently attends a four-year school within the state, we find this research valuable and important when trying to understand our surroundings.

Indiana is a Midwestern state with a population of 6,537,334 (U.S. Census Bureau 2011). Since 2000, the general poverty rate and the poverty rate for children under 18 have almost doubled to 15.8% and 22.6%, respectively. Although the unemployment rate for Indiana is 8.4%, 0.2% higher than the national average, the state ranks #1 in the United States at 17.1% for employment in manufacturing. Manufacturing is the production of goods using tools such as chemical and biological processing and well known for exposing workers to hazardous wastes. (OSHA)

Manufacturing companies in Indiana include the Great Lakes Chemical Corporation and Transilwrap. The Great Lakes Chemical Corporation in West Lafayette, IN produces specialty bromine-derived chemicals that can have neurological, respiratory, and kidney effects (Darnerud 2003, CorpWatch, Great Lakes 2013). Transilwrap, based in Richmond, IN, is a plastics extruder and uses substrates such as styrene to produce polyester, polypropylene, and synthetic papers (Transilwrap 2012). Styrene exposure is linked to negative effects in the central nervous system and increased spontaneous abortions (EPA 2000, Tranfo et al. 2012).

Debilitating health effects, including cancer, endocrine disruption, and birth defects, can result from both occupational exposure and unintentional environmental exposure (EPA 2013). Hazardous wastes produced as byproducts by manufacturing companies are often leaked into the environment through improper or illegal disposal. The waste's environmental impacts are dependent on a set of properties, including short- and long-term toxicity, persistence, dispersion, chemical reactions the compound can undergo, bioaccumulation tendency, and ease of control (Holdgate 1979 as read in Alloway and Ayres 1993). Chemical properties and persistence can be exacerbated by the environmental properties and location of the site. Many different organizations such as the WHO, EPA and CDC have established safe levels for pollutants as many pollutants such as lead, sulfur dioxide and carbon monoxide, among others, have been linked to diseases such as birth defects, lung cancer and nervous system damage (Air quality and health 2011 and Health-based Guidelines 2013).

We predicted a positive correlation between the locations of high emissions and hazardous waste with areas of higher child poverty and minority populations. We also predicted higher rates of birth defects and cancer as a possible result of high prolonged pollutant exposure from airborne emissions and hazardous waste during in-utero and juvenile development. In addition to investigating birth defects, we also researched the relationship between lead, particulate matter, ammonia, carbon monoxide (CO),sulfur dioxide (SO2), nitrous dioxide (NO2), and volatile organic compounds (VOC's) and cancer rates (lung, colon, breast).

Methods:

Emission Index:

Everything except for statistical analysis was completed in ArcMap 10.1, while the statistical analysis was completed in SPSS 19. Emission data was downloaded from the internet and then imported into ArcMap. Then this data was interpolated which allowed us to create a gradient of emission from individual points. This interpolation was completed for each pollutant: Lead, SO_2, NO_2, Particulate Matter, Carbon Monoxide, Ammonia and Volatile Organic Compounds. Then these interpolations were reclassified and given weights for each pollutant (for more information see the Appendix). Once these interpolations were completed, they were added together to give a total emission map (see Figure 1).

Hazard Index:

The hazard index was created from the following 9 layers which were downloaded from the internet: industrial waste sites, cleanup sites, brownfield sites, waste treatment storage disposal, waste disposal storage handling, public airports, superfund sites, mine entries and ethanol production. These features were given buffers and these buffers were given weights (see appendix for further details). Then these features were added together to form a hazard index **(see Figure 2)**.

Impaired Streams:

Impaired streams were downloaded from the internet. They were reclassified based on how many pollutants were present in each stream. This data was then weighted giving streams with more pollutants a higher weight (see appendix for further details).

Environmental Index (EI):

An environmental index was created through the addition of total emission, the hazard index and the impaired streams (see Figure 3).

Health and Socioeconomic Data:

Health data for total cancer, breast cancer, lung cancer, colon cancer and birth defects was downloaded from the internet and then normalized by population to control for different population sizes. Socioeconomic data such as child poverty, household income and high school graduation rate was also downloaded from the internet. High school dropout rate was determined by: 100 - graduation rate.

Analysis:

Finally, random points were created for Indiana and information was extracted from individual pollutants, total emissions, hazard index, impaired streams, EI, health data and socioeconomic data. This data was then statistically tested in SPSS by using a linear regression to determine if there was a correlation between any of this data. For more information about the methods used in this paper see the appendix for further details.

Results/ Discussion

Superfund sites are defined as uncontrolled or abandoned sites of hazardous waste and brownfield sites are properties with potential contamination (EPA 2013). We found that 53.01% of superfund sites and 43.1% of brownfield sites were located in areas of medium to very high child poverty (16.12 - 55.63% poverty rate) (Figure 4). In addition to superfund and brownfield sites, 44.6% of industrial waste sites are located in areas of of medium to high child poverty and 18.6% in areas of high to very high child poverty (23.73-55.63% poverty rate). Although funds are dedicated for cleanup, only 17.3% of clean-up sites are in areas of high to very high child poverty and 36.8% in areas of medium to very high child poverty.

We found that birth defects increase as ammonia levels and hazard index increase (Table 1). Although there were significant results linking an increased rate of birth defects and ammonia, no supportive literature could be found supporting the evidence (ATSDR 2004). In spite of the fact that we did not find significant results relating frequency of birth defects to the single elemental impacts of SO2, NO2, polluted streams, and lead, various combinations of those pollutants are found in sites listed in the hazard index, the hazard index has a significant positive correlation with an increase in birth defects (Figure 5, Table 1). Negative effects linking exposure to the hazard index and subsequent health problems is to be expected, as the index reflects the location of hazardous waste emission points and storage sites. The National Research

Council Committee on Environmental Epidemiology (1991) reported that in 1991, 40 million people lived within 4 miles of a Superfund site which raises the question, how many of these 40 million individuals suffer from negative related health effects?

Significant results relating various chemical exposures to birth defects are not unique to Indiana, but are recorded across the U.S. as well. A nationally representative study of pregnant women found that levels of 163 tested individual chemicals, including PFCs, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons, were detected in 99-100% of women (Woodruff et al. 2011). Although a majority of the women tested were a nationally representative group, the broad spectrum of chemical identification suggests that even women who do not reside in close proximity to a hazardous waste site are at a high risk for chemical exposure. The study found that over 99% of nonpregnant and 94% of pregnant women had blood lead levels over the LOD (limit of detection), which is 0.28 µg/dL of blood lead content. We predict that women living near hazardous sites will have an even greater level than the national average of absorbed chemicals in their bodies.

Lead is a highly detrimental element that affects almost all systems in the body if ingested or inhaled (EPA 2012). High levels of lead target the brain and central nervous system and detection of blood levels as low as 10 ug/dL can lower IQ, cause delays in mental and physical development, shorten attention spans, and cause an increase in behavior issues (CDC 2013). Studies have also found significant associations between blood lead levels of mothers and birth weights, with 5-10 ug/dL associated with an average of 61 g and 87 g decrease in birth weights, respectively (Zhu et al. 2010). Lead absorption in children can be lessened through ingesting normal amounts of iron and calcium, which are found in eggs, red meat, and dairy.

However, families living in poverty may not have reliable access to funds necessary to reliably purchasing nutrient-dense food, and thus may resort to buying low nutrient foods from fast food restaurants which comprise from 15-74%, with an average of 50%, of restaurants in Indiana (County Health Rankings and Roadmaps 2013). This means that people in lower economic classes may not have the nutrition necessary to prevent prenatal and juvenile developmental complications such as birth defects and developmental delays, thus perpetuating the cycle of exposure to potentially preventable high risk situations. Structural issues can result in food-insecure areas, known as food deserts, that can lead to an inability to promote social mobility, neighborhood stability, successful students, and potential for job creation. This is a clear example of a wider structural issue in environmental injustice. Having the ability to prevent lead-related illnesses by having access to proper nutrition should be an easily preventable issue, but due to a variety of other factors it is not. (Bluestone 2013).

Although we did not find any significant correlation between emissions of individual pollutants or total emission (Table 1), many other studies and organizations have found such correlations and therefore have established pollutant exposure limits. VOC's (volatile organic compounds) include both suspected and proven carcinogens to humans, and exposure can cause nausea, dizziness, dyspnea, and respiratory system irritations (CDC 2012). Although there is no single air quality standard for VOC inhalation, there are inhalation limits associated with individual compounds, ranging from 15 ppm (parts per million) for diesel vapor to 29 ppm for kerosene/jet fuel vapor to 600 ppm for pentane. Although we were unable to calculate daily exposure limits in ppm of certain chemicals with the data available to us, we are able to provide the lowest, highest, and average tons emitted per year by manufacturing companies in Indiana as a general reference for exposure rates (Figure 6, Table 2)

Both sulfur dioxide (SO2) and nitrous dioxide (NO2) are irritants that affect the respiratory tract and can cause decreased lung function and increased asthma symptoms (CDC 2012, EPA 2012). Short-term exposure to low levels of SO2 leads to increased hospital admissions for respiratory illnesses and continual exposure to high NO2 levels are linked to both acute and chronic bronchitis. Fossil fuel combustion at power plants emits 73% of SO2 and other industrial facilities are responsible for the release of 20% of SO2. NO2 emissions result mainly from cars, trucks, power plants, and off-road equipment. The EPA set 24-hour limits for outdoor NO2 exposure as 54 ppb and SO2 at 140 ppb. The two compounds can react with other atmospheric compounds to form PM.

According to the EPA, if particulate matter is inhaled, it can cause premature death in people with existing heart or lung disease, heart attacks, asthma, and irritate the respiratory system. The EPA's health-based national air quality standard for PM-10 is 50 $\mu g/m^3$ (measured as an annual mean) and 150 $\mu g/m^3$ (measured as a daily concentration), and although the average daily measure of PM in Indiana is 13 $\mu g/m^3$, the state ranks in the 90th percentile of particulate matter pollution in the U.S. Studies have found that individuals can lose between 0.7 and 1.6 years of life expectancy attributable to 10 μg/m3 long-term exposure to fine particulate air pollution (Pope et al. 2009). However, although we did not find correlations between emissions health data, we did find correlations when using the environmental index.

We identified 10 counties in Indiana with the highest environmental index values >80 which will be referred to as EI (Cass, Daviess, Howard, Lake, Marion, Tippecanoe, Vanderburgh, Vermillion, Vigo, and Warrick) (Figure 7). EI counties were found to have a 0.13% higher chance of having a child with a birth defect than non-EI counties (see table 2). Although EI counties did not have higher percentages of the population with breast, lung, or colon cancer, the rates were very similar (Table 1). This may be due to the development and epidemiological study of cancer being a slow process, making current data difficult to update. It may also be that cancer is such a complex disease that our environmental index does not include everything and isn't comprehensive enough to establish a relationship cancer rates.

Our results also found a significant inverse relationship between the number of white inhabitants and the environmental and hazard indexes (Table 3). The hazardous and environmental indexes are also correlated with socio-economical factors such as poverty and race, with increased hazardous waste in poorer areas with higher minority populations (Table 3 and 4). These correlations are backed by outside research this strongly suggests that environmental racism is present in Indiana and that minority and economically disadvantaged are disproportionately exposed to hazardous waste (Sicotte and Swanson 2007).

Conclusions / Future Directions

Although many relationships are significant, they are only able to explain a small proportion of the variance of the dependent variables. For example, the relationship between the hazardous index and birth defects was only able to explain 1.4% of the variation in birth defects. This indicates that although our results suggest a correlation between variable, much of the variation is a result of wider, outside factors, many of which may not quantifiable or identifiable. Furthermore, our study did found a correlations with the hazard index and health and socioeconomic variable, but did not find these correlations with emissions.

Further studies with a broader scope may help explain more of this variance. In the future, further investigations focusing on health data such as hospitalization, access to hospitals, and looking at a broader range of emissions that include pollutants from cars, which have been associated with many various ailments (**Gilboa et al. 2005, Padula et al. 2012**). Further studies could also obtain more specific data on industrial emissions that include ppm data as well as specific pollutants being released clearer picture of the effects of pollutants on health could be established.

This is evidence that poorer areas are at a higher risk from hazardous waste and that this is especially for minority groups while whites are at a lower risk (Figure 4). This supports the well established literature on environmental racism that exists and serves to show that this is present in Indiana and that something needs to be done. This should serve as the framework for additional studies to investigate the relationships between the hazardous site index and poverty and racial composition that we found. These studies could find additional evidence for the environmental racism, and might even lead to increased awareness and action towards this issue.

Table 1: Statistical analysis for Total emission, Hazard index, Environmental index, Impaired streams and for individual pollutants when compared to cancer and birth defect rates. Shaded boxes represent significant results, and + R^2 represents a positive correlation while - R^2 indicates an negative correlation. Statistical analyses were completed in SPSS using a linear regression.

	Lung Cancer	Colon Cancer	Breast Cancer	Birth Defect
Total Emissions	F= .531	F= .309	F= .022	F= .016
	P= .466	P= .578	P= .882	P= .900
Hazard Index	F= .241	F= .146	F= .768	**F= 7.968**
	P= .624	P= .702	P= .381	**P= .005 R^2= .014**
Environmental Index	F= 1.153	F= .567	F= 1.138	**F= 7.899**
	P= .283	P= .452	P= .287	**P= .005 R^2= .049**
Impaired Streams	**F= 4.929**	F= 3.636	**F= 6.594**	F= 2.871
	P= .026 R^2= .009 (+)	P= .057	**P= .010 R^2= .012 (+)**	P= .091
Lead	F= .076	F= .002	F= .044	F= .227
	P= .782	P= .964	P= .834	P= .634
Particulate Matter	F= 1.039	F= .525	F= .003	F= .874
	P= .309	P= .469	P= .959	P= .350
Ammonia	F= .302	F= .441	F= .381	**F= 14.760**
	P= .583	P= .507	P= .537	**P= .000 R^2= .026**
Carbon Monoxide	F= .005	F= .026	F= .083	F= .477
	P= .945	P= .873	P= .773	P= .490
SO2	F=.410	F= .065	F= .044	F= .181
	P= .522	P= .801	P= .834	P= .671
NO2	F= 1.091	F= .512	F= .415	F= 1.506
	P= .297	P= .474	P= .520	P= .220
Volatile Organic Compound	F= .008	F= .109	F= .194	F= .006
	P= .929	P= .742	P= .659	P= .939

Table 2: Statistical analysis for Environmental Index, Total emissions and Hazard index and racial composition of areas. Shaded boxes represent significant results, and + R^2 represents a positive correlation while - R^2 indicates an negative correlation. Statistical analyses were completed in SPSS using a linear regression.

	Asian	Black	White	Hispanic
Environmental Index	**F= 9.899 P= .002 R^2= .018 (+)**	**F= 21.664 P= .000 R^2= .038 (+)**	**F= 25.182 P= .000 R^2= .044 (-)**	**F= 22.493 P= .000 R^2= .022 (+)**
Total Emissions	F= .533 P= .466 R^2= .001	F= .872 P= .351 R^2= .002	F= 2.28 P= .132 R^2= .004	**F= 5.389 P= .021 R^2= .010 (+)**
Hazard Index	**F= 28.293 P= .000 R^2= .049 (+)**	**F= 43.035 P= .000 R^2= .072 (+)**	**F= 55.074 P= .000 R^2= .091 (-)**	**F= 26.424 P= .000 R^2= .046**

Table 3: Statistical analysis for Environmental index, Total emissions, Hazard Index, Impaired streams and Child poverty, Household income and high school dropout rates. Shaded boxes represent significant results, and + R^2 represents a positive correlation while - R^2 indicates an negative correlation. Statistical analyses were completed in SPSS using a linear regression.

	Child Poverty	**Household Income**	**High school dropout rates**
Environmental Index	**F= 34.170**	F= .012	F= 1.239
	P= .000	P= .912	P= .266
	R^2= .058 (+)	R^2= .000	R^2= .002
Total Emissions	F= .000	F= .789	**F= 5.529**
	P= .990	P= .375	**P= .019**
	R^2= .000	R^2= .001	**R^2= .010 (-)**
Hazard Index	**F= 52.370**	F= .359	F= 1.372
	P= .000	P= .350	P= .242
	R^2= .086 (+)	R^2= .001	R^2= .002
Impaired Streams	F=	F= 1.559	**F= 8.532**
	P=	P= .212	**P= .004**
	R^2=	R^2= .003	**R^2= .015 (-)**

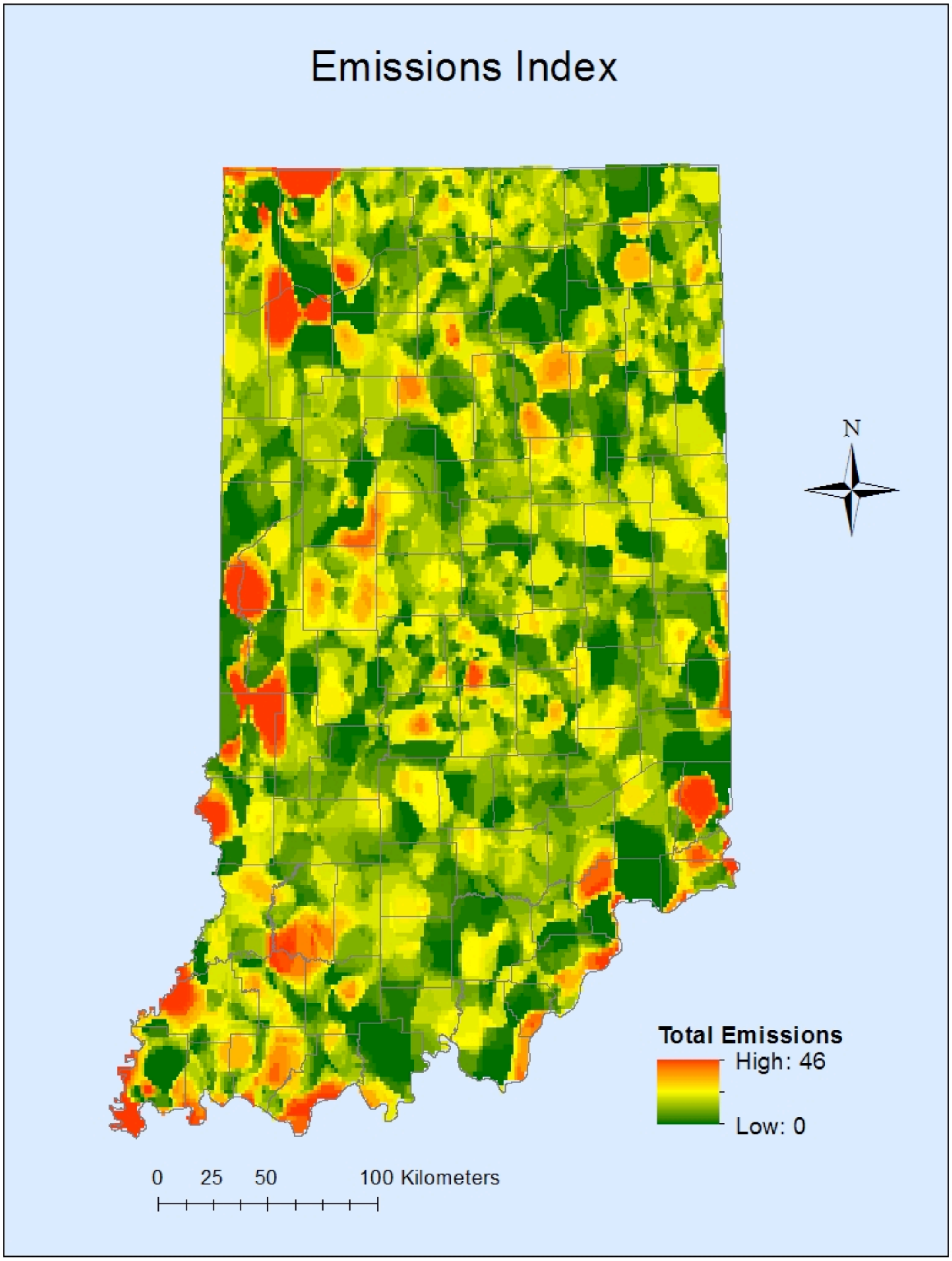

Figure 1: Map indicating total impact of point emitters. Red indicates areas with highest emission rates.

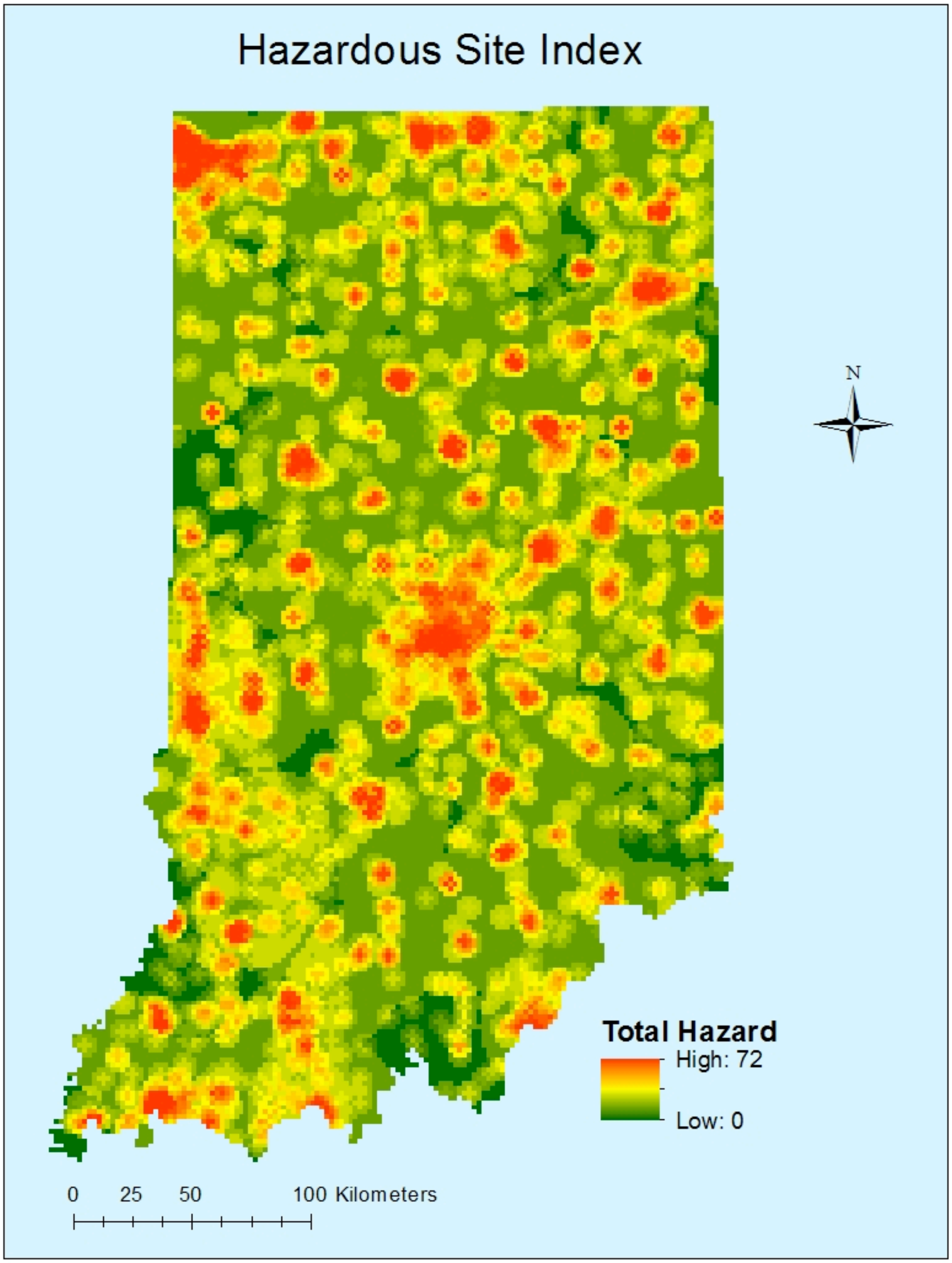

Figure 2: Index indicating the impact of all hazardous sites, including industrial waste sites, cleanup sites, brownfields, waste treatment storage disposal, waste disposal storage handling, public airports, superfund sites, mine entries, ethanol production. Red indicates highest negative impact.

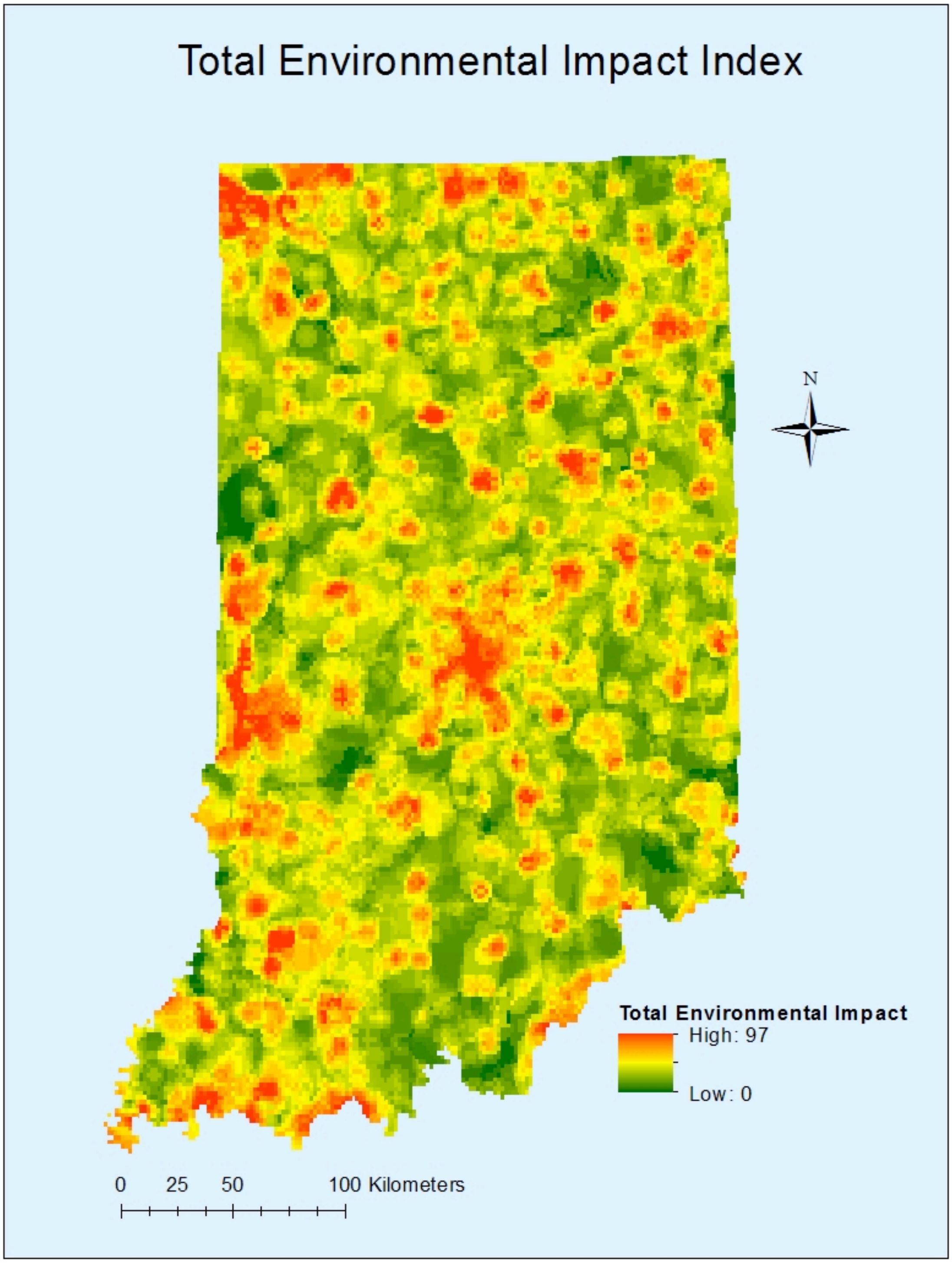

Figure 3: Map indicating total environmental impact index, comprised of Hazardous Site Index, Emissions Index, and Impaired Rivers and Streams. Red indicates areas of highest negative impact.

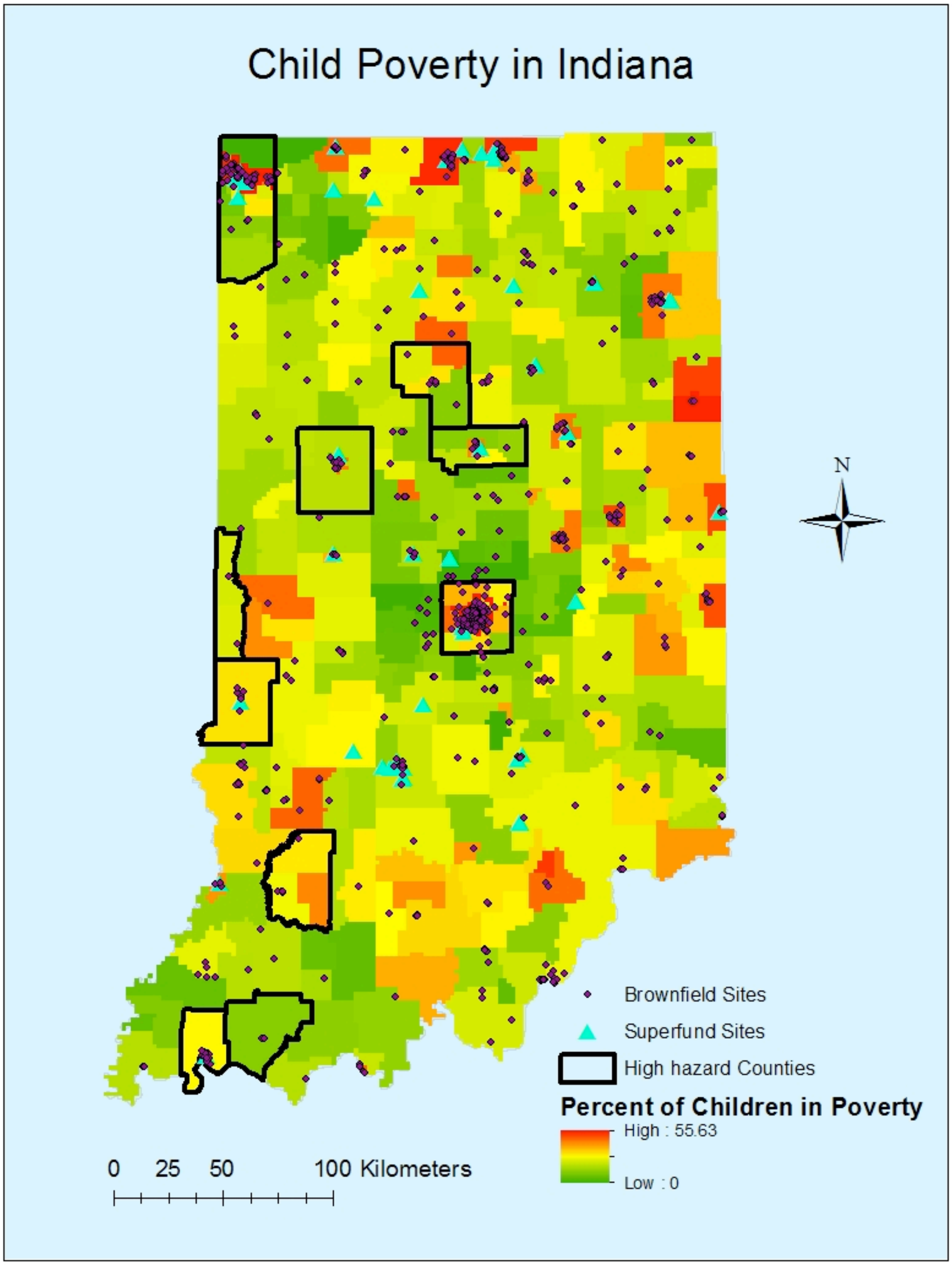

Figure 4: Map of child poverty percentages divided by school districts. Red indicates higher child poverty rates and green indicates lower child poverty rates. Background layer is counties containing an area with an EI value of >80 as well as location of brownfield sites.

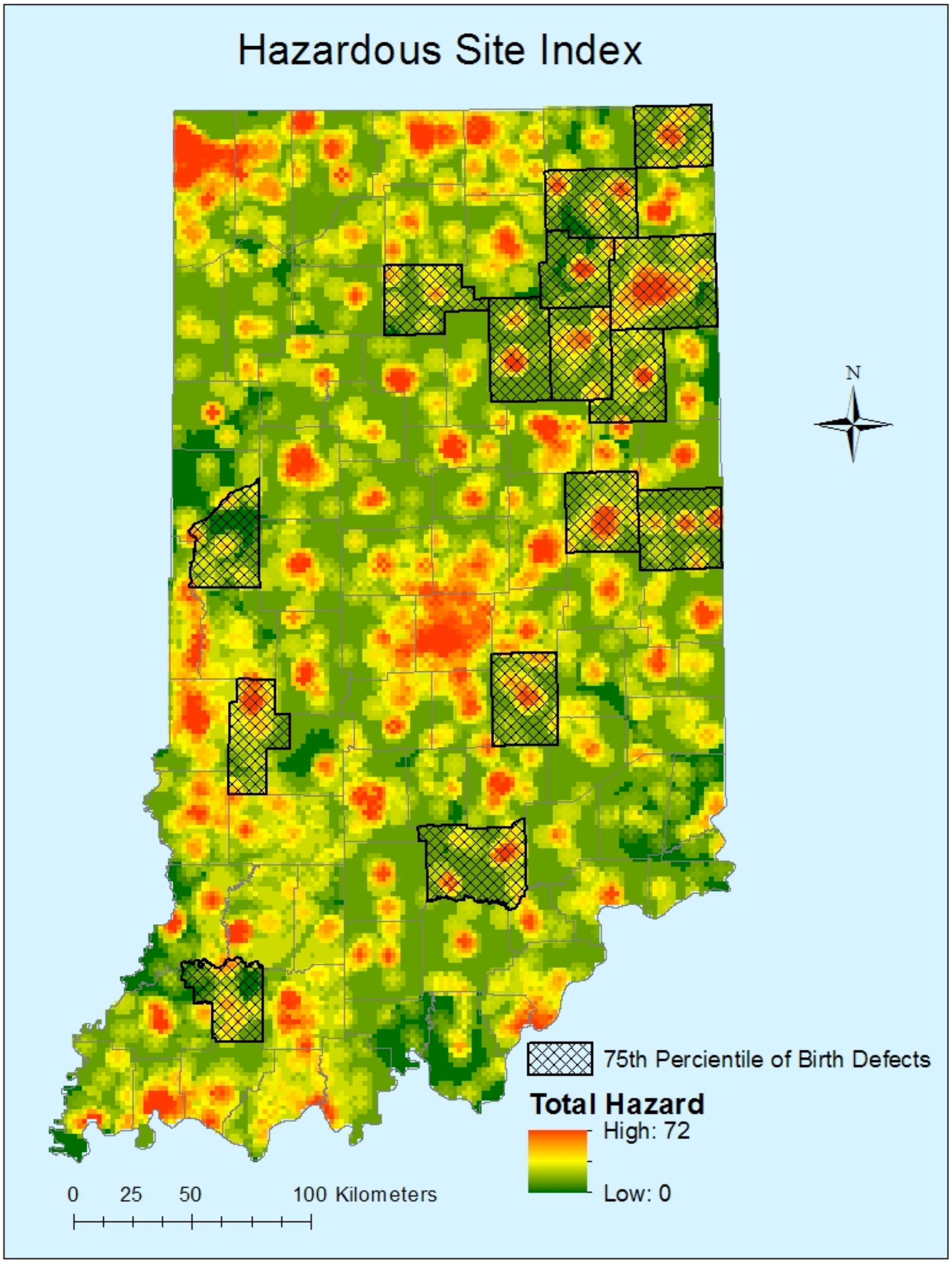

Figure 5: Map of hazardous site index. Red indicates areas with the highest hazardous site impact. Background layer is counties within the top 75th percentile for percent of birth defects.

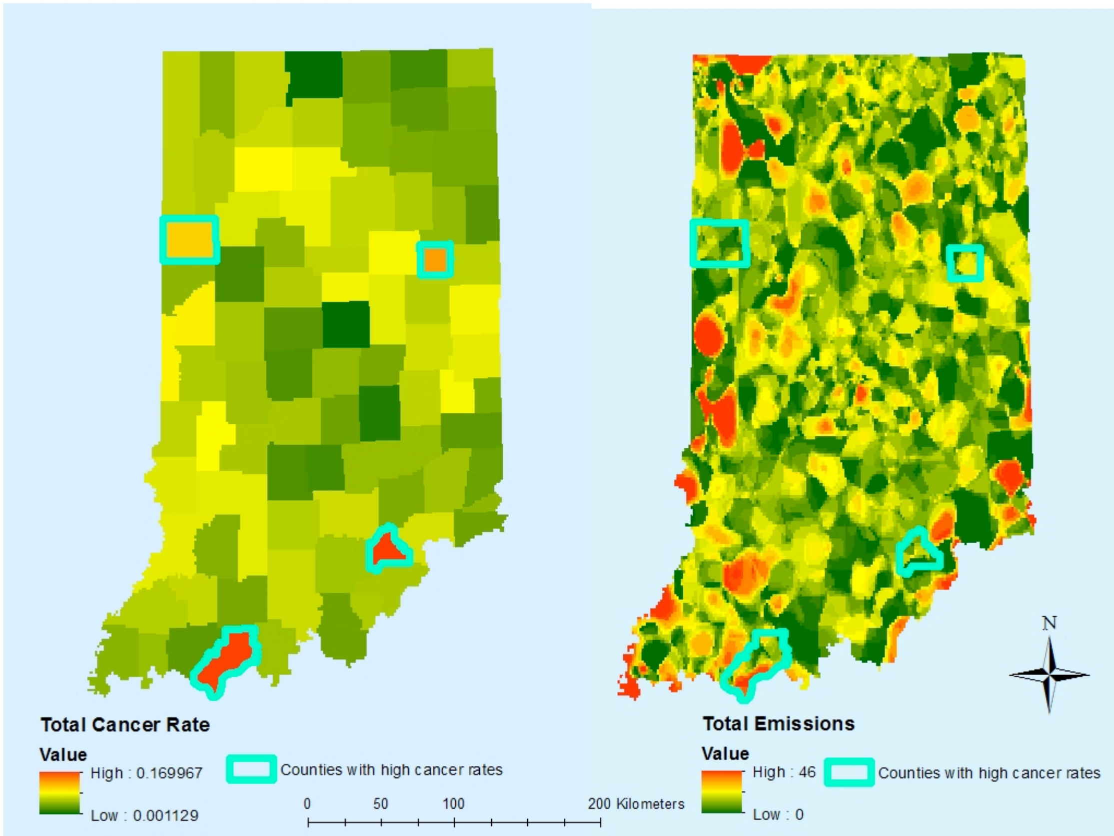

Figure 6: Total cancer rates in Indiana and Total emissions. The blue outline represents the counties with this highest total cancer rates.

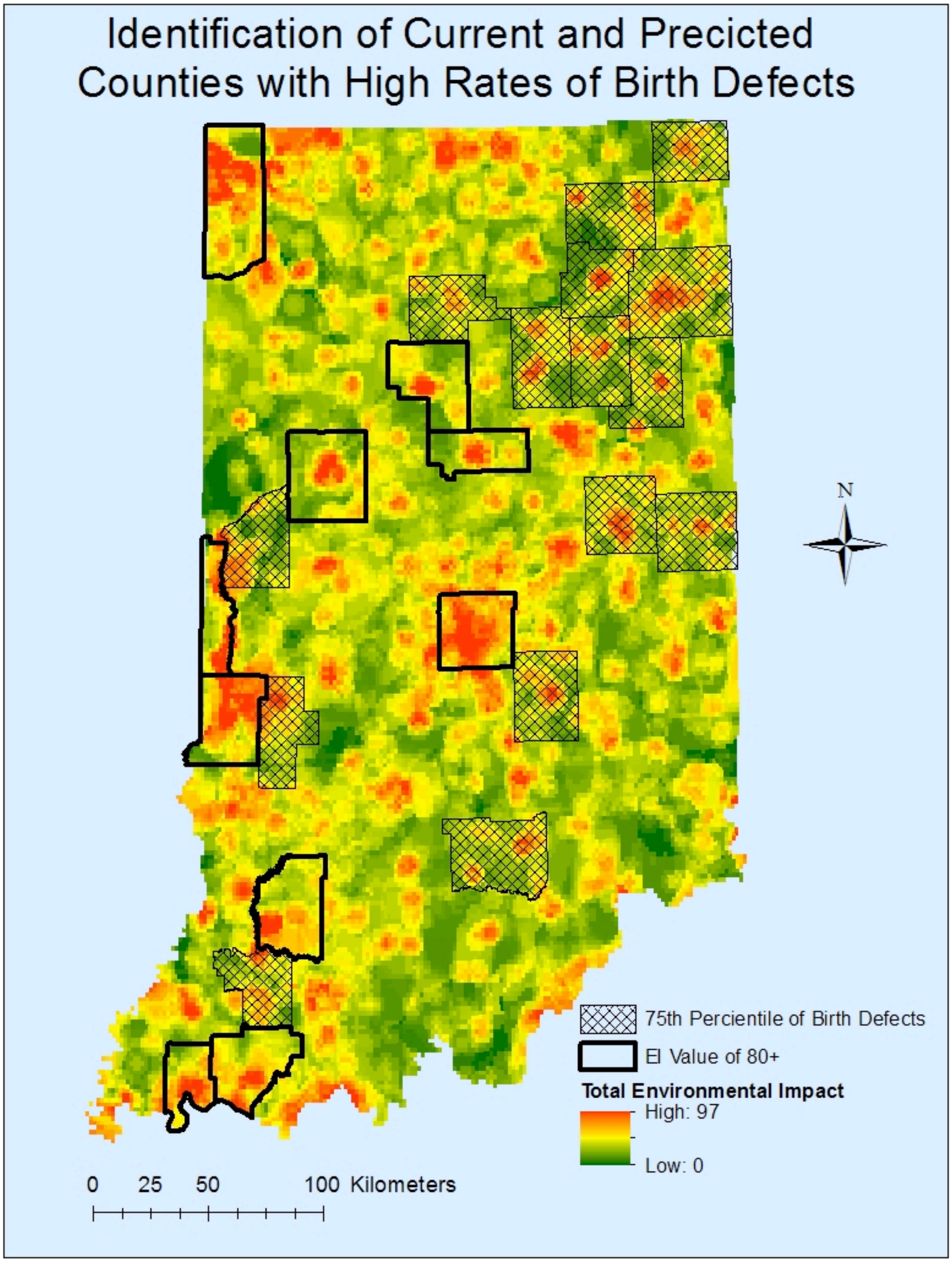

Figure 7: Map comparing location of counties with a high EI value (>80, outlined in black) and counties within the top 75th percentile for percent of birth defects (cross hash pattern). Background layer is total environmental impact index with red indicating the highest negative impact.

Acknowledgements

We would first like to thank Wendy Tori and Jose Ignacio for their invaluable assistance in the final project process that included troubleshooting, conceptual model formation and much more. We would also like to thank our GIS classmates for their helpful ideas and comments on our project. Finally we would like to thank Earlham College for providing us the facilities to conduct this research, and especially the Earlham Biology Department and the Wildman Science Library for access to the computer lab and ArcMap.

GIS Appendix

Emission Raster:

-Emission data was obtained from http://www.epa.gov/air/emissions/where.htm and were downloaded as an excel file.
-Saved as a text file and imported into ARC map
-Rexported into Excel to fix duplicated longitude / latitude points
-Values of 0,0 for the change in latitude and longitude, or data points that had the exact same coordinates were removed from the data. This allowed for ARC Map to run a Spline without an error.
-Emission data was divided into into each of the seven pollutants, VOC, NO2, Carbon Monoxide, Particulate Matter, SO2, Ammonia and Lead through select by attribute.
-Created a spline for each pollutant layer using Indiana as the processing extent
-All of this was done with a cell size of .01799 decimal degrees or 2000 meters
-The spline was then reclassified into categories based on the relative danger and proportion of pollutants (see below for further detail)
-Then the spline was extracted by mask with an extent of Indiana to clip the spline
-Once these rasters had been created for each pollutant, they were added up with the raster calculator to create an emission index for Indiana.
-Additionally, a Moran's I test was run on the emissions layer through spatial autocorrelation

Pollutant classification and weights

Pollutants are listed in order of severity for human health. This was determined through regulations on the amount of each pollutant obtained from the websites below:

(Air quality and health, 2011)

(WHO, urban air pollution kills over 1 million people worldwide every year)
PM: heart and lung disease, lung cancer, lowers life expectancy (10ug/m^3)
NO_2: inflammation of airways, decreased lung function, very harmful to asthmatic children (40ug/m^3)
SO_2: decrease lung function, coughing, bronchitis, more prone to respiratory infections, possible link to cardiac disease, forms sulfuric acid when SO^2 interacts with water (20ug/m^3 24hr)

(Health-based Guidelines, 2013)

CMO: 10 mg/m^3 (8 hr)
PM: 50ug/m^s (24hr), 20ug/m^3 (annual)
NO_2: 100ug/m^3 (24hr)
SO_2: 120ug/m^3 (24hr)
Lead: .2ug/m^3 (3 month), .25ug/m^3 (annual UK 2008) and .5ug/m^3 (annual WHO 1999)
Decrease in academic performance, when exposed to lead prenatally it can lead to mental disabilities,
(Ammonia in drinking-water, 2003)

(WHO information)
Ammonia: toxic effects seen at 200mg/kg, no guideline established for acceptable levels

(An introduction to Indoor Air Quality (IAQ), 2012)

VOC: headaches, organ and nervous system damage, possible links to cancer, irritation of the nose, throat and eyes
Some VOC's are quite dangerous, others have no major health impacts

(Controlling Volatile Organic Compounds Emissions from Industrial Sources in New Hampshire, 2011)

(VOC's in New Hampshire)
Define a major source of VOC's as one that emits over 50 tons per year

Lead was ranked highest because of the very low levels of lead that can lead to serious health issues, Particulate matter was second because higher levels than Lead were needed before restrictions occurred. Then VOC's, NO_2 and SO_2 were ranked equally because they all had a very similar restriction level and health effects. Carbon monoxide was ranked lower because of higher levels were needed for restrictions to be place. Ammonia was ranked last because there are no current restrictions are in place. The three categories were established using a quantile classification. The weights were place depending on the pollutant ranking (lead was highest..) and when multiple pollutants were ranked the same were based on proportions (NO_2 was ranked lower because it had lower emissions than SO_2).

The values for the categories on the left represent the tons of pollutant emitted, while the right is the weight place on these categories.

Lead:
0-2: 1
2-5: 5
5-10: 10

Particulate Matter (Combined PM 2.5 and PM 10)
0-1000: 3
1000-10000: 5
10000-57,000: 8

Volatile Organic Compounds:
0-50: 1
50-500: 3
500-1500: 5

NO_2
0-1000: 2
1000-10000: 4
10000-30000: 7

SO_2
0-2000: 3
2000-15000: 5
15000-80000: 8

Carbon Monoxide
0-500: 1
500-7000: 3
7000-112000: 5

Ammonia
0-10: 1
10-100: 2
100-500: 3

Hazard Index:

Downloaded data from http://maps.indiana.edu/layerGallery.html
Included the following 9 layers: industrial waste sites, cleanup sites, brownfields, waste treatment storage disposal, waste disposal storage handling, public airports, superfund sites, mine entries, ethanol production.

- Converted the downloaded vector shape files into raster using a cell size of 2000 meters, or .01799 decimal degrees
- Then used the euclidian distance with an extent of the Indiana county polygon layer
- Extract by mask was used for Ethanol Production facilities, public airports, superfund sites and mine entries to ensure that all points were within Indiana
- Reclassified layers by values listed below
- Used the Raster Calculator to create an Index of hazardous sites by adding all of the reclassified layers

-Researched safe distances from each type of site. Safe distances for airports were determined to be 1.5 km for the highest environmental effects, but this had to be changed to 2km as that was our minimum cell size and 24km being a lesser environmental risk (EPA, 1999, Pepper et al. 2003, U.S. Department of Housing and Urban Development 2013). Buffers for the other features were given an inner value of 2km as a conservative estimate, most values given for environmental impact were below this but we were again limited by cell size, and a larger 5km buffer for a milder environmental impact (Wang, 2008. Columbia University, 2012 and EPA, 2013). Weights of 10 were given to the inner buffer, and 5 to the outer buffer in all cases except Cleanup sites and Brownfields which have a lower environmental impact (Wang, 2008. Columbia University, 2012 and EPA, 2013)

All buffers except airports were given an inner buffer of 2km and an outer buffer of 5km. Values outside these buffers were given a weight of 0.

Industrial Waste Sites
Inner buffer value- 10
Outer buffer value- 5

Cleanup Sites
Inner buffer value- 8
Outer buffer value- 4

Brownfields
Inner buffer value- 8
Outer buffer value- 4

Waste Treatment Storage Disposal
Inner buffer value- 10
Outer buffer value- 5

Waste Disposal Storage Handling
Inner buffer value- 10
Outer buffer value- 5

For the following layers, an Extraction by Mask was used to allow for reclassification

Ethanol Production Facilities
Inner buffer value- 10
Outer buffer value- 5

Public Airports: The inner buffer was 2km and the outer buffer was 24km
Inner buffer value: 10
Outer buffer value: 8

Superfund Sites:
Inner buffer value- 10
Outer buffer value- 5

Mine Entries:
Inner buffer value- 10
Outer buffer value- 5

Impaired Streams:

-Downloaded data from http://maps.indiana.edu/layerGallery.html
-Converted to raster (cell size=2000, extent=indiana polygons, etc)
-Reclassified based on how many pollutants the stream covered
-Higher weights were given to streams with a greater number of pollutants (WHO, 2013)

# pollutants in stream	Weight
1	3
2	4
3	5
4	6
5	7
6	8
7	9
8	10

Environmental Index:

-This layer was generated by using raster calculator to add up the total emission layer, the hazard index layer and the impaired stream layer

Socioeconomic Factors:

-Data for high school graduation and median household income were downloaded from: http://www.stats.indiana.edu/uspr/a/us_profile_frame.html.
-This data was then entered into Arc Map and then a new field was created from high school dropouts which was determined by 100- graduation rate to determine dropouts. -Then information on child poverty was downloaded from http://maps.indiana.edu/layerGallery.html.
-This data was then normalized by total population and then reclassified by natural break into these categories: 0-10%, 10.01-15%, 15.01-20%, 20.01-30%, 30.01-55.64%. – This data was then converted into raster.
-Data for racial demographics was downloaded from http://maps.indiana.edu/layerGallery.html
-It was then separated into Asian, White, Black and Hispanic.
-This data was then normalized for each feature class by total population. This data then represents the % composition of an area by race.
-Then this data was converted to raster.

Health Data:

-Layers for Total cancer rate, breast cancer, colon cancer, lung cancer and birth defect were obtained from http://www.in.gov/isdh/files/factsfigures2006.pdf and http://www.in.gov/isdh/files/NBDPN_2012_Table8_2005_2009.pdf
-This data was then normalized by total population of the country to account for different population sizes
-Then these layers were converted into raster through the conversion tool
-Then 1000 random points were placed with the extent of Indiana.
-These were then clipped as some were still outside of Indiana, by the Indiana layer
-Then data was extracted to these points by using the extract by mulit values to point: data was extracted from individual pollutants, total emissions, hazard index, impaired streams, child poverty, racial composition, as well as the environmental index
-This data was then exported into Excel as a text file and then pasted into SPSS
-Once in SPSS this data was analyzed through linear regression between independent variables: individual pollutants, total emissions, hazard index, impaired streams and environmental index and the dependent variables: breast, lung, colon, total cancer, birth defects, racial composition (White, Black, Hispanic, Asian), child poverty
-F,P and R^2 values were recorded to determine significance and how much of the dependent variable could be explained by the independent variable

Literature Cited

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxic Substances Portal-Ammonia. <www.atsdr.cdc.gov>. Accessed December 6 2013.

Alloway, B. J. and D. C. Ayres. 1993. Chemical principles of environmental pollution. Chapman and Hall, Great Britain.

Bluestone, A. 2013. Food and revitalization: examining the underlying structural problems of food deserts. Washington University Political Review. Available from the Washing University website <www.wupr.org>. Accessed 2013 December 7.

Bullard, R. D. 2002. Poverty, pollution and environmental racism: strategies for building healthy and sustainable communities. Environmental Justice Resource Center. <www.ejrc.cau.edu>. Accessed 2013 December 1.

Center for Disease Control and Prevention (CDC). 2013.Workplace Safety and Health Tips. <www.cdc.gov>. Accessed 2013 December 6.

Chavis, B. 2009. Concerning the historical evolution of the “environmental justice movement” and the definition of the term: “environmental racism”. <http://drbenjaminchavis.com>. Accessed 2013 November 30.

CorpWatch. 1997. Great Lakes Chemical Corporation. <www.corpwatch.org>. Accessed 2013 December 5.

County Health Rankings and Roadmaps (CHRR). 2013. Fast food restaurants. <www.countyhealthrankings.org>. Accessed 2013 December 4.

Darnerud, P. O. 2003. Toxic effects of brominated flame retardants in man and in wildlife. Environment International 29: 841-853.

Environmental Protection Agency (EPA). 2000. Styrene. <http://www.epa.gov>. Accessed 2013 December 5.

Environmental Protection Agency (EPA). 2012. An introduction to Indoor Air Quality (IAQ). <http://www.epa.gov/> Accessed 2013 December 2.

Environmental Protection Agency (EPA). 2012. Six Common Air Pollutants. <www.epa.gov>. Accessed 2013 December 7.

Environmental Protection Agency (EPA). 2013. Environmental Justice. <www.epa.gov>. Accessed 2013 December 5.

Environmental Protection Agency (EPA). 2013. Superfund. <www.epa.gov>. Accessed 2013 December 5.

Gilboa, S. M., P. Mendola, A. F. Olshan, P. H. Langlois, D. A. Savitz, D. Loomis, A. H. Herring, and D. E. Fixler. 2005. Relation between Ambient Air Quality and Selected Birth Defects, Seven County Study, Texas, 1997–2000. American Journal of Epidemiology 162: 238-252.

Great Lakes. 2013. <www.greatlakes.com>. Accessed 2013 December 5.

Holdgate, M. W. 1979. A perspective of environmental pollution. Cambridge University Press, New York, United States of America.

Ministry for the environment. 2013. Health-based Guideline Values. <http://www.mfe.govt.nz> Accessed 2013 5 December.

National Research Council Committee on Environmental Epidemiology. 1991. Public Health and Hazardous Wastes. Available from the National Academies Press website. <www.nap.edu>. Accessed 2013 December 6.

New Hampshire Department of Environmental Services. 2011. Controlling Volatile Organic Compounds Emissions from Industrial Sources in New Hampshire. <http://des.nh.gov> Accessed 2013 December 1.

Occupational Safety and Health Administration (OSHA). Hazardous and Toxic Substances. <www.osha.gov>. Accessed 2013 December 6.

Padula, A.M., K. Mortimer, A. Hubbard, F. Lurmann, M. Jerrett, I. Tager. 2012. Exposure to traffic-related air pollution during pregnancy and term low birth weight: estimation of causal associations in a semiparametric model. American Journal of Epidemiology 179: 815-824.

Papaleo, C. Fiumalbi, P. Garofani. 2012. Occupational exposure to styrene in the fibreglass reinforced plastic industry: comparison between two different manufacturing processes. Med Lav. 103: 402-12.

Pope, C. A., M. Ezzati, D. W. Dockery. 2009. Fine-particulate air pollution and life expectancy in the United States. N Engl J Med. 360: 376-86.

Sicotte, D. and S. Swanson. 2007. Whose risk in Philadelphia? Proximity to unequally hazardous industrial facilities. Social Science Quarterly 88:515-534.

Tranfo, G., M. Gherardi, E. Paci, M. Grotto, A. Gordiani, L. Caporossi, S. Capanna, R. Sisto, B. Transilwrap. 2012. <http://www.transilwrap.com>. Accessed 2013 December 5.

U.S. Census Bureau. 2011. Small Area Income and Poverty Estimates. <www.census.gov>. Accessed 2013 December 5.

Woodruff, T. J., A. R. Zota, J. M. Schwartz. 2011. Environmental chemicals in pregnant women in the United States: NHANES 2003-2004. Environmental Health Perspective 119:878-85.

World Health Organization. 2003. Ammonia in drinking-water. <http://www.who.int/water_sanitation_health/dwq/chemicals/ammoniasum.pdf> Accessed 2013 December 4.

World Health Organization. 2011. Air quality and health. <http://www.who.int/mediacentre/factsheets/fs313/en/> Accessed 2013 December 5.

Zhu, M., E. F. Fitzgerald, K. H. Gelberg, S. Lin, and C. M. Druschel. 2010. Maternal low-level lead exposure and fetal growth. Environ Health Perspective 118: 1471-1475.