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Distribution of environmental justice metrics for exposure to CAFOs in North Carolina, USA

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Abstract

Background: Several studies have reported environmental disparities regarding exposure to concentrated animal feeding operations (CAFOs). Public health implications of environmental justice from the intensive livestock industry are of great concern in North Carolina (NC), USA, a state with a large number and extensive history of CAFOs.

Objectives: We examined disparities by exposure to CAFOs using several environmental justice metrics and considering potentially vulnerable subpopulations.

Methods: We obtained data on permitted animal facilities from NC Department of Environmental Quality (DEQ). Using ZIP code level variables from the 2010 Census, we evaluated environmental disparities by eight environmental justice metrics (i.e., percentage of Non-Hispanic White, Non-Hispanic Black, or Hispanic; percentage living below the poverty level; median household income; percentage with education less than high school diploma; racial residential isolation (RI) for Non-Hispanic Black; and educational residential isolation (ERI) for population without college degree). We applied two approaches to assign CAFOs exposure for each ZIP code: (1) a count method based on the number of CAFOs within ZIP code; and (2) a buffer method based on the area-weighted number of CAFOs using a 15km buffer.

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Declaration of interests
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Results: Spatial distributions of CAFOs exposure generally showed similar patterns between the two exposure methods. However, some ZIP codes had different estimated CAFOs exposure for the different approaches, with higher exposure when using the buffer method. Our findings indicate that CAFOs are located disproportionately in communities with higher percentage of minorities and in low-income communities. Distributions of environmental justice metrics generally showed similar patterns for both exposure methods, however starker disparities were observed using a buffer method.

Conclusions: Our findings of the disproportionate location of CAFOs provide evidence of environmental disparities with respect to race and socioeconomic status in NC and have implications for future studies of environmental and health impacts of CAFOs.

Keywords

CAFOs; Disparities; Environmental justice; Vulnerable population

1. Introduction

Intensive livestock production in the US has grown substantially and generated various concerns regarding the negative environmental and socioeconomic impacts, as well human health. Production of a large number of livestock in a relatively small area, referred to as concentrated animal feeding operations (CAFOs), can produce large amounts of animal waste, which potentially pollutes air, soil, and water and can thereby affect the health of workers and communities. These facilities also tend to cluster in space, due to economic constraints. Many studies have reported significant environmental detriment from CAFOs such as harmful airborne emissions (e.g., ammonia, particulate matter, hydrogen sulfide, volatile organic compounds, and endotoxins), harm to soil and water quality, and negative health impacts (e.g., respiratory dysfunction, lower immune function, mental health, and quality of life) for workers and populations living near CAFOs (Donham et al. 1995; Harden 2015; O'Connor et al. 2017; Schinasi et al. 2011; Wilson et al. 2002; Wing and Wolf 2000; Wing et al. 2000; Wing et al. 2008).

Several epidemiological studies on environmental justice have investigated disproportionate distribution of CAFOs and health burden of CAFO-related environmental exposure (Borlée et al. 2017; Fisher et al. 2020; Lenhardt and Ogneva-Himmelberger 2013; Mirabelli et al. 2006; Sicotte and Swanson 2007; Wing et al. 2000). A study on the location and attributes of industrial hog operations in relation to race and poverty in neighboring Census block groups in Mississippi found that the majority of the state's industrial hog operations are located in areas with high percentages of African Americans and persons in poverty (Wilson et al. 2002). Other studies conducted in different regions also found distributional inequities of the location of CAFOs in low-income and/or minority communities (Nicole 2013; Wing et al. 2008). Environmental disparities from CAFOs exposures may therefore contribute to racial and socioeconomic disparities in health.

Previous research on CAFOs have used several approaches to estimate population's exposure to CAFOs such as presence of a facility within a specified buffer (Smit et al. 2012; Smit et al. 2014), distance to nearest facility (Smit et al. 2014), number or density of CAFOs

(Radon et al. 2007; Smit et al. 2014), and total quantity of emitted pollutants (Hoopmann et al. 2006; Radon et al. 2007; Schulze et al. 2011). Although a number of studies found environmental disparities regarding various environmental justice metrics such as race and socioeconomic status (SES), some studies reported inconsistent findings (Davidson and Anderton 2000; Carrel et al. 2016). Yeboah et al. (2009) examined whether relatively poor and nonwhite populations in eastern North Carolina are disproportionately exposed to hog waste directly or indirectly. They found that minorities are not directly targeted for exposure to hog farm locations, but are disproportionately exposed and that this disparity may relate to poverty as well as being a rural population. This inconsistency may result from several factors such as differences in exposure assessment and methodologies. Capturing the complex environmental exposures from CAFOs is limited for commonly-applied methods using a simple surrogate such as CAFOs emissions or proximity to a CAFO. Traditional methods, such as a binary indicator for the presence or absence of a facility are useful, but obscure differences in sizes of facilities, presence of multiple facilities, etc. Thus, more precise exposure assessment is needed to reflect multi-faced environmental impacts from CAFOs.

Livestock production is a major industry in North Carolina (NC). NC is the second largest state for the hog industry in the US (US Department of Agriculture 2017). Most CAFOs in NC are spatially clustered and located in the southeastern coastal plain region. CAFOs have emerged as an environmental justice issue as the locations of CAFOs include low-income and minority communities. Few studies provided comparison of CAFOs exposure metrics, however no previous research provided the associated disparities based on use of multiple environmental justice metrics and different CAFOs exposure metrics (e.g., differences in racial/ethnic or socioeconomic distributions by CAFOs exposure based on different CAFOs exposure metrics). Appropriate exposure assessment is important to evaluate the environmental disparities from CAFOs exposure, as well as to study the associated human health consequences in future work. This study examines the disproportionate exposure to CAFOs with several environmental justice metrics, with consideration of potentially vulnerable subpopulations and different CAFO exposure metrics.

2. Material and methods

We obtained data on permitted animal facilities from the NC Department of Environmental Quality (NC DEQ 2016). This dataset provides information on the operation such as facility name, permit number, and location for facilities in operation through February 2019, including facilities operating in previous years. To evaluate the environmental disparities by several environmental justice metrics, we used ZIP code level variables obtained from 2010 Census data: percentage of the population that is Non-Hispanic White (NHW), percentage Non-Hispanic Black (NHB), percentage Hispanic, percentage living below the poverty level, median household income, and percentage of adults with education less than high school diploma. We also used 2010 Census data to calculate racial residential isolation (RI) for Non-Hispanic Black. Racial residential isolation is a dissimilarity index that is intended to capture measures of segregation, as opposed to overall percentage minority. The RI index ranges from 0 (no isolation) to 1 (complete isolation). Using 2010 US Census data on the population count by race/ethnicity and 2010 US tract level Census boundary files (TIGER

Line files), RI index was calculated by accounting for the population composition in the index tract along with adjacent tracts. Calculation of the RI index is provided in the Supplementary Material. The local spatial measure of racial isolation is described in detail in previous studies (Anthopolos et al. 2011; Bravo et al. 2016; Bravo et al. 2019). Educational residential isolation (ERI) for population without a college degree (i.e., population without a 4-year bachelor's degree or higher) was calculated using 2013–2017 American Community Survey (ACS) tract level population count, educational achievement counts and 2010 US tract level Census boundary files (TIGER Line files). Similar procedures with RI were applied for ERI calculations.

In this study, we used two exposure metrics to assign CAFOs exposure for each ZIP code: (1) a commonly applied *count method* based on the number of CAFOs within a ZIP code; (2) a more advanced method, the *buffer method*, based on the area-weighted number of CAFOs using a 15km buffer. Because both metrics consider the possibility of more than one facility, they account for exposure based on multiple facilities and improve upon previously used binary metrics that consider only the presence or absence of a facility. In the count method, we summed the number of CAFOs within each ZIP code. This approach generated areas designated as having exposure to no CAFOs, 1 CAFO, 2 CAFOs, etc. and has been applied in previous work (Smit et al. 2014). In the buffer method, we first generated a 15km buffer around each CAFO location. We chose a 15km buffer based on the previous research. This distance represents the possible range of manure application from CAFOs, which could be an indicator of CAFOs impacts. Exporting liquid manure from CAFOs is usually limited to an area within 15km from the facility due to economic feasibility (Bergström et al. 2005; Long et al. 2018). Many of these buffers overlapped, meaning some locations were within 15km of multiple CAFOs. This approach allows for exposure to CAFOs that are nearby but in a different ZIP code, and accounts for the area covered by the CAFO in relation to the area of the ZIP code. For example, in a case where a ZIP code has one CAFO, but it is on the edge of the ZIP code, the buffer method would reflect that most of the ZIP code is far from the CAFO; if the CAFO is at the center of the ZIP code, the buffer method would reflect that much more of the ZIP code is close to the CAFO, whereas the count method has the same value of exposure in both cases.

For each ZIP code, we calculated the percentage of area categorized as being within 15km of a specific number of CAFOs. Then we calculated the overall weighted number of CAFOs for exposure for each ZIP code using area-weighting. For example, if ZIP code 1 has 6% areas with exposure to 3 CAFOs (i.e., an area for which 15km buffers from 3 CAFOs overlapped), 11% areas with exposure to 2 CAFOs, 41% areas with exposure to 1 CAFO, and 42% areas with exposure to no CAFOs, then the area-weighted number of CAFOs for exposure for ZIP code 1 is 0.81 ($0.06\times3+0.11\times2+0.41\times1+0.42\times0$) in the buffer method, while under the count method, the number of CAFOs depends on whether the CAFOs are within the ZIP code's boundary (Figure S1 (B)). The two approaches have different scales and distribution (e.g., different number of ZIP codes having 0 CAFO). We determined the rank for each ZIP code from 0 exposure (no exposure) to highest exposure among all 808 NC ZIP codes under each method. We assigned ZIP codes having 0 CAFO as the "No CAFO exposure" group and classified the remaining ZIP codes into four groups based on their rank from low exposure (quartile 1) to high exposure (quartile 4), separately under the count and buffer methods.

To investigate environmental disparities regarding CAFOs exposure, we compared the distribution of various environmental justice metrics in relation to different estimates of CAFOs exposure using the count and buffer methods. We mapped CAFOs exposures and environmental justice metrics to examine their spatial relationships and investigated distribution of several environmental justice in relation to rankings of CAFOs exposure by ZIP code. We used ArcGIS Pro 10.6.1 (ESRI, Redlands, CA), R 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria) and SAS 9.4 (SAS Institute, Cary, NC, USA).

3. Results

Figure 1 shows the location of the 2,577 permitted CAFOs in NC for 2019. Most CAFOs were clustered (i.e., near other CAFOs) and located in the southeastern NC, although many CAFOs were in central NC and western NC as well. Most operations were swine CAFOs (88.3%).

Table S1 provides the distribution of the number of CAFOs based on the count and buffer methods. Among the 808 ZIP codes, no CAFO exposure was estimated for 530 ZIP codes (65.6%) using the count method and 155 (19.2%) using the buffer method. A population of 4,822,381 (52.0% of the total population) is exposed based on the buffer method, but are not included as exposed in the count method. Considering only ZIP codes exposure to CAFOs (i.e., eliminating ZIP codes with no CAFO exposure), ZIP codes had an average number of 9 CAFOs based on the count method and a value of 13 CAFOs using the buffer method.

Figure 2 compares the distribution of ZIP codes with no CAFO exposure using the two exposure metrics, indicating a distinct difference. Note that the exposure metrics account for more than the presence or absence of a CAFO. For this figure, we condensed CAFO exposure for any count of 1 or higher for the count method, and any count of CAFOs (>0) for the buffer method in order to compare the areas that did and did not have exposure based on the two methods. This indicates that the count method generally underestimates exposure.

Figure 3 shows the relationship between for CAFOs exposure based on the number within each ZIP code by the count method and value of CAFOs exposure using the buffer method. Values are generally higher using a buffer method (i.e., area-weighted number of CAFOs using a buffer) than the count method as the buffer method allows exposure from CAFOs located outside the ZIP code. Some ZIP codes (see upper left of Figure 3) showed substantial differences in CAFOs exposure between the two metrics (e.g., 51 versus 208 CAFOs when using the count and buffer methods, respectively).

We compared distribution of ZIP code rank by two exposure metrics. Figure 4 provides distribution maps of CAFOs exposure by using the count method, buffer method, and both methods simultaneously. Generally, the overall patterns of CAFOs exposure were similar between the two methods, with higher exposure in southeastern NC. Clustered areas with many CAFOs generally showed similar rankings for both methods. However, there were some differences. When using the buffer method, some ZIP codes with no CAFO exposure in the count method had high rank of CAFOs exposure due to CAFOs located near the ZIP codes' boundaries, indicating a dramatic shift in the estimate of exposure for these communities.

Table S2 shows correlations among selected environmental justice metrics. Percentage Non-Hispanic Black was positively correlated with percentage below poverty and negatively correlated with median household income. Median household income was negatively correlated with percentage education less than high school diploma and ERI for population without college degree.

Figure 5 and Figure S2 provide distribution maps of selected environmental justice metrics. The geographic distribution of CAFOs was roughly similar to that of some environmental justice metrics such as percentage of NHB, residential racial isolation for NHB, and educational residential isolation for population without college degree. For example, most areas with high percentage of NHB are located near the CAFOs, which is predominate in the eastern coastal region.

We compared distribution of environmental justice metrics based on the two CAFOs exposure metrics. Table 1 provides average values for environmental justice metrics by CAFOs exposure group (0 exposure and 4 quartiles of exposure) based on the different CAFOs exposure metrics. Exposure was higher in areas with higher percentages of NHB, higher percentages of Hispanic, higher percentages of persons in poverty, low median household income, higher percentage of persons with less than high school education, higher racial residential isolation index score for NHB, and higher educational residential isolation for population without a college degree for both exposure metrics. Disparities were starker when using a buffer method compared to the count method for some environmental justice metrics (e.g., percentage of NHW, percentage of NHB, racial residential isolation). This indicates that environmental justice concerns are muted using the more simplistic method of exposure assessment.

4. Discussion

We evaluated environmental disparities by investigating the distribution of CAFOs exposure based on the different exposure metrics in NC. We found that spatial distributions of CAFOs exposure showed generally similar patterns between two exposure methods. However, some ZIP codes had different CAFOs exposure based on the different approaches. For example, some ZIP codes had higher exposure using the buffer method (i.e., area-weighted number of CAFOs using a buffer) and lower exposure using the count method (i.e., number of CAFOs within a ZIP code). Our findings of environmental justice metrics distributions showed that CAFOs are located disproportionately in communities with higher percentage of minorities and in low-income communities. Distributions of environmental justice metrics generally showed similar patterns for both methods, but the buffer method illuminated starker disparities. Our area-weighted approach could capture the exposure from multiple facilities beyond the boundaries. To the best of our knowledge, this is the first study to evaluate disparities based on use of multiple environmental justice metrics by different CAFOs exposure metrics. There was no study to compare distributions of CAFOs exposure and distributions of multiple environmental justice metrics by two different exposure metrics in NC. Our study considered various environmental justice metrics such as racial residential isolation, and educational residential isolation, which have not examined in the previous research. We also compared population characteristics with CAFOs exposure to non-CAFO exposure (e.g., racial, socioeconomic, and educational differences).

Previous studies investigating CAFOs exposure have used various metrics for the exposure such as density of CAFOs within specific area, distance to nearest facility from the subject's residence, odor severity, presence (or number) of facility around the subject's residence, and emissionsfrom facilities (Radon et al. 2007; Smit et al. 2012; Smit et al. 2014). Our more advanced exposure metric of area-weighted and buffer-based CAFOs exposure could reflect the potential impacts of multiple CAFOs located outside of the ZIP code boundary (e.g., located in the boarder of other ZIP codes), while count approach only considers the number of CAFOs within the ZIP code boundary. CAFOs emissions and pollution from CAFOs may affect population in some distance from the facility. Emissions from these facilities (e.g., manure, waste lagoons) can aerosolize and create a fine mist that can travel airborne for several miles (Wing et al. 2008) or surface and ground water pollution from CAFOs lagoons can send fecal wastes to other areas during rainfall or hurricane (Heaney et al. 2015; Wing et al. 2002). Thus, our approach using more refined metric of considering a buffer around CAFOs and area-weighted method may better capture CAFOs exposure and may be more appropriate to assess CAFOs exposure than the simpler methods. However, this method also has limitations; it is difficult to estimate actual exposure to CAFOs as several factors such as topography, wind direction and speed, and multiple interactions may affect exposure. Future study considering more accurate exposure assessment including direct measures of exposure or exposure intensity using the size of CAFOs, type and number of animals, and manure production is needed.

Environmental justice issues regarding NC livestock industry have been investigated in the several previous studies (Nicole 2013; Wilson et al. 2002; Wing et al. 2008). Consistent with our findings, these earlier works found that CAFOs were located and clustered disproportionately in areas with high percentage of Non-Hispanic Black, high percentage of Hispanic, high percentage of people below poverty, high percentage of low educated. Wing et al. (2000) investigated the location and characteristics of hog CAFOs in eastern North Carolina in relation to race and socioeconomic variables and found that there are higher number of hog operations in the highest quintile of poverty variable compared to the lowest quintile group. Further, they reported that the number of hog operations was highest in areas with both high poverty and high percentage of nonwhites. Another study in Ohio examined the distribution of CAFOs and their relationship to socioeconomics, finding that CAFOs primarily clustered along the western boarder of the state and that Black and Hispanic populations and households with relatively low incomes are disproportionately exposed to CAFOs compared to other populations (Lenhardt and Ogneva-Himmelberger 2013). Another study examining the relationship of the racial and economic characteristics of students enrolled in public schools in NC estimated exposure to airborne effluent from nearby CAFOs and found that economic disadvantage was associated with proximity to the nearest CAFO and with the strength of the odor (Mirabelli et al. 2006). To our knowledge, there was no study to use RI index as an environmental justice metrics with CAFOs exposure. We considered two RI index (i.e., racial residential isolation, educational residential isolation), which measure the geographic separation of each group from other groups (e.g., geographic separation of Non-Hispanic Black residents from other racial groups). CAFOs exposure was higher in areas with higher racial residential isolation index score for NHB, and higher educational residential isolation for population without a college degree. Our findings indicate that higher isolation may be associated with disparities in CAFOs exposure.

This disproportionately clustering of CAFOs in some communities may contribute to several adverse health outcomes and environmental justice for the population living near CAFOs. The health effects associated with CAFOs are not fully understood, but research indicates impacts on respiratory conditions (e.g., chronic bronchitis, asthma), irritation symptoms, mental health and quality of life, and infectious disease risk (Guidry et al. 2018). CAFOs workers and communities near CAFOs are exposed to harmful airborne emissions from CAFOs; contaminated ground and surface water and private wells resulted from high volume of waste and leakage from lagoons (Wing et al. 2002). Wing and Wolf (2000) investigated the health effects of airborne emissions from swine CAFOs in eastern North Carolina. They compared three neighborhoods (two neighborhoods within a 2-mile radius of a CAFO and a rural location not proximate to a CAFO) and found that incidence of respiratory, gastrointestinal, and mucous membrane irritation was elevated for residents living near a CAFO. Another study examined associations of reported hog odor and air pollutants with physical symptoms and lung function in people living near hog operations (Schinasi et al. 2011). They suggested that air pollutants near hog operations are related to acute physical symptoms, particularly upper respiratory symptoms and irritation of the nose and eyes. Moreover, some studies reported evidence on the health impacts of CAFO emissions (e.g., air pollution, soil, water) on susceptible population such as children. Merchant et al. (2005) reported that children living near CAFOs in Iowa have higher rates of asthma than other children. Another study in Iowa found a significantly higher prevalence of asthma among students in a school located near a CAFO compared to another school (Sigurdarson and Kline 2006).

We found that CAFOs in NC are located disproportionately in minorities and low SES communities. These communities may be more vulnerable to CAFOs exposure due to limited resources and less access to protective measures. For example, they may not afford resources such as air conditioning so their behaviors (e.g., opening windows for ventilation, drying clothes outside) may increase exposure to harmful emissions and some populations cannot afford to move away from the environmental hazard. Also, these communities may have high rates of existing chronic diseases that may aggravate the risk of adverse health outcomes. To address environmental justice issues regarding exposure to CAFOs, it is critical to understand the complex CAFOs exposures from air, water, and soil and multiple other factors that may play a role in inequalities in vulnerable populations. Thus, more research is needed on accurate exposure assessment and impacts of complex CAFOs exposures on the vulnerable population such as low SES group.

Our study has limitations. Our analysis only included regulated CAFOs with provided information on the location and characteristics of operations due to data availability. We do not have information on facilities that are not included in the database (e.g., smaller facilities with fewer animals, which are not regulated) and could not validate the data. A limitation of our work is that the data from the NC Dept. of Environmental Quality do not capture most facilities operating with dry waste management, most notable poultry CAFOs. While 88.3% of the included CAFOs were for swine, 10.6% were for cattle and 0.74% were for poultry, although many poultry CAFOs were not included. Future work is needed to develop exposure metrics with detailed information such as CAFO size and manure production to assess the intensity of CAFOs exposure and to consider the implications of using different buffer sizes to assess exposure. Finally, while our work was designed to examine small spatial scales, future work could further examine neighborhood, or within-neighborhood, differences in various types of exposure and consider other spatial scales.

5. Conclusions

Exposure to CAFOs has negative impacts on the environment and surrounding neighborhoods. CAFO-produced pollution may have substantial impacts on health in nearby communities, especially in communities of minorities and low SES. We suggest assessment of CAFOs consider exposure metrics that go beyond proximity metrics, and such as area-weighted number of CAFOs using a buffer to evaluate the impacts of CAFOs beyond the boundaries, and that further more complex metrics be developed. Our findings of the disproportionate location of CAFOs provide evidence of environmental disparities with respect to race and SES in NC and have implications for future studies of environmental and health impacts of CAFOs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

CAFOs	Concentrated animal feeding operations
RI	Racial isolation
ERI	Educational residential isolation
SES	socioeconomic status

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Highlights

- CAFOs exposure showed generally similar patterns between different exposure metrics.
- However, some areas had different estimated CAFOs exposure for the different approaches.
- CAFOs are located disproportionately in minority communities and low-income communities.
- Environmental justice metrics showed similar patterns for both methods, but buffer method illuminated starker disparities.
- Disproportionate location of CAFOs provide evidence of environmental disparities.

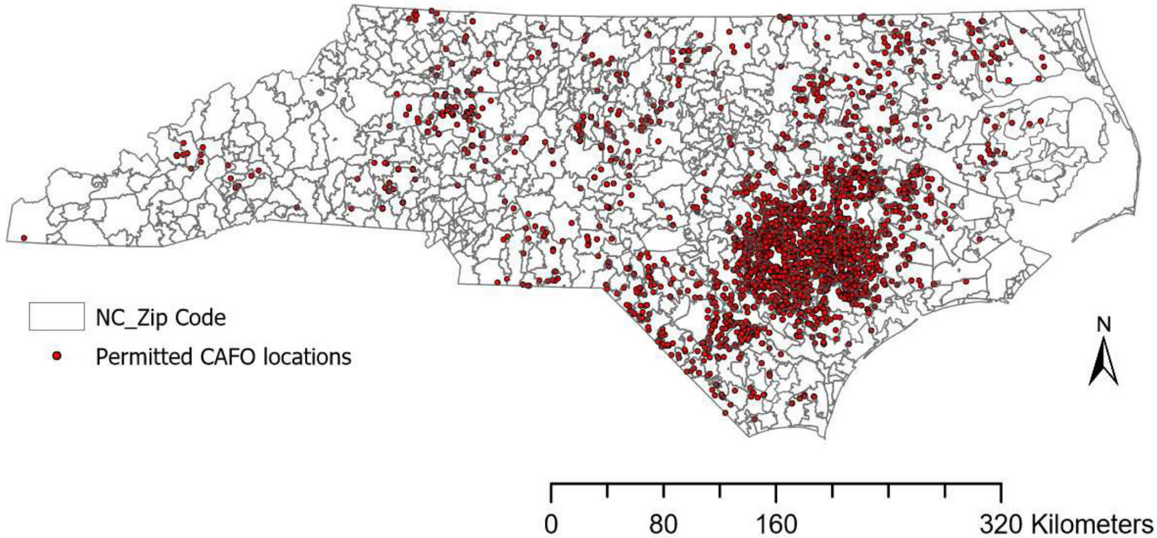


Figure 1.
Locations of permitted animal facilities in NC (2019)

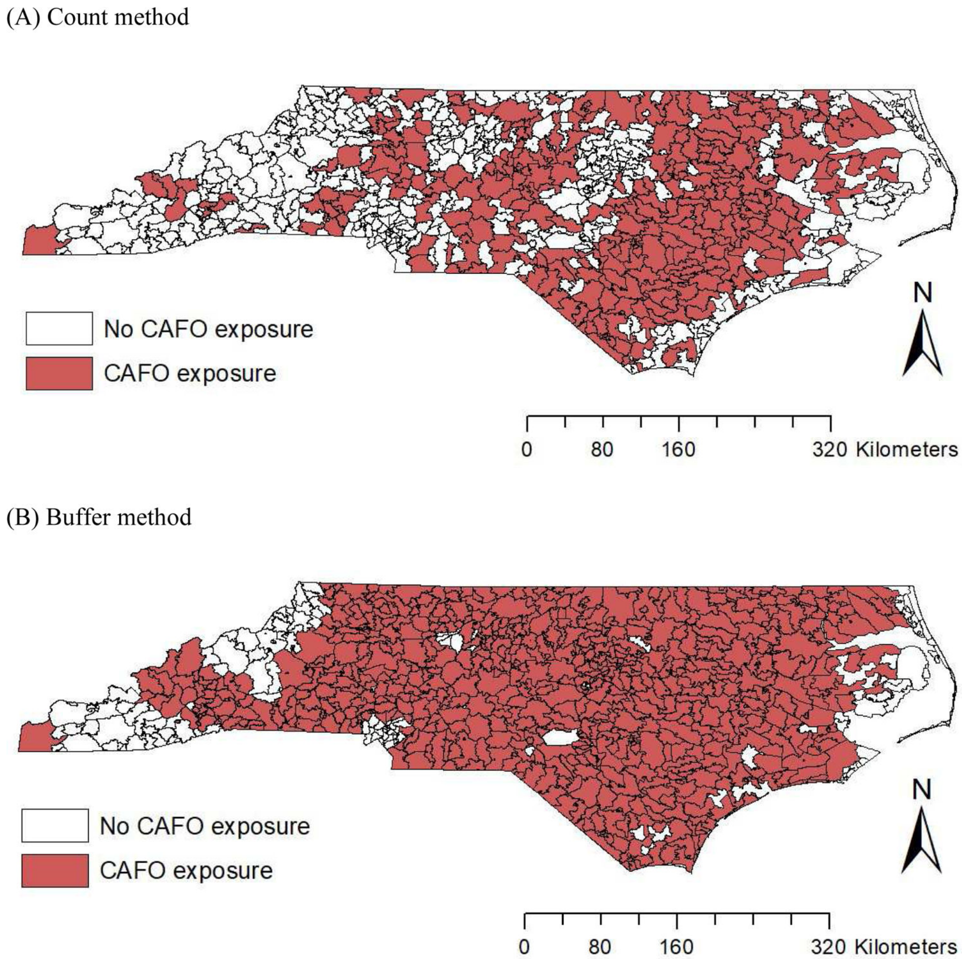


Figure 2.

ZIP codes with no CAFO exposure by reducing the two exposure metrics to a binary metric based on (A) count and (B) buffer method.

Note: The exposure metrics account for more than the presence or absence of a CAFO. For this figure, we condensed CAFO exposure for (A) any count of 1 or higher for the count method and (B) any count of CAFOs (>0) for the buffer method in order to compare the areas that did and did not have exposure based on the two methods.

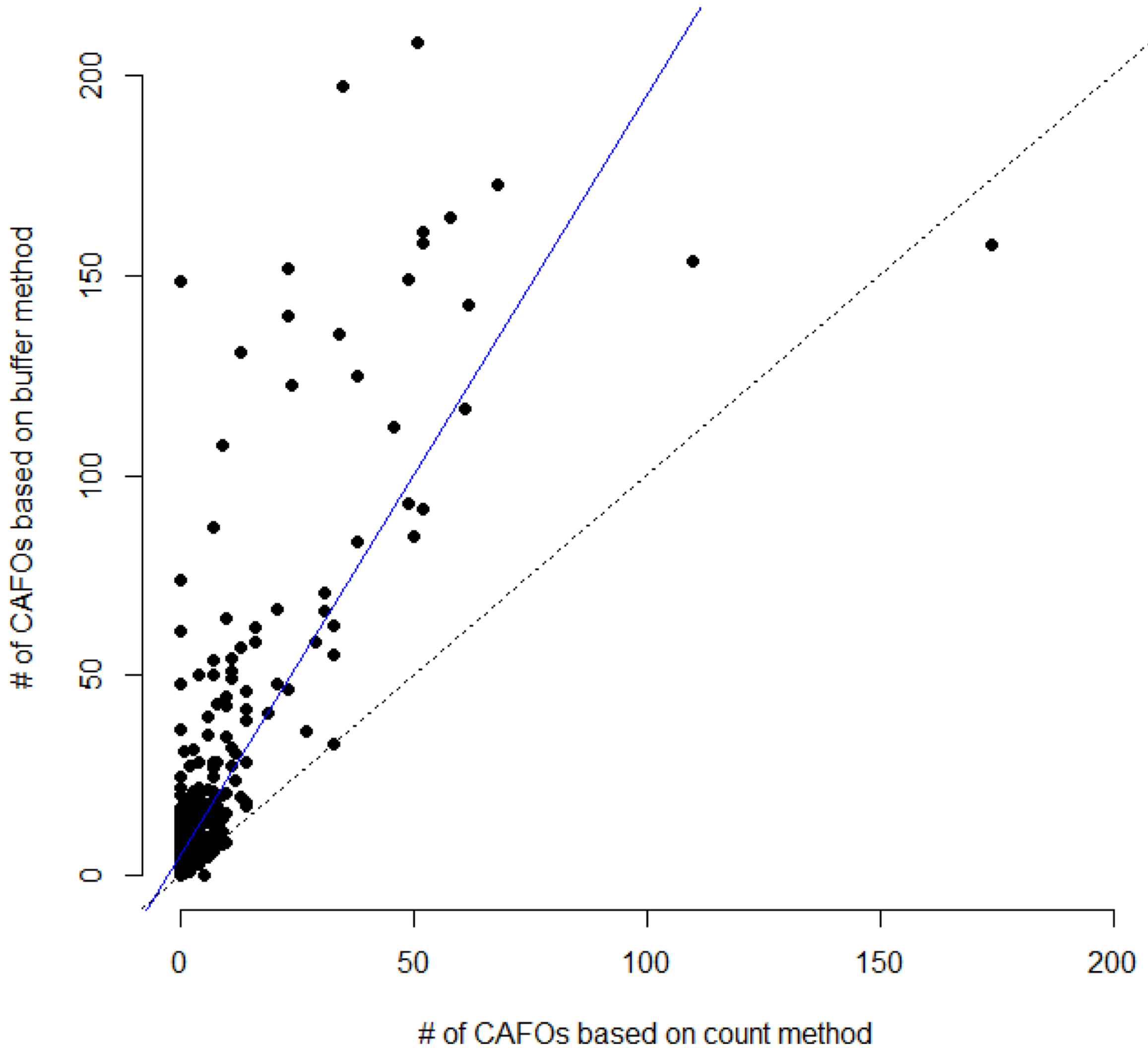
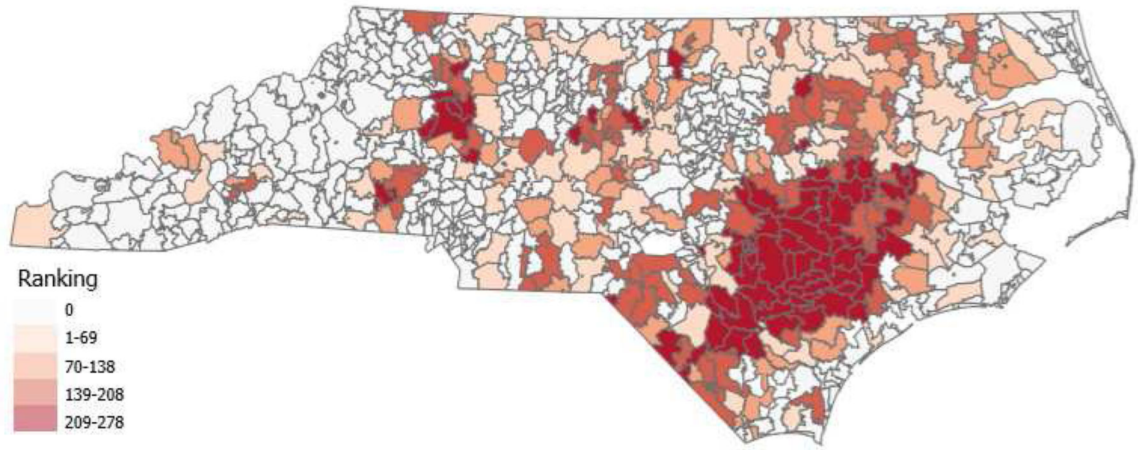


Figure 3.

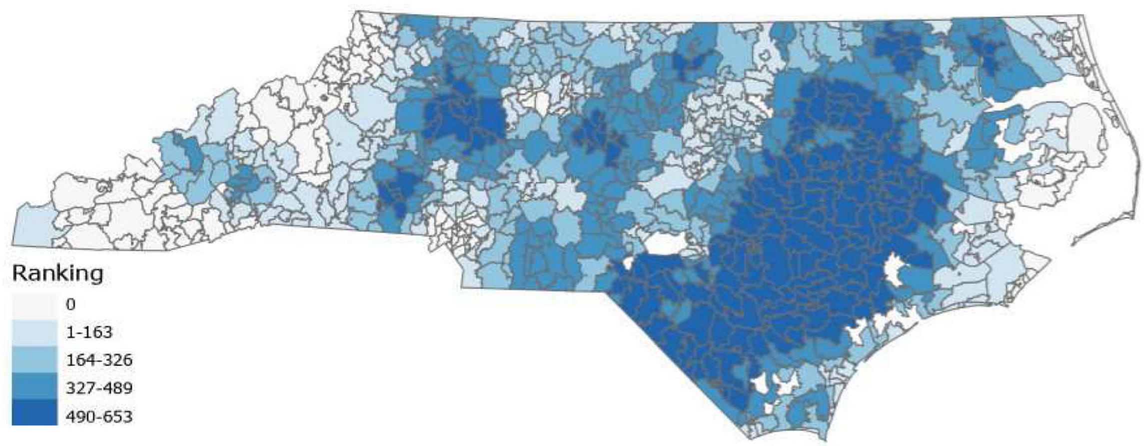
Relationship between for CAFOs exposures based on the number within each ZIP code by the count method and value of CAFOs exposure using the buffer method.

Note: Each point represents a ZIP code.

(A) Count method



(B) Buffer method



(C) Bivariate choropleth map

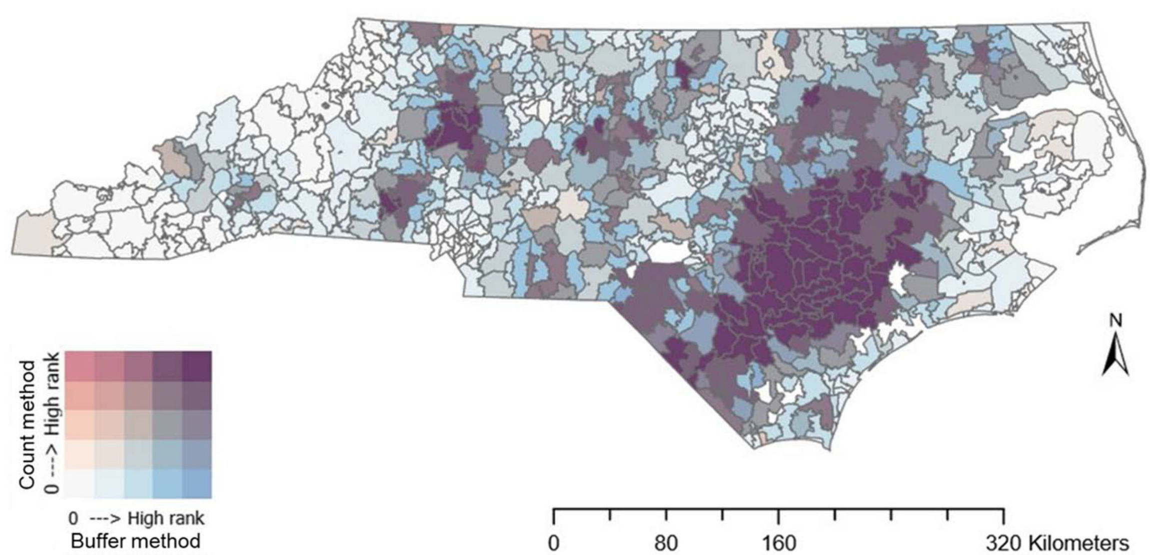


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Figure 4.

Distribution maps of CAFOs exposure by (A) use of the count method, (B) use of the buffer method, and (C) displaying both methods simultaneously

Note: The ranks by ZIP code compare exposures for each method. The lower ranking reflects lower exposure (0 = lowest, with no exposure) and the higher ranking reflects higher exposure.

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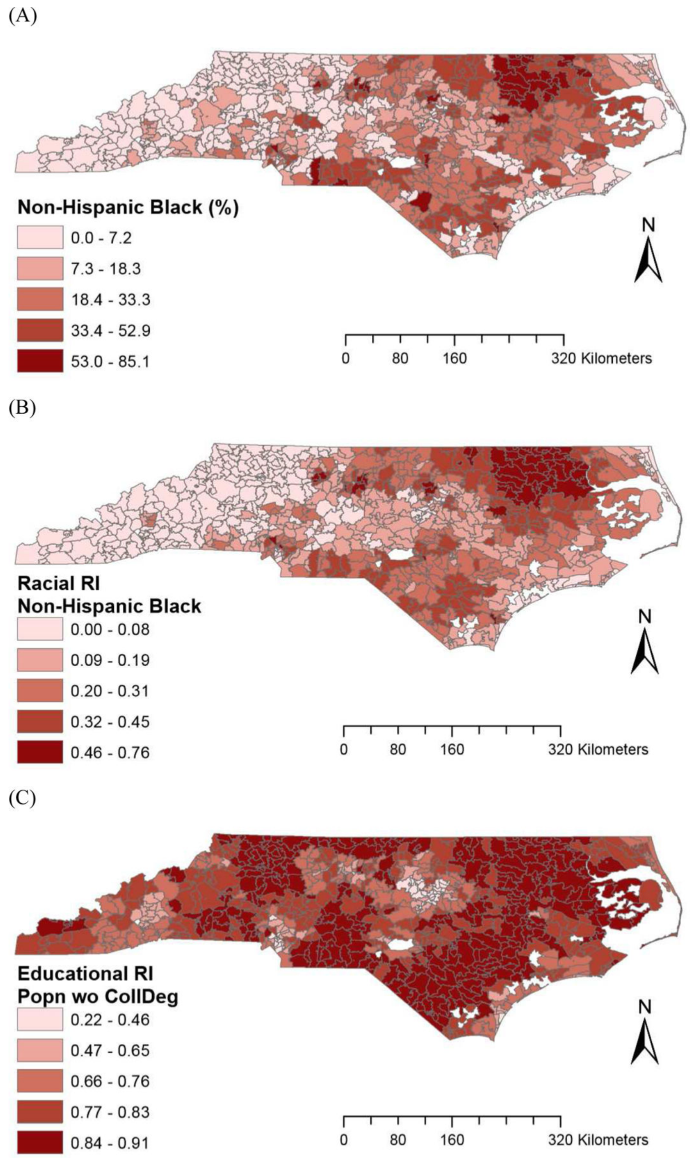

Figure 5.

Distribution of selected environmental justice metrics: (A) % Non-Hispanic Black (B) Racial residential isolation for Non-Hispanic Black (C) Educational residential isolation for population without college degree

Table 1.

Distributions of environmental justice metrics for the two CAFO exposure metrics

	Rank category based on # of CAFOs within ZIP code	% Non-Hispanic White	% Non-Hispanic Black	% Hispanic	% Below Poverty	Median household income ($)	Education (% <High School)	Racial Residential Isolation for Non-Hispanic Black	Educational Residential Isolation for population without college degree
	Count method								
	0 (No CAFOs exposure)	74.18	15.77	5.98	15.19	47112.84	29.94	0.16	0.73
Quartiles of ZIP codes (excluding those with 0 CAFO)	1 (Lowest quartile)	66.29	23.39	6.30	17.64	42316.65	33.56	0.23	0.80
	2	66.15	24.96	5.37	16.78	42468.27	34.56	0.24	0.81
	3	61.56	26.61	6.62	18.85	39727.86	34.41	0.26	0.83
	4 (Highest quartile)	62.30	23.65	10.88	19.38	38590.27	34.74	0.24	0.85
	Buffer method								
	0 (No CAFOs exposure)	81.20	9.46	5.51	15.52	45634.60	27.94	0.10	0.71
Quartiles of ZIP codes (excluding those with 0 CAFO)	1 (Lowest quartile)	75.02	15.48	5.67	13.67	50772.02	28.75	0.16	0.70
	2	73.14	17.37	5.93	15.41	47027.56	31.19	0.18	0.75
	3	64.57	24.91	6.31	17.43	41855.34	34.69	0.24	0.81
	4 (Highest quartile)	60.13	26.42	8.70	18.99	39421.47	34.48	0.27	0.84

Note: Values represent average number in each category.