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Research Article

Distribution of Industrial Farms in the United States and Socioeconomic, Health, and Environmental Characteristics of Counties

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The method of producing food animals has changed in the United States over the past century, moving from traditional burns to enclosed structures resembling industrial buildings, where animals are raised in high stocking density (commonly known as "Concentrated Animal Feeding Operations," CAFOs). The objective to maximize profit has resulted in poor farm management; raised issues of environmental pollution, public health, animal rights, and environmental justice, and had socio-economic impacts. Studies concerning the issues are limited to specific regions and types of CAFOs. In addition, studies on the spatial distribution and temporal changes of CAFO at a country scale are lacking. This study bridges some of the gaps by analyzing the spatial distribution of industrial farms in the United States in 2002 and 2007 and their relationship with vulnerable population and exploring the relationships among the concentrations of farms, socio-economic, health, and environmental characteristics of the counties. A range of spatial statistics tools were applied in this study. The study revealed variations in spatial distribution depending on the type of the CAFOs. The issue of environmental justice was found prevalent depending on the types of industrial farms. Each type of industrial farm was found to interact uniquely with the selected demographic, health, and environmental parameters.

1. Introduction

American agriculture has shifted from traditional small family farms to large agricultural industry over the past century to keep up with the increase in meat demand and objective of maximizing profit by minimizing the costs of producing food animals. These kinds of farming facilities are known as Concentrated Animal Feeding Operations (CAFO) and also regarded as industrial farms or factory farms. In the industrial farms, the animals are raised in high stocking density, and antibiotics and pesticides are used to mitigate the spread of disease and pestilence exacerbated by these crowded living conditions [1]. CAFO encompass all aspects of breeding, feeding, raising, and processing animals or their products for human consumption [2]. Industrial farming practice is a product of the postindustrial revolution era and began to grow in the 1920s soon after the discovery of vitamins A and D; by adding the vitamins to feed, animals no longer required exercise and sunlight for growth [3]. This advancement in agricultural practice has increased efficiency in agricultural production. In the eighteenth century, it took nearly five acres of land to feed one person, whereas due to the improved agricultural practice, today, it takes only half an acre, which thereby demonstrates tenfold increase in productivity [4]. The increase in population and consequent increase in food demand catalyzed the growth of this industry. According to the United States Department of Agriculture (USDA), the number of industrial farms has increased by 230 percent, increasing from 3600 in 1982 to almost 12,000 in 2002 [5]. Only four companies in the United States produce 81% of cows, 73% of sheep, 50% of chickens, and 60% of hogs that Americans eat [6]; however, the increase in this farming practice has brought new challenges. Improper management of the generated wastes, exposure of neighborhood to the pollutants, decrease in aesthetic and property values, and location of the facilities in areas of environmental justice population have raised questions about the sustainability of industrial farming.

The three root causes of environmental degradation from industrial farms are the large volume of waste produced, lack of appropriate management and disposal of these materials, and unsustainable water usage and soil degradation associated with feed production [7]. Animal farming is estimated to account for 55% of soil and sediment erosion, 37% of nationwide pesticide use, 80% of antibiotic usage, and more than 30% of the total nitrogen and phosphorus loading to national drinking water resources [8]. The trend of industrial farms has resulted in the generation of large volume of waste in relatively confined geographical areas. For example, swine manures are usually stored in deep pits or outdoor lagoons and then applied to agricultural fields as a natural fertilizer. The runoff and percolations have impacted surface water and groundwater proximal to swine farms, thereby posing health risk to the environment and human populations [7, 9, 10]. In the report for the year 2001, the USDA estimated the output of manure from farm animals at 920,000 US short tons of dry matter per day. Of this mass, 86% (788,000 tons per day) was projected to stem from animals in industrial farms [11]. Swine, beef, and poultry facilities are the source of an array of chemical and biological pollutants discharged to air, water, and soil, where they have been observed to cause ecological effects and disease in exposed individuals [12, 13]. Reports have documented associations between industrial farms in rural communities and increase in self-reported respiratory diseases including asthma and bronchitis, impaired mental health including depression, anxiety and posttraumatic stress disorder, harassment of outspoken community members, and a general perception by local residents of societal neglect [14, 15]. Sneeringer [16] in her study has established the association of the factory farms with release of air particulate matter which is responsible for respiratory disease and increased mortality. Workers are subject to occupational hazards in the CAFOs and act as vector of diseases by transmitting animal borne diseases to a wider population [17]. The decline in the aesthetic value of the neighborhood of the farms caused decline in property values [7, 18]. In addition to environmental degradation and consequent socioeconomic and health impacts, CAFOs are criticized for raising environmental justice issues.

The United States Environmental Protection Agency (EPA) defines environmental justice (EJ) concern as the actual or potential lack of fair treatment or meaningful involvement of minority, low income, or indigenous populations or tribes in the development, implementation, and enforcement of environmental laws, regulations, and policies. It refers to acts that cause disproportionate impact on minority, low income, or indigenous population who can be referred to as EJ population. Researchers have identified EJ issues associated with CAFOs in many studies [9, 19–21]. In the southeast of Halifax county in North Carolina, hog farms were established in the town of Tillery where 98% of the population were African Americans, and caused pollution to the shallow aquifer which was the source of the drinking water [22]. Donham et al. [23] in their review article have mentioned that many hog farms have been established in the midwest of USA in the low income and nonwhite population dominated areas despite being unwanted by the local communities because of their low political influence. Wilson et al. [24] examined locations of 67 industrial hog operations in relation to race and poverty in Mississippi. It was found that the majority are located in the areas that have high percentage of African Americans and persons in poverty. Wing et al. [19] did a statistical analysis to establish relationships between environmental justice variables and hog productions in North Carolina, and found that the hog productions were highest in the areas with high poverty level and high percentage of non-white populations.

Considering the studies conducted to date it is quite evident that there are issues concerning environmental degradation, socio-economic impacts and environmental justice associated with CAFOs. However, the studies are concentrated on small areas and mostly related to hog farms. However, the issues that were raised in the studies do not confirm that the phenomenon exists in all geographical locations in the US and in all types of CAFOs. If the environmental justice issue does not prevail in case of other types of farms then generalizing the issue of environmental justice in relation to industrial farms will be an exaggeration. Additionally there is no study that identifies the locations of the industrial farms at national level. If the areas with high concentration of industrial farms are not identified, then the management approach to solve the issues associated with the facilities will lack comprehensiveness. Moreover, there has been lack of initiatives to understand the relationship of the industrial farms with the socio-economic, health, and environmental characteristics. Based on the identified shortfalls, this study addressed three specific questions: (a) What is the spatial distribution of industrial farms in USA and how did it change from the year 2002 to 2007? (b) Where are the hotspots of the industrial farms and do their demographic characteristics confirm the issue of environmental justice? (c) What is the relationship between the concentration of industrial farms and the socio-economic, health, and environmental characteristics?

The study was conducted on the conterminous 48 states of the United States of America (USA). Alaska and Hawaii were excluded from the study because of their noncontiguous geographical location and the negligible number of industrial farms in those areas. The unit of analysis was county. The study was performed on three categories of industrial farms: chicken farms, cattle farms, and hog farms for the entire study area.

2. Data and Methods

2.1. Data. Data for this study was collected from three sources. First, the data for the industrial farms was acquired from the US agricultural censuses of 2002 and 2007 provided by the National Agricultural Data Service of the United States Department of Agriculture (USDA) [25]. Data was collected for three types of farms: chicken (layer and broiler), hog, and cattle. No precise information on CAFOs is provided in the agricultural census. Thus, the definition of CAFO provided by the United States Environmental Protection Agency (USEPA) was consulted to select the appropriate data for the research [26]. Certain criteria were set from the USEPA definition of CAFO for this process. Based on the set criteria, variables from the agricultural census data were selected to calculate the number of factory farms in each category for each county. For example, two variables that were used to calculate the number of factory farms with only cattle were "cattle on feed that are more than 500 in a farm" and "milk cows that are more than 500 in a farm." The factory farms for chicken were calculated using information on "broilers and other meat type chickens that are more than 500,000 in a farm" and "layers that are 20 weeks or older and are more than 100,000 in number". For hogs, the variable selected was "hogs and pigs that are more than 1,000 in a farm".

Second, the socio-economic data was collected to define the EJ population. The US population census data for 2000 was used for this purpose [27]. Since the data for CAFO was derived using the 2002 and 2007 agricultural censuses, the population census data for 2000 was assumed to be the appropriate representative of the time period. A number of variables related to the characteristics of EJ population were included in the study: population density (number of people per sq. mile); percentage of white population; percentage of African-American population; percentage of other minority populations (the percentage of population who are Hispanic and Latino, Asian, and other small minority groups); percentage of indigenous populations (percentage of population who are American Indian, and Alaska Natives, and Native Hawaiian and other Pacific Islanders); percentage of population below poverty level; percentage of white population below poverty level; percentage of African-American population below poverty level; percentage of other minority population below poverty level; percentage of indigenous population below poverty level; and per capita income (in thousands of US Dollars).

Finally, factors related to health and environmental characteristics of US counties were collected from the county health ranking of 2010 produced by the University of Wisconsin Population Health Institute [28]. Based on previous studies on factory farms, the following key variables were selected: (a) premature death rate of years of potential life lost before the age of 75; (b) fair or poor health; (c) physically unhealthy days per month for adults; (d) mean mentally unhealthy days per month for adults; (e) percentage of live births with low birth weight (less than 2500 grams); and (f) annual number of unhealthy air quality days due to fine particulate matter. The data produced in the "county health ranking" website was accumulated from various sources.

The "premature death-rate of years of potential life lost before the age of 75" is a standard measure of calculating mortality. The county health ranking derived the years of potential life lost rate by using the deaths occurring before the age of 75 per 100,000 populations in each county. The vital statistics of the National Center of Health Statistics (NCHS) data for 2004–2006 were used to derive this variable. The "fair or poor health" was measured in "percentage of adults reporting fair or poor health" and was obtained from the Behavioral Risk Factor Surveillance System (BRFSS) data of 2002–2008. The information on "physically unhealthy days per month for adults" and "mean mentally unhealthy days per month for adults" was also derived from the same source. The vital statistics of NCHS for 2000–2006 were used to find the "percentage of live births with low birth weight (less than 2500 grams)". "Annual number of unhealthy air quality days due to fine particulate matter" was provided by the Environmental Protection Agency (EPA) for the year 2005 and was included in the study as a surrogate of environmental characteristics.

2.2. Methods. The study was conducted in three different parts. First, the spatial distribution of the industrial farms in the upper 48 states of the USA was analyzed for 2002 and 2007. The counties that had the highest number of industrial farms were identified as the hotspots. Second, the defined EJ population and its spatial interaction with the identified hotspots were analyzed. Finally, a statistical analysis was performed to identify the relationship between the concentrations of industrial farms at the county level and their socio-economic and environmental characteristics. All GIS analysis was completed in ArcMap 9.3, and calibrations and statistical analysis were performed in MS Excel and SPSS.

2.2.1. Spatial Distribution and Hotspot Analysis. To understand the spatiotemporal changes of the industrial farms, weighted mean center, and standard deviational ellipses were calculated. The total number of the industrial farms in each county was used as the weight for assessing the spatial distribution. The product of weighted mean center analysis is a point that represents the center of the nationwide distribution of the industrial farms. Using the weighted mean centers as inputs, standard deviational ellipses were calculated by squaring the sums of the differences between the X and Y coordinates of each county's centroid and the X and Y coordinates of the weighted mean centers. They measured the degree to which features are concentrated or dispersed around the weighted mean [29].

The clusterization of the farms was studied using global Moran's I, local Moran's I, and Getis-Ord statistics (Gi$*$). The global and local Moran's I tests are capable of providing the general information about clustering and spatial autocorrelation, whereas Gi$*$ can identify the locations of clusters of high and low values that are referred to as hotspots and cold spots, respectively [30]. The choice of conceptualization of spatial relationships was influenced by the objective of putting higher weight on the closer features and decreasing weight with an increase in distance. Thus, inverse distance method was used to calculate the clusterization. In addition, inverse distance provided the best output compared to other conceptualization methods, as the highest z-score, representing the greatest spatial autocorrelation, was obtained using this method. For both the Moran's I and Gi$*$, the values were standardized to obtain a z-score. A z-score above 1.96 indicates that there is less than 5% likelihood that the clustering is due to chance. A higher z-score further reduces the uncertainty of occurrence due to chance. Thus, the higher the z-score, the higher the significance of the clustering. For both Moran's I and Gi$*$, a z-score higher than

2 was considered as significant for identifying the hotspots. These statistical measures are commonly applied in spatial analysis. For example, Orford [31] applied the local Moran's I to identify concentrated poverty and affluence within cities. Pacheco and Tyrrell [32] also used similar methods to analyze the spatial patterns of household distribution in clusters of cities. Ceccato and Wilhelmsson [33] applied Getis-Ord statistics to identify the hotspots of burglaries in Stockholm and also assessed the underlying socio-economic issues.

2.2.2. Environmental Justice Issue at the Hotspots. To identify the EJ population in the hotspots, two broad categories were considered: minority population (including indigenous people) and poverty. The minority population was divided into two categories: African-American population and other minorities (minority races other than African American and indigenous population). The population below the poverty level was considered with respect to total population, white population, and minority population. The demographic characteristics were compared between the hotspots and non-hotspots based on the above-mentioned variables. t-test was executed with an alpha level of 0.5 (95% confidence interval) on the mean values of hotspots and non-hotspots to identify whether the EJ population is significantly higher in identified hotspots compared to nonhotspot counties.

2.2.3. Modeling the Relationship. The relationship between the concentration of industrial farms and socio-economic, health, and environmental factors was assessed using density of the industrial farms (number of farms in a county per 1000 population) as the dependent variable. Using density instead of the number of farms removes the biases created by counties with higher population [30]. Only counties that had one or more industrial farms were included in the analysis. The relationship was modeled using multivariate regression using SPSS statistical software. Logarithmic transformation of the dependent variable was performed to restrict the violation of assumptions (in this case, violation of homoscedasticity). This process helped to ensure random distribution of the residuals and to reduce the problem with multicollinearity to the maximum possible extent. Performing the regression analysis with the best fit model identified in ArcGIS facilitated the graphical representation of the findings. The best model was chosen from several models based on two criteria—the value of the R^2 (the higher the better) and the number of independent variables that had statistically significant coefficient in the regression equation (0.05 significance level). Global Moran's I was used to determine clustering of residuals.

3. Results and Discussion

3.1. Spatial Distribution and Hotspot Analysis. The spatial distribution of industrial farms showed variations with respect to the type of farms (Figure 1). For the cattle farms, the center of distribution moved a little westward to southwest of Nebraska for 2002, but a little eastward shift to the center of Nebraska was found in 2007. In both years, the farms expanded in southwest-northeast direction. The chicken farms were centered in the southern parts of the United States and extended to the eastwest direction. The hog farms were centered in the central part of the United States in Illinois and extended in southeast-northwest direction. No trend of change was observed between 2002 and 2007, because the number of factory farms increased over the years, but farms were located in the same geographic areas. From 2002 to 2007 the total number of farms increased from 23,356 to 25,992.

Table 1: Clustering of industrial farms in 2002 and 2007.

Categories	2002		2007	
	I value	Z-score	I value	Z-score
Cattle farms	0.05	53.13	0.07	69.7
Hog farms	0.13	142.9	0.15	154.99
Chicken farms	0.1	105.65	0.1	108.56

Global Moran's I demonstrated strong clusterization of all types of CAFOs with a high statistical significance (99% confidence interval) as shown in Table 1. The hotspot analysis (Figure 2) indicated that for cattle farms, the hotspots were widely distributed from California to Vermont. However the maximum areas of clustering were identified in Iowa, Nebraska, Illinois, and Minnesota. A number of counties in Georgia, Alabama, Arkansas, North Carolina, Missouri, and Delaware were identified as hotspots for chicken farms. The hotspots of hog farms were clustered at the counties in Iowa, Minnesota, Indiana, Illinois, and North Carolina.

3.2. Environmental Justice Issue at the Hotspots. The hotspots identified for the year 2007 were considered in the analysis as no change in location of hotspots was identified between 2002 and 2007. Figures 3 and 4 show the demographics of population at the hotspots identified for each category of factory farms. The population is summarized in Table 2.

In the identified hotspots, the African-American population and other minority races constitute a small proportion of the total population (about 15% to 20%). In non-hotspots, similar situation is observed. The minority races and indigenous people constitute a small percentage compared to the percentage of white population. About 10–15% of the total populations were found to be below poverty level in the hotspots, and in the non-hotspot areas, the percentage also varied within this range. As white population was dominant in hotspot and non-hotspots, greater percentage of population below poverty level was found to be white. African-American population being the least percentage of the total population was found to be the lowest among the population who are below poverty level in both hotspots and non-hotspots. So, apparently no difference in population characteristics in hotspots and non-hotspots was observed. However, without understanding the significance of difference in the demographic characteristics at the hotspots and non-hotspots, no conclusion on the environmental justice issue can be drawn. Thus t-test was performed at 95% confidence interval to identify the difference between the hotspot and non-hotspot demography (Table 3).

While performing the t-test it was hypothesized that if the percentage of African-American population, minority population, and the indigenous population and their

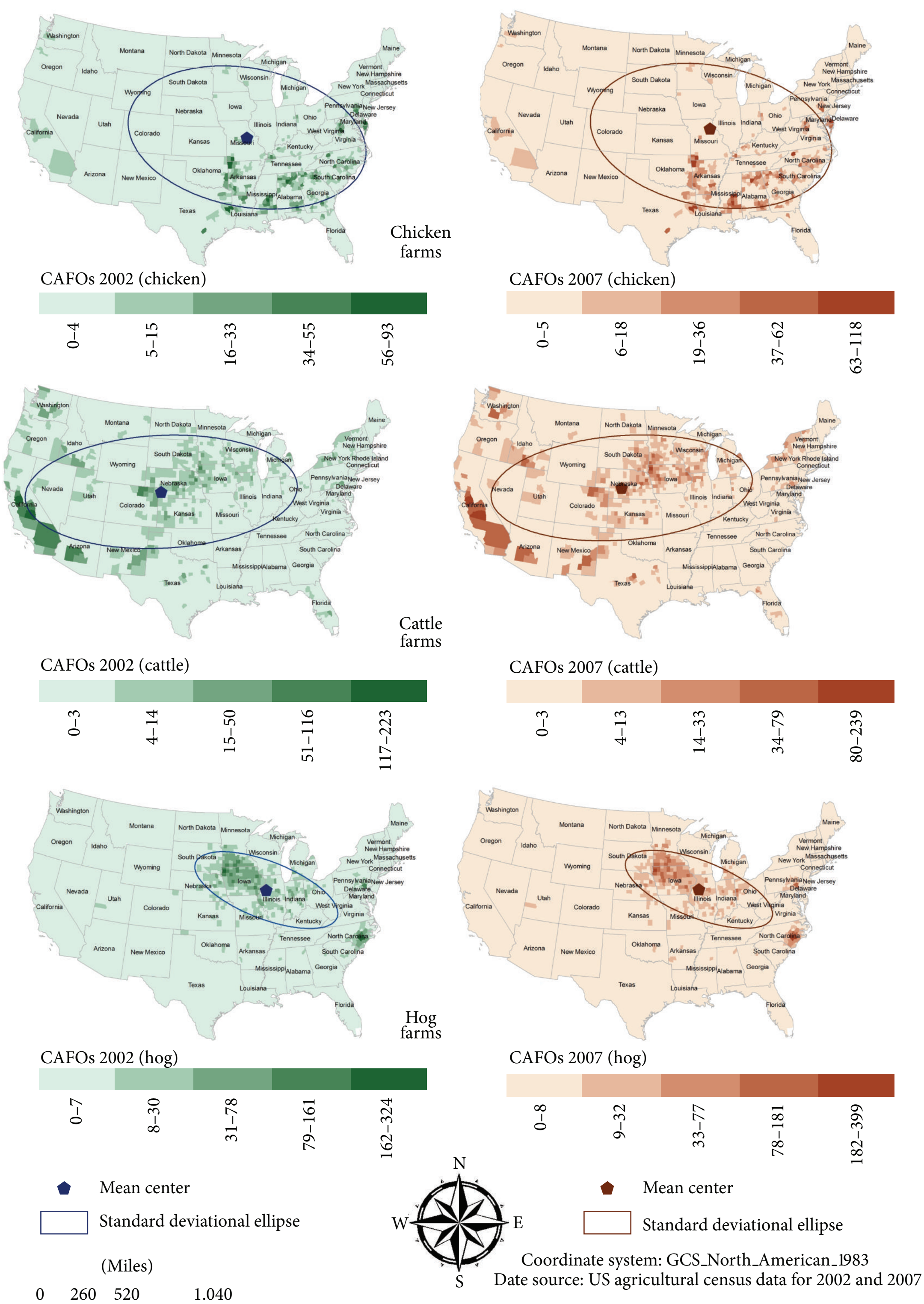


FIGURE 1: Spatial distribution of industrial farms in 2002 and 2007.

related attributes (below poverty level) were found to be significantly higher in the hotspots compared to the non-hotspots, then the claim can be made that the environmental justice issue exists. For the chicken farms, the percentage of African-American population, percentage of population below poverty, and the percentage of African-American population below poverty were significantly higher in the hotspots compared to non-hotspots. However, the difference with regard to other minority population and the indigenous population was not significant at 95% confidence interval.

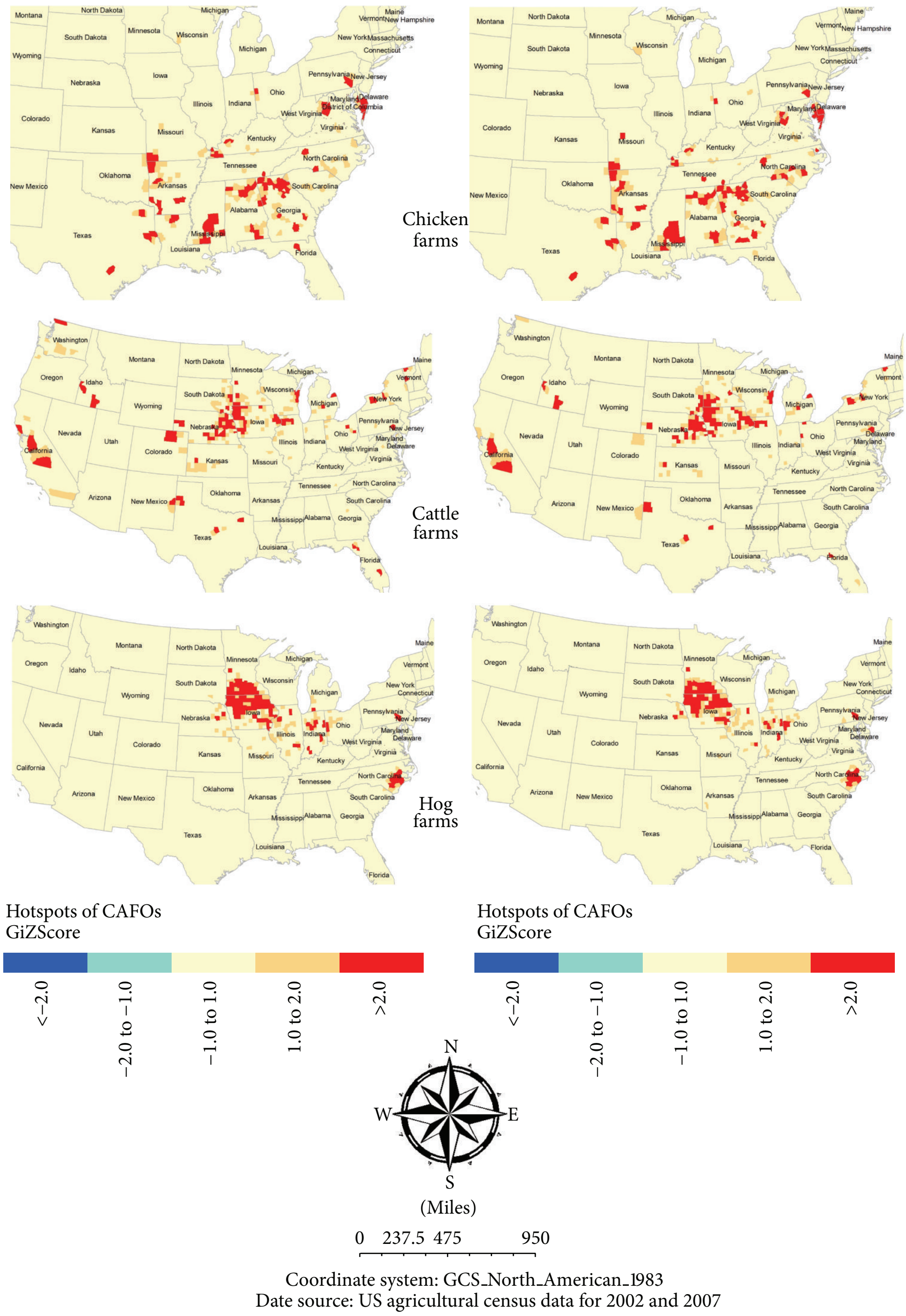
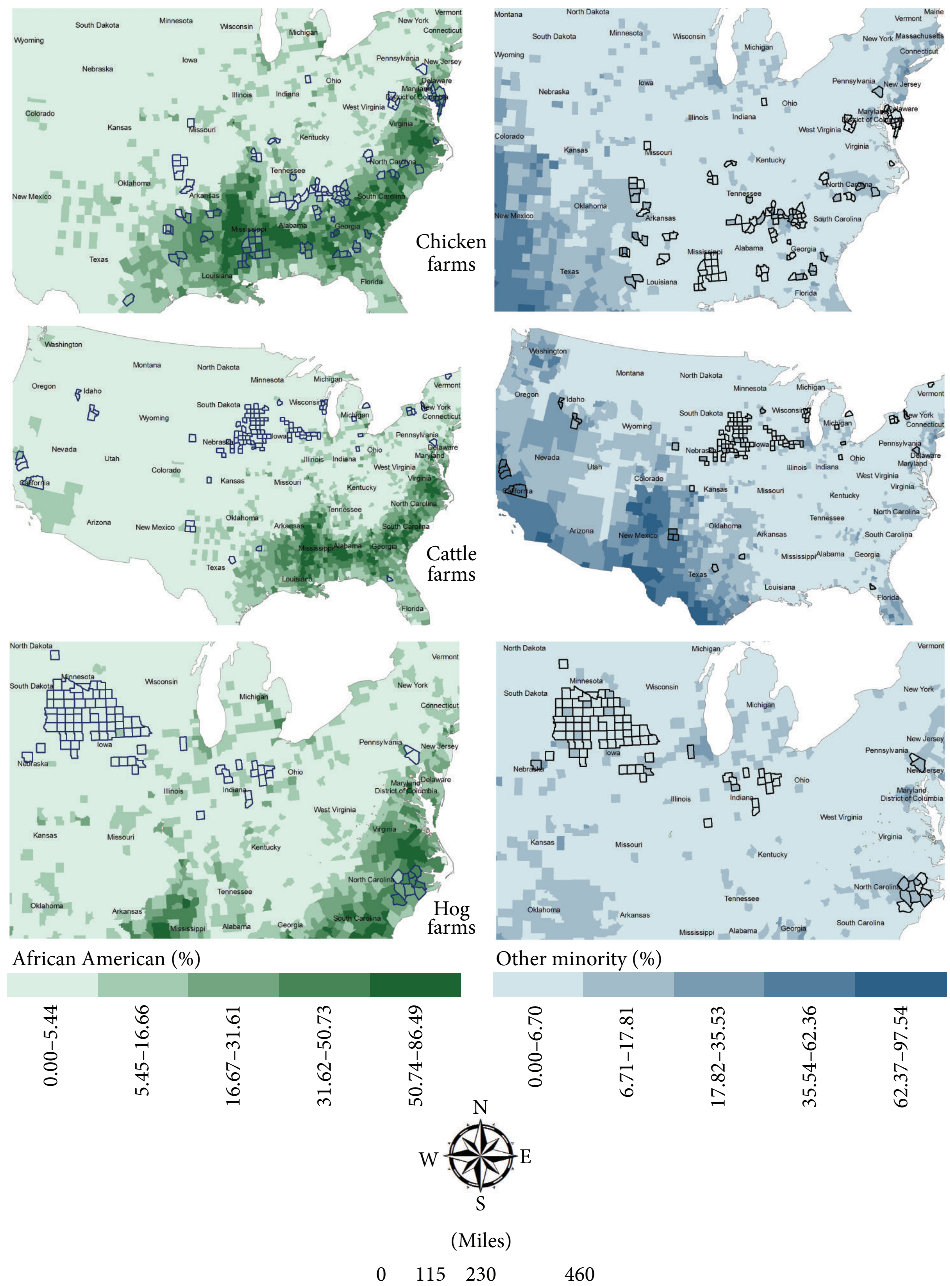


FIGURE 2: Hotspots of industrial farms in 2002 and 2007.

White population and the percentage of white population below poverty level were found significantly higher in case of the cattle farms. However the attributes related to the minority population (including African-American and indigenous population) and the total percentage of population below poverty level were found to be not significant or significantly lower. Similar pattern is observed in case of the hog farms. The percentage of white population was found to be significantly higher in the hotspots and consequently the white population below poverty was also significantly higher. No significant difference or significantly low difference in minority and indigenous population was found between the hotspots and non-hotspots of hog farms.

Considering the findings, the high percentage of African-American population, percentage of population below poverty level, and percentage of African-American population below poverty level demonstrate the prevalence of EJ issue only in case of chicken CAFOs. However, this finding



Coordinate system: GCS_North_American_1983
Date source: US agricultural census data for 2002 and 2007

FIGURE 3: Demographic character of the hotspots.

TABLE 2: Demographic characteristics in the hotspots and non-hotspots of industrial farms in 2007.

Population attributes	Hotspots			Nonhotspots		
	Cattle	Hog	Chicken	Cattle	Hog	Chicken
African-American population (%)	2.68	7.05	13.13	12.04	11.90	11.84
Other minority groups (%)	17.40	4.38	5.37	12.57	12.71	12.74
Population below poverty (%)	13.01	9.50	14.19	11.94	11.95	11.91
White: below poverty (%)	52.93	71.47	61.69	56.02	55.99	55.98
African American: below poverty (%)	4.48	18.84	27.00	23.55	23.22	23.13
Others; below poverty (%)	42.60	11.32	11.31	26.62	27.06	27.19

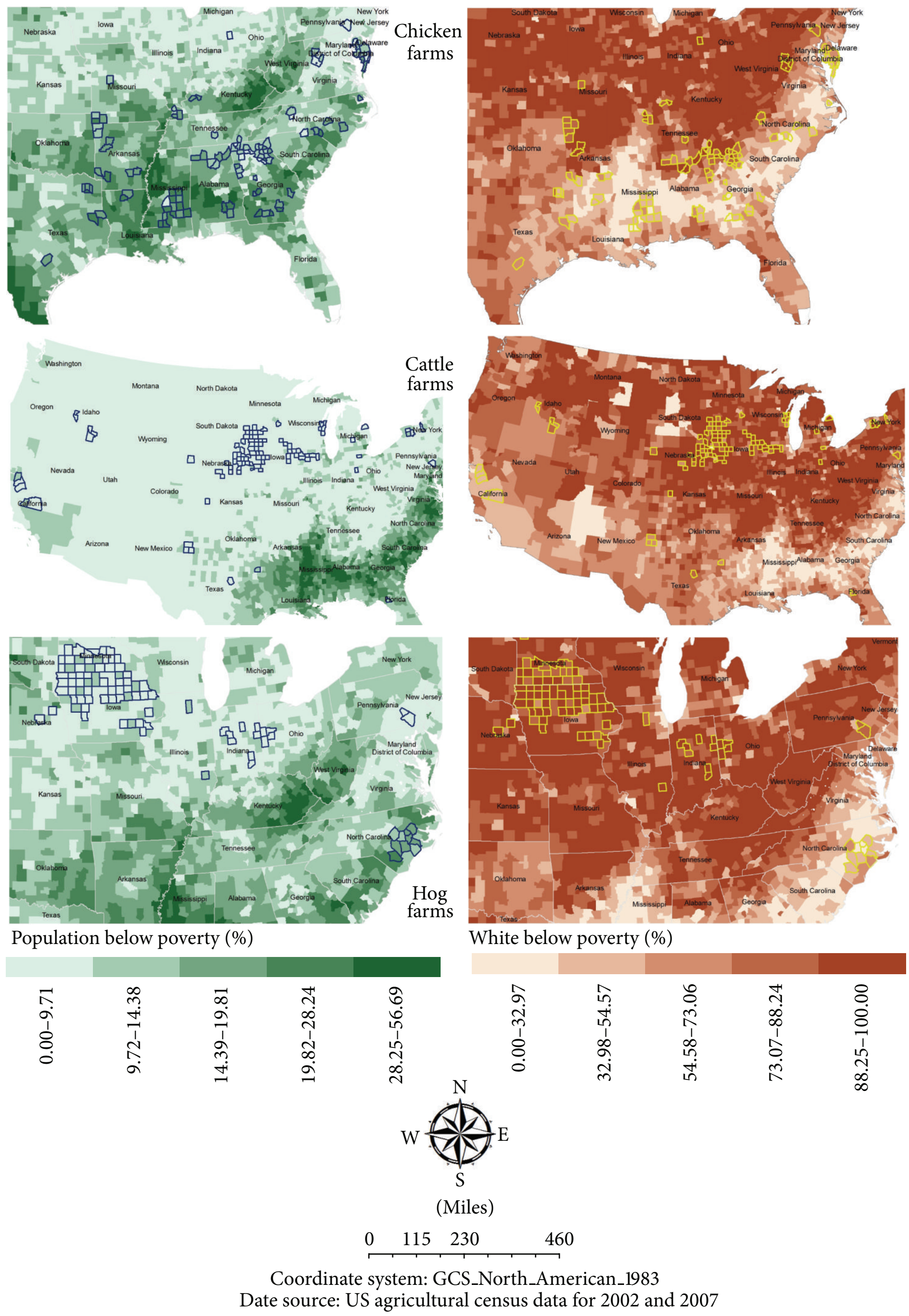


FIGURE 4: Socio-economic character of the hotspots.

contradicts the concern of EJ by other researchers as they have found EJ issue in the areas with hog farms. However, it should be noted that other studies were conducted at a smaller scale, and this research looks at the presence of industrial farms nationwide at the county level.

3.3. Modeling the Relationship. Multivariate regression analysis was performed to establish the relationship between the concentration of industrial farms and the socio-economic, health, and environmental characteristics of the counties. The counties that had one or more industrial farms were selected for this analysis. The dependent variable in three regressions was the number of industrial farms per 1000 population in selected counties. Three models were selected (one for each category of industrial farm) depending on the significance level and ability to express the variation in the relationship between the dependent and independent variables.

The multiple R^2 value for the chicken farms model was 0.398 meaning that about 40% of the variation can be explained by the model. The factors that were closely related

Table 3: Comparing demographics in the hotspots and non-hotspots.

Categories	Attributes	HS	NHS	Upper limit	Lower limit	Significance
Chicken farms	White population	79.13	69.65	−0.872	−9.163	SL
	AA population	**13.13**	**11.84**	**11.492**	**5.155**	**SH**
	Other minority population	6.89	17.49	0.361	−5.215	NS
	Indigenous population	0.86	1.02	0.555	−2.313	NS
	Population below poverty level	**13.89**	**11.91**	**3.209**	**0.408**	**SH**
	White below poverty level	63.05	55.98	−6.652	−16.989	SL
	Black below poverty level	**27.60**	**23.13**	**19.789**	**9.994**	**SH**
	Others below poverty level	12.81	29.00	0.41	−8.063	NS
Cattle farms	White population	**73.63**	**69.67**	**11.684**	**2.72**	**SH**
	AA population	2.68	12.04	−4.226	−11.118	SL
	Other minority population	22.60	17.27	6.66	−5.259	NS
	Indigenous population	1.08	1.01	12.372	−12.834	NS
	Population below poverty level	11.92	11.94	−2.526	−5.546	SL
	White below poverty level	**57.77**	**56.02**	**15.515**	**4.283**	**SH**
	Black below poverty level	4.89	23.55	−7.467	−18.151	SL
	Others below poverty level	48.27	28.42	8.036	−1.105	NS
Hog farms	White population	**87.06**	**69.58**	**14.313**	**5.773**	**SH**
	AA population	7.05	11.92	−1.459	−8.037	SL
	Other minority population	5.56	17.48	−0.957	−6.715	SL
	Indigenous population	0.33	1.02	0.022	−2.939	NS
	Population below poverty level	9.50	11.96	−3.32	−6.192	SL
	White below poverty level	**71.47**	**55.95**	**16.72**	**6.008**	**SH**
	Black below poverty level	18.84	23.25	−2.569	−12.757	SL
	Others below poverty level	11.89	28.90	−0.598	−9.351	SL

Note. (1) All the demographic attributes in hotspots and non-hotspots are in percent. (2) HS: hotspots. (3) NHS: non-hotspots. (4) The t-test was performed considering 95% confidence interval. (5) SH: significantly high. (6) SL: significantly low. (7) NS: no significant difference.

to the density of chicken farms through the model were population density, percentage of minority population, percentage of population below poverty, and the premature death rate. Positive relationship was observed between the density of chicken farms and population density and percentage of minority population, whereas the percentage of population below poverty and the premature death rate were found to be negatively correlated. This model indicates that the density of the chicken farms increases with the increase in the population density. This means that there is high density of chicken farms mostly in the areas where there is high density of population. The density of the chicken farms increases in the areas where there is a high percentage of minority population. With the increased density of the chicken farms, the percentage of population below poverty decreases. The model also revealed that the premature death rate decreases in the areas where there are increased densities of industrial farms. So, as per the model, chicken farms are situated mostly in high population density areas which also have high percentage of minority population. However the farms were not situated in the areas which had high percentage of population below poverty. The negative relationship with the premature death rate does not confirm the adverse health impact on the population in relation to higher density of chicken farms. However, association of high percentage of minority population with the increase in the density of chicken farms was identified through the model, which indicates the existence of environmental justice issue in this case.

The second model was developed to find out the relationship between the hog farms and the socio-economic, health, and environmental characteristics. The multiple R^2 value of the model was 0.434 which means that about 44% of the variations in the relationship can be captured through the model. Population density, percentage of minority population, percentage of indigenous population, percentage of minority and indigenous population below poverty, premature death rate, mean mentally unhealthy days, and low birth weight were closely related to the number of hog farms in each county. The percentage of minority and indigenous population below poverty was found to be positively related. The model suggested that the density of the hog farms increases in less densely populated areas. The areas that had low percentage of minority and indigenous population had increasing density of hog farms. Decrease in premature death rate, mentally unhealthy days, and low birth weight is observed in the areas where there is high density of hog farms. An increase in the density of the hog farms is observed when the percentage of minority (other than African American) and indigenous population below poverty is found to increase. Thus as the low income population particularly comprising other minority groups and indigenous population is observed, high density of hog farms is more likely to appear. Thus environmental justice issue may not be neglected for hog farms based on the model finding.

The third model for cattle farms had the multiple R^2 value of 0.452, which means that the model could explain about 45% of the variations in the dependent variable. Population density, percentage of population below poverty level, premature death rate, mean physically and mentally unhealthy days, and low birth weight were found to be significantly related; that could explain the variation in the density of the cattle farms. The percentage of population below poverty level was found to be positively related to the density of cattle farms. The model indicated that the density of the cattle farms increases in the areas which have low population density. The density of the cattle farms increases where there is an increasing population below poverty level. The premature death rate, physically unhealthy days, mentally unhealthy days, and low birth rate were found to decrease in relation to the density of the cattle farms at county level. So, considering the issue of environmental justice, as the density of the cattle farms increases with the increase in the total population below poverty level, thus it may be concluded that the EJ issue is prevalent in this type of industrial farm also.

On selecting the best fit model, other than the coefficient of determination (multiple R^2) many other criteria were also considered. First, all the models that were selected were statistically significant at 95% confidence interval. Each finally selected variable was also statistically significant. Second, the Koenker (BP) statistic was assessed for its significance. As in all the models this indicator was found to be statistically significant, so it can be said that the coefficients were significant in the model. Third, the VIF value for each of the finally selected variables in each of the models was less than 7, which ensured that the explanatory variables in the models were not redundant. Fourth, the significance of Jarque-Bera test was consulted. Apart from the model developed for hog farms, in all other models it was found that the Jarque-Bera statistic was significant. This implied that in those models one or more key variables were missing. Finally, the residuals of the models were assessed for spatial autocorrelation using Moran's I test. The value of the Moran's I of the standardized residuals varied from 0.05 to 0.2. The value indicated that the residuals were not very clustered. However the high z-scores associated with the "I" values made the clusterization statistically significant. The residuals were assessed and were found to be normally distributed as no specific pattern was observed.

However, it must be considered that the relationships that are established through the models are valid at a larger geographical scale, that is, county level only. The correlations among the explanatory and dependent variables may appear differently while the same analysis is performed at a smaller scale such as census block group and tract level. The data for CAFOs were available only at county level. However the vulnerable population is widely dispersed in counties and is potentially concentrated in smaller pockets [34, 35]. Discrepancy in the choice of areal units affects the comparability of studies and the strengths of associations, which is referred to as the "Modifiable Areal Unit Problem (MAUP)" that leads to ecological fallacy [36, 37]. In the MAUP effect, when the smaller units of analysis are aggregated to form larger units, the original values are averaged or smoothed at the aggregate level. If standard statistical procedures such as regression analysis are performed when the MAUP effect is pervasive, the correlations among variables for the aggregate units will likely be different from that for the disaggregated level [36, 38]. Therefore, inconsistent correlations across scales imply that statistical results will also vary across scales. Since, aggregated data for different scales cannot provide a consistent picture on the individual situation, extrapolating the model findings from this study and implying to smaller scale may lead to erroneous conclusions. However, Wong [36] recognizes that a result based on one dataset is only one of many possible results, and thus the range of possible results should be reported whenever possible. Several studies on inequality/deprivation and health outcomes were conducted at county level [39–41]; however, most of the studies related to inequalities and CAFOs concentrate on smaller scales [19, 21, 22, 24]. This study examines the relationships at a larger geographical scale. It is strongly recommended that similar study needs to be conducted at the ZIP Code Tabulation Area (ZCTA) level to establish the relationships of CAFOs and inequalities to derive more specific conclusions. Nevertheless, identifying data on CAFOs at smaller scale will be a challenge because information about exact geographic location of CAFOs is only available for a few states.

4. Conclusion

This study revealed that the geographic distribution of factory farms varied by type of farm. The cattle farms were more concentrated from central to western parts of the United States; the hog farms were clustered in the central part, and the chicken farms were distributed at the southeastern part of USA. From the year 2002 to 2007, no change in geographic distribution was observed as the number of factory farms increased in the same geographic location over the time period. The counties in Iowa, Nebraska, Minnesota, Illinois, and Indiana at the central part of the United States; Georgia, Arkansas, Mississippi, and Alabama in the southern part of the United States; North Carolina, Delaware, Pennsylvania in the eastern part of the United States; and California in the western part of USA were the hotspots of the factory farms.

The race that dominated the hotspots is primarily white population. African-American population was found to be very small proportion of the total population. The population below poverty level was not a significant proportion of the total population. However, of the total population who were below poverty level, white population is the highest in this category and African-American population is the lowest. The large number of white population in the hotspots constituted this higher percentage in the population who were below poverty level. The difference in the demographic characteristics of the hotspot and non-hotspot areas confirmed that the environmental justice issue was prevalent for chicken farms only, because of the significantly high percentage of the African-American population, percentage of population below poverty level, and the percentage of African-American population below poverty level.

The regression analysis provided a different insight on the environmental justice issue. The explanatory models developed for analyzing the relationship between the number of industrial farms and the selected socio-economic, health, and environmental characteristics demonstrated that each type of industrial farms interacted differently with the explanatory factors. Thus general inference cannot be drawn for industrial farms per se, without exploring each type of farm. The chicken farms were more likely to appear in the areas of high population density, but the cattle and hog farms in low population density areas. The increase in the concentration of chicken farms was also associated with high percentage of minority population that was opposite to the case of the density of hog farms. Positive relationship with the percentage of population below poverty level was observed for cattle farms. The hog farms demonstrated positive relationship with the percentage of minority and indigenous population below poverty level. In none of the models, environmental characteristic was found to be significantly associated with the density of the industrial farms. If it is considered that meeting any one criteria of EJ confirms the prevalence of EJ issue, then as per the model findings, the EJ issue is found to be valid for all the categories of industrial farms.

Although the study provides a distinct overview of the spatial distribution of industrial farms and coarsely clarifies the EJ issue, there are few limitations associated with the study. The limitations are centered on the issue of data availability and uncertainty. First, there is no specific category for CAFO in the US agricultural census data. Thus, there is a chance of overestimation or underestimation in this study. Second, many studies have shown the connection between the industrial farms and the environmental pollution characteristics. The connection between the public health and the industrial farms is understudied. So, it was difficult to decide on the variables to include in the model for assessing relationship. In addition, availability of the data at county level at nationwide scale was a limitation. Finally, the study draws on conclusions about the relationships between the CAFOs and inequalities based on county level data, which may be different if the analysis was performed at a finer scale. Despite these limitations, this study provides a strong basis of understanding of the spatiotemporal distribution of CAFOs and their interaction with humans and the environment at a larger geographical scale. It provides a strong basis for exploring the relationships at multiple spatial scales in future studies and also facilitates framing future research opportunities for policy and planning.

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