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Understanding Geographic and Neighborhood Variations in Overdose Death Rates

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Abstract

The current opioid epidemic continues to challenge us in new and potentially troubling ways. For example, research today finds more overdose deaths occurring in rural, rather than urban, geographic areas. Yet, studies have often ignored heterogeneities within these spaces and the neighborhood variations therein. Using geodemographic classification, we investigate neighborhood differences in overdose death rates by geographical areas to further understand where and among what groups the problem might be most concentrated. For deaths between 2013 and 2016, we find significant variation in rates among neighborhoods, defined by their socio-economic and demographic characteristics. For example, overdose death rates vary up to 13-fold among neighborhoods within geographic areas. Our results overall show that while the rural or urban classification of a geographic area is important in understanding the current overdose problem, a more segmented analysis by neighborhood's socio-economic and demographic makeup is also necessary.

Keywords Overdose deaths · Rural and urban areas · Neighborhoods · Geodemographic classification · Delaware

Introduction

Drug overdoses have become the leading cause of death for Americans under 50 years of age [1]. The epidemic, and its continued escalation, has shown it can hit nearly anyone anywhere. One segment of research on the distribution of overdoses in America has focused on the difference between rural and urban areas. Unlike previous American drug epidemics that were concentrated in urban areas, the current opioid epidemic is manifesting more in rural areas [1]. For example, between 1991 and 2004 United States overdose death rates increased 16% in metropolitan counties and 248% in non-metropolitan or rural counties [2]. Furthermore, use of illicit drugs was higher among adults in urban counties for the period from 2003 to 2014, yet overdose death rates in rural counties ranked above urban counties in 2015 [3]. Similarly, recent studies showed a shift in heroin overdose deaths from the most urban counties to small metro and non-metro counties [4, 5]. And in recent years, riskier patterns of drug use [6–8], as well as higher prescribing rates and prescription drug poisoning rates were found among rural populations [9–11]. Accordingly, past research has stressed the need to investigate geographic variations in overdose deaths [1–3, 5, 8, 10–14].

Still, research that focuses on urban/rural differences in opioid use are not conclusive in demonstrating the epidemic is hitting rural areas harder than urban areas. For example, studies of prescription opioid misuse found higher rates for adults in urban areas but for adolescents in rural areas [13, 15]. Moreover, a recent meta-analysis of prescription drug overdose research shows conflicting and inconclusive results regarding measured urban and rural differences [14]. One of the main reasons for these conflicting results may be the definitions that group together areas of varying urbanicity and rurality [10, 14]. But more importantly, debates about rural and urban overdose deaths treat the geographic designations of rural and urban as largely homogenous areas [10, 16]. Studies that focus on overdose death trends in rural states or counties necessarily ignore variations within these geographic areas. While this spatial aggregation of overdose deaths eases reliable estimation of trends, it overlooks

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features that may contribute to variation in overdose death rates within the geographic areas, such as neighborhood characteristics.

This is apparent when we look at the complex relationships between place and health, or, specifically, between place and overdose deaths [10, 17]. While researchers have conceptualized the mechanisms that underlie spatial effects on the neighborhoods level, empirical research too often relies on spatial aggregation and abstracts from the underlying mechanisms research has proposed. For instance, spatial dimensions impact overdose death rates through socio-economic and demographic neighborhood characteristics which are heterogeneous within rural and urban areas (e.g., within counties or ZIP-Codes) [10, 17]. Studies on overdose deaths have pointed toward important variations by an area's economic traits [18–22], and racial and ethnic composition [23, 24]. Urban low-income areas have reported higher overdose death rates due to lower investment in health resources and higher health stressors associated with poverty [18–22, 25]. In rural areas, studies attribute overdose increases to a lack of treatment and emergency resources, higher prescribing rates of opioids, more employment with a high risk of injury, reduced economic infrastructure and out migration of young people, and an overall increased strain on otherwise "cohesive" communities [10, 11, 14, 26, 27]. Thus, if neighborhoods differ by demographic or other socio-economic factors, then overdose death rates might vary not only by their geographic location, but also by their population characteristics [11].

The purpose of our paper is, therefore, to investigate patterns in overdose deaths by space and demographic makeup by applying a geodemographic classification approach to the state of Delaware. We draw out differences between *neighborhood types* within *geographic areas* to advance our understanding of where and why overdose deaths are occurring. Using a multidimensional classification of neighborhoods, we demonstrate that investigations of overdose death rates must go beyond imprecise understandings of rural vs. urban geographic areas, or wealthy vs. disadvantaged neighborhoods. Thus, we argue that refining our understanding of rural and urban geographic areas can contribute to more meaningful, targeted interventions.

Background: Geodemographic Classification

Geodemographic classification shows promising capabilities to tackle some of these consistent problems of overdose death research. Geodemographic classification advances a contextual mode of inquiry [28], that emphasizes the shared social, economic, and demographic characteristics of different types of neighborhoods, which shape opportunities, local culture, and individual identities and behaviors [17, 29, 30]. Geodemographic classification is a neighborhood-level analysis of "people where they live" [31]. As a data reduction strategy, it aggregates populations based on multidimensional neighborhood characteristics and divides them into meaningful subpopulations [32], thus mirroring closely the complex models of neighborhoods that have been developed [8].

Applying a geodemographic classification approach to understanding patterns in overdose deaths (e.g., how they might vary between and within urban, suburban and rural areas) becomes especially useful since overdose deaths are not homogenous across demographic groups or degree of urbanization [18–24]. The technique allows us to investigate how neighborhood types, not just their geographic location, affect overdose deaths. Within urban and rural areas, we might find neighborhoods with especially high or low overdose death rates but for quite differing reasons, thus justifying unique interventions. For example, the gentrification of inner city neighborhoods and cycling of lower income populations into suburban areas as neighborhoods age, might suburbanize or alter problems (like overdose deaths) traditionally located within socially disadvantaged urban neighborhoods. And, questions such as whether protective effects of wealthy neighborhoods are consistent across all types of wealthy neighborhoods, for instance in urban and suburban areas, can be addressed using geodemographic classification. Similarly, neighborhoods with unique occupation and economic structures (often risk factors for high prescribing and drug dependency) within rural areas require independent investigation and we might under- or overestimate overdose death rates if we group neighborhoods together by their geographical designation only [10, 11].[1] Thus, investigations across space might tell only half the story about these developments [32, 33].

Accordingly, our geodemographic approach asks: *how do neighborhood types in Delaware vary within geographic areas along the rural–urban continuum in regard to their overdose death rates?* We hypothesize significant variation between neighborhood types within geographic areas and expect the socio-economic status of neighborhoods to be a central differentiation category, with more wealthy neighborhoods having lower rates of overdose deaths and more disadvantaged neighborhoods having higher ones. However,

[1] Moreover, the approach allows us to address a methodological issue that has complicated neighborhood level research on overdose deaths in the US. Since the American Community Survey (ACS) has replaced the long form of the decennial census, it is the most prominent source for contextual information for geographic areas in the US [28, 34]. However, small scale data on the block group level or census tract level, which most closely align with our understandings of neighborhoods, show high levels of uncertainty [28, 34–36]. In geodemographic classification based on ACS data uncertainty for small scale data is reduced by using a composite of multiple variables [28].

we also expect variations based on socio-cultural characteristics of neighborhoods to further refine the relationship between economic status and overdose deaths.

Methods

We classify Delaware census tracts along a rural–urban continuum to analyze variations among geographic areas. And, we use Spielman and Singleton's [28] geodemographic classification of U.S. census tracts to examine variations in overdose death rates between neighborhood types. Additionally, we investigate variations within the geographic areas between neighborhood types. The analysis of differences in Delaware overdose death rates from 2013 to 2016 uses direct standardization controlling for confounding factors such as age, sex, and race. Our study and use of these data was approved by our university's Institutional Review Board.

Geographic Areas

We use the term *geographic area* to refer to larger areas defined as urban, suburban or rural based on population density. We use the term *neighborhood type* to refer to smaller spaces within geographic areas that differ in demographic and economic indicators. Our analysis distinguishes four geographic areas for Delaware census tracts: Rural areas with a housing density of less than 65 units per square mile; Small Town and Outer-Suburban areas with 65 to 640 housing units per square mile; Inner-Suburban areas between 641 and 1600 units per square mile; and Urban areas with more than 1600 housing units per square mile [37, 38].

Geodemographic Classification

For our study, rather than using a bespoke classification (e.g., based only on Delaware census tracts, or only on variables found previously predictive of overdose deaths), we applied Spielman and Singleton's [28] general-purpose classification, which is derived from national data. General-purpose classifications have been proven reliable tools and are widely used in the private and public sectors (U.K.) [39–41]. Moreover, using an established general-purpose classification based on national data that is readily available for all states has the potential to allow for reliable comparisons between our study and other studies, and so to better inform and advance regional **and** national debates about overdose deaths and neighborhood effects.

Spielman and Singleton's [28] geodemographic classification builds on three conceptual frames, population, environment, and economy which are further divided into domains: for population—age, race, education, family structure, and language; for environment—stability, housing, and density; and for economy—commuting, occupation and wealth. Spielman and Singleton [28] identified 2,864 variables in the 5 year 2011 American community Survey (ACS) that corresponded to the three concepts and reduced these to 136 variables based on criteria such as reasonably low margin of error, low correlation with other variables, and near universal coverage among census tracts.[2] Range standardized measures were k-mean clustered with 250 starting clusters, 100,000 random initiations, a maximum of 1,000,000 iterations, and were further refined using Ward's method [28]. Decisions about cluster solutions were based on average silhouette width, with a ten and 55 cluster solution showing the best separation between clusters.

To examine variations between neighborhood types within and across geographic areas, we used the ten-cluster solution for the 214 Delaware census tracts.[3] This allows us to balance investigating variations with the need for sufficiently large overdose deaths counts for reliable rate estimations and significance tests. Of these ten clusters or super-types common across the US we find eight in Delaware (see Fig. 1).

Figure 1 shows a heat-map of selected neighborhood characteristics. Neighborhood types are ranked for each variable, with darker shadings indicating higher rankings and, accordingly, stronger associations between the neighborhood characteristic and the respective neighborhood type. The variables in the upper third of the table are mainly indicators of social disadvantage, for instance lower income levels, the percentage of the population with public assistance, or indicators of residential instability. In the middle of the table we positioned middle income categories, and occupational fields. The lower third of the table shows indicators of privilege, such as higher incomes, or advanced educational degrees.

All neighborhoods are defined by specific socio-economic patterns. For example, while neighborhood types A and B are associated with higher levels of wealth and privilege, G and H show strong associations with social disadvantage. Neighborhood types D and E show associations with middle-income categories, albeit D skews towards the wealthier side while E shows associations with social disadvantage. Moreover, neighborhood types C and F combine higher rankings for indicators on the lower side (wealth, privilege)

[2] The five-year 2011 ACS data conveniently aligns with the beginning of our study period 2013–2016 making the classification valuable for our investigation. Input, output, and validation data of Spielman and Singletons classification are available at https://www.openicpsr.org/openicpsr/project/100235/version/V5/view. R code for cluster analysis and data visualization is available at https://github.com/geoss/acs_demographic_clusters.

[3] Delaware has 218 census tracts, four of these have no civilian population and were excluded from the analysis.

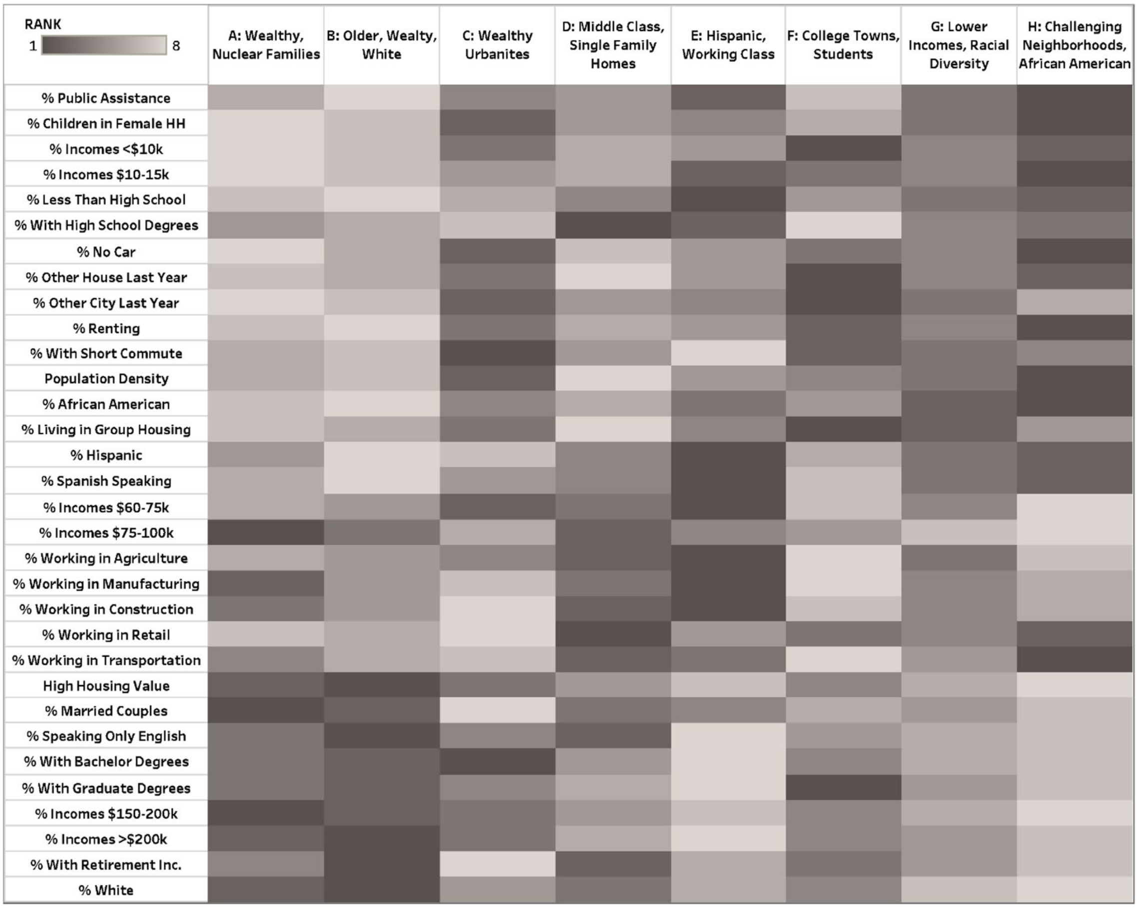

Fig. 1 Heat map of selected ACS population characteristics for geodemographic classified neighborhoods. Neighborhoods are ranked from 1 (Highest) to 8 (Lowest) depending on the percentage of the ACS characteristic they contain. Darker shadings indicate a higher rank and a higher percentage

and upper side of the table (social disadvantage). Neighborhood type C is here especially interesting. The neighborhood type shows, for example, the third highest levels of overall incomes, the highest percentage with bachelor's degrees, and high housing values; but, neighborhood type C is also one of the most urban neighborhoods with high levels of residential instability and very low-income populations. Neighborhood type C so describes a specific urban, wealthy neighborhood type which would be difficult to identify using other common approaches in studies on neighborhood effects, such as reliance on income quartiles, or concentrated disadvantage scores.[4]

Neighborhood clusters are also defined by, for example, demographic pattern, such as specific compositions of their populations' age, race, and ethnicity. The neighborhood names we use in the following sections are adapted from Spielman and Singleton [28] and show two or three defining characteristics of the neighborhood types, abstracting, of course, from the complexity and variability all neighborhood types entail. Figure 2 provides the reader a short narrative overview of the eight neighborhood types with some additional characteristics.

Outcome Variable: Delaware Overdose Deaths 2013–2016

Postmortem toxicology reports were conducted by medical examiners from the state of Delaware. The medical examiners investigates and certifies the cause and manner of death of those who die within the state's boundaries and fall under the statutory jurisdiction of the office. Suspected overdose deaths identified by a medical examiner are then subjected to

[4] For instance, we found that the neighborhood type shows comparable scores to the wealthy-neighborhood types A and B when defined by a common concentrated disadvantage measure (http://www.amchp.org/programsandtopics/data-assessment/Documents/Tip%20Sheet_Concentrated%20Disadvantage_LC-06_Final.pdf) and fall into the same income quartile.

Narrative Overview of Delaware Neighborhood Types

A: Wealthy, Nuclear Families: Few young adults; advanced degrees; married families; high residential stability; White and Asian; newer, high value single family homes; wealthy, high incomes; high levels of car ownership and work commuting.

B: Older, Wealthy, White: Older population; college educated; high residential stability; English speaking; White; wealthy, stable retirement incomes and high incomes; expensive rentals and higher vacancy rates (includes coastal towns with seasonal tourism).

C: Wealthy Urbanites: Many young adults; White, Asian, non-citizens; college educated and advanced degrees; few married couples and higher rate of same-sex HH; high residential instability; high percentage of renters; lower levels of car ownership; occupational concentration in management, finance, information; wealthy, high incomes.

D: Middle Class, Single Family Homes: Somewhat older population; predominantly White; high school degrees and some college; mix of single parents and married couples; residential stability; English speaking; retirement incomes, middle HH incomes; high levels of car ownership; single family homes and higher levels of mobile homes.

E: Hispanic, Working Class: High percentage of kids; high Hispanic population; higher share of high school drop outs and few college degrees; single mothers; multilingual; high mobility within cities; multi-family homes rentals; high public transit usage; occupations concentrated in Agriculture, Manufacturing, and Construction; lower incomes and higher share of public assistance.

F: College Towns, Students: Young People; college educated and advanced degrees; few married couples; high residential instability; high public transit usage; group quarters; service occupations; lower incomes.

G: Lower Incomes, Racial Diversity: Few seniors; high school and some college; single parent families; high residential instability; multilingual; racial/ethnic mix; short commutes; renting in multi-family homes; occupations concentrated in service, public administration; lower incomes.

H: Challenging Neighborhoods, African American: African American; high school degrees or less most frequent; high share of single moms; multilingual; high residential instability; older houses and high-rise units; relative expensive rents; high public transit usage; transport and service occupations; lower incomes and high share of public assistance.

Fig. 2 Narrative overview of neighborhood types

further toxicological examination. The Forensic Toxicology Unit works in tandem with pathologists in the ME Unit to determine what substances were present in the decedent at the time of death. The toxicology report is then reviewed by the assigned pathologist and a cause and manner of death is determined.

The present sample includes toxicology reports for drug overdose deaths in the state of Delaware compiled from a 4-year period (2013–2016). Assignment of decedents to census tracts was based on the home address of the decedents. Cases with home addresses outside the state of Delaware or that were determined to be homeless were excluded from the analysis. Addresses were geocoded using ESRI ArcGIS address locators and, finally, mapped to census tracts. This amounted to a total of 851 overdose deaths from 2013 to 2016, with 174, 209, 218, and 250 deaths for each respective year (see Table 1 below). Cases included information about decedents' ages, sex, and race. Subsequently cases were aggregated to the census tract level and merged with the neighborhood classification and population data.

Table 1 2013–2016 overdose death rates by geographic areas

Geographic areas	Overdose deaths 2013–2016	Person-years	Crude Overdose death rate[a]	Adjusted Overdose death rate[b]
Rural areas	86	385,944	22.3	19.4 (15.4–24.6)[c]
Small towns and outer suburban areas	333	1,619,284	20.6	20.3 (18.2–22.7)[c]
Inner suburban areas	201	831,556	24.2	24.1 (20.9–27.7)[c]
Urban areas	231	812,020	28.4	31.7 (27.6–36.2)[d,e,f,g]
State of Delaware	**851**	**3,648,804**	**23.3**	**23.3 (21.8–24.9)**

[a]The crude overdose death rate is not adjusted for the age, sex, or racial composition of geographic areas

[b]Adjusted overdose death rates account for the age, sex, and racial composition of geographic areas. In parentheses, 99% confidence intervals are displayed

[c]Indicates significant differences from Urban Areas (α = 0.01)

[d]Indicates significant differences from Rural Areas (α = 0.01)

[e]Indicates significant differences from Outer Suburban Areas (α = 0.01)

[f]Indicates significant differences from Inner Suburban Areas (α = 0.01)

[g]Indicates significant differences from the State of Delaware (α = 0.01)

Analysis

We calculate standardized death rates to control for confounders across neighborhood types [42]. Neighborhood rates were standardized based on characteristics that have been found to be directly correlated with overdose deaths, such as age, sex, and race/ethnicity.[5] We use direct standardization against the Delaware 2010 census, thus geographic areas and neighborhood types can be safely compared. We use the Stata command *distrate* developed by Consoni et al. [43] that builds on Stata's *dstdize* command. *Distrate* uses modified gamma intervals and delivers more reliable confidence limits, especially for rare events, since it is more conservative in their estimation [44]. To test for statistical difference between geographic areas and neighborhood types, we calculated standardized rate ratios of the overdose death rates, and their 99% confidence limits. All rates are calculated per 100,000 person-years.[6]

Results

Delaware Overdose Deaths 2013–2016 by Geographic Areas

Table 1 displays the overdose deaths counts and person-years for geographic areas during the study period. The table also shows the crude overdose death rates, as well as the age, sex, and race adjusted overdose death rates with 99% confidence bands. The overall overdose death rate in Delaware for the study period is 23.3 per 100,000 person-years. Table 1 allows to compare variations in overdose death rates by geographic areas. Specifically, the lowest adjusted overdose death rates are found in Rural, and in Small Towns and Outer Suburban areas with rates of 19.4 and 20.3 respectively. Overdose death rates are highest in Urban areas, 31.7 per 100,000 person-years. And, Urban areas are the only geographic areas that are statistically different from the State rate (α = 0.01). Urban areas are, moreover, significantly different from all other geographic areas (with an up to 60% higher rate). Overall, for the study period crude and adjusted overdose death rates are highest in Urban areas while all other geographic areas are neither significantly different from one another nor from the State.

Delaware Overdose Deaths 2013–2016 by Neighborhood Types

The geodemographic classified neighborhoods show remarkable variation (see Table 2), ranging from an adjusted overdose death rate of 13.9 per 100,00 person-years (crude overdose death rate 7.3) in neighborhood type F (College Towns, Students) to 82.2 (crude overdose death rate 87) in type C (Wealthy Urbanites). Four neighborhood types show significantly different rates from the state. In addition to type C (Wealthy Urbanites) with a significantly increased rate, neighborhood type A (Wealthy, Nuclear Families) has a significantly lower rate of 16.2. Type D (Middle Class, Single Family Homes), 26.6 per 100,000 person-years, has a significantly higher rate than the state. And, neighborhood type H (Challenging

[5] There were 851 overdose deaths among Delaware residents in the study period from 2013 to 2016. 64% of the decedents were male, 84% were white and the median age of the decedents was 43 years.

[6] Person-years are calculated as four times the 2010 census population for the respective geographic areas or neighborhood types.

Table 2 2013–2016 overdose death rates by neighborhood types

Neighborhood types	Overdose deaths 2013–2016	Person-years	Crude overdose death rate[a]	Adjusted overdose death rate[b]
A: Wealthy, nuclear families	189	1,095,900	17.2	16.2 (13.9–18.7)[c,d,f]
B: Older, wealthy, white	26	172,348	15.1	15.5 (8.5–26.5)[d]
C: Wealthy urbanites	12	13,800	87	82.2 (40.1–155.4)[c,e,f]
D: Middle class, single family homes	455	1,673,732	27.2	26.6 (24.2–29.2)[e,d f]
E: Hispanic, working class	32	131,628	24.3	30.5 (20.6–43.7)[e,d]
F: College towns, students	9	123,664	7.3	13.9 (6.1–26.9)[d]
G: Lower incomes, racial diversity	59	247,376	23.9	28.3 (21.2–36.9)[e,d]
H: Challenging neighborhoods, African American	69	190,356	36.2	60.8 (42.3–83.9)[c,e,f]
State of Delaware	**851**	**3,648,804**	**23.3**	**23.3 (21.8–24.9)**

[a]The crude overdose death rate is not adjusted for the age, sex, or racial composition of neighborhood types

[b]Adjusted overdose death rates account for the age, sex, and racial composition of neighborhood types. In parentheses, 99% confidence intervals are displayed

[c]Indicates significant differences from the Middle Income, Single family Homes neighborhood type ($\alpha = 0.01$)

[d]Indicates significant differences from the Lower Income, Minority neighborhood type ($\alpha = 0.01$)

[e]Indicates significant differences from the Wealthy Nuclear Families neighborhood type ($\alpha = 0.01$)

[f]Indicates significant differences from the State of Delaware neighborhood type ($\alpha = 0.01$)

Neighborhoods, African American), with an adjusted rate of 60.8 per 100,000 person-years (crude overdose death rate of 36.2), has the second highest rate of all neighborhood types. All neighborhood types, except for neighborhood type C (Wealthy Urbanites), show significantly lower rates then type H (Challenging Neighborhoods, African American). Type H (Challenging Neighborhoods, African American) and type C (Wealthy Urbanites) show significantly higher overdose death rates compared to all other neighborhood types. Type D (Middle Class, Single Family Homes) and type E (Hispanic, Working Class) show significantly higher rates than the wealthy neighborhood type A (Wealthy, Nuclear Families).

Overall, the investigation of neighborhood types reveals significant variation, with the general tendency of wealthy neighborhoods, such as type A (Wealthy, Nuclear Families) and B (Older, Wealthy, White), to display the lowest rates, while rates increase towards middle-income neighborhoods, such as type D (Middle Class, Single Family Homes), and are further increased for lower income neighborhoods, such as types E (Hispanic, Working Class), G (Lower Incomes, Racial Diversity), or H (Challenging Neighborhoods, African American). There are, however, significant differences between types of lower income neighborhoods. For example, type H (Challenging Neighborhoods, African American) shows a significantly higher rate than all other lower income neighborhood types. And, neighborhood type C (Wealthy Urbanites), with the highest rate of all neighborhood types, illustrates that there is no perfect relation between lower overdose death rates and wealthy neighborhoods.

Delaware Overdose Deaths 2013–2016 by Geographic Areas and Neighborhood Types

We make three types of comparisons to draw out relations between geographic areas and neighborhood types. First, we compare neighborhood types with the geographic areas they are nested in. Second, we examine each neighborhood type separately and compare their rates in the different geographic areas and with their overall rate. And third, we compare neighborhood types within each geographic area with each other.

1. Table 3 shows that while all neighborhood types are present in Urban geographic areas, only four types have tracts in Rural areas. Neighborhood type A (Wealthy, Nuclear Families) and G (Lower Incomes, Racial Diversity) are located in all four geographic areas, while type C (Wealthy Urbanites) is the only neighborhood type restricted to one geographic area (Urban areas). Within all geographic areas, except for Rural areas, we find neighborhood types that have significantly increased or decreased rates compared to the respective geographic area at large. For instance, in Small Town and Other Suburban Areas neighborhood type A (Wealthy, Nuclear Families), and F (College Towns, Students) show significantly lower rates than the geographic area, while type D (Middle Class, Single Family Homes) shows here a significantly increased rate compared to the geographic area. Type D (Middle Class, Single Family Homes) shows, moreover, a significantly increased

Table 3 2013–2016 overdose death rates by geographic areas and neighborhood types

Geographic areas and neighborhood types	Overdose deaths 2013–2016	Person-years	Crude overdose death rate[a]	Adjusted overdose death rate[b]	Standardized rate ratio[c]
Rural areas	**86**	**385,944**	**22.3**	**19.4 (15.4–24.6)**	**1.0**
A: Wealthy, nuclear families	16	76,748	20.8	15.5 (8.8–30.1)	1.0
B: Older, wealthy, white	5	18,032	27.7	23.4 (7.6–70.9)	1.5 (0.4–5.5)
D: Middle class, single family homes	61	274,708	22.2	20.9 (15.7–27.9)	1.4 (0.6–2.6)
G: Lower incomes, racial diversity	4	16,456	24.3	31.6 (6.8–207.3)	2 (0.3–15.4)
Small towns and outer suburban areas	**333**	**1,619,284**	**20.6**	**20.3 (18.2–22.7)**	**1.0 (0.8–1.4)**
A: Wealthy, nuclear families	77	534,440	14.4	13.9 (10.9–17.4)[d,h]	1.0[e]
B: Older, wealthy, white	13	81,912	15.9	13.6 (7–28.1)	1.0 (0.5–2.1)
D: Middle class, single family homes	199	753,688	26.4	26.2 (22.7–30.2)[d]	1.9 (1.4–2.5)[g]
E: Hispanic, working class	19	81,032	23.4	29.9 (17.6–47.8)	2.2 (1.2–3.7)[g]
F: College towns, Students	1	53,076	1.9	2.7 (0.1–18.2)[d]	0.2 (0–1.4)
G: Lower incomes, racial diversity	23	107,328	21.4	22.7 (13.9–34.6)	1.6 (0.9–2.7)
H: Challenging neighborhoods, African American	1	7,808	12.8	3.8 (0.1–119.7)	0.3 (0-8.8)
Inner suburban areas	**201**	**831,556**	**24.2**	**24.1 (20.9–27.7)**	**1.2 (0.9–1.6)**
A: Wealthy, nuclear families	65	344,124	18.9	17.7 (13.6–22.8)	1.0[e]
B: Older, wealthy, white	5	36,012	13.9	47 (3.3–183.4)	2.6 (0.2–10.7)
D: Middle class, single family homes	111	367,400	30.2	31.3 (25.7–37.7)[d,h]	1.8 (1.3–2.5)[g]
E: Hispanic, working class	8	19,812	40.4	40 (16.7–92)	2.3 (0.9–5.5)
F: College towns, students	3	39,156	7.7	37.3 (6.1–114.9)	2.1 (0.3–6.8)
G: Lower incomes, racial diversity	9	25,052	35.9	40.7 (18.4–77.4)	2.3 (1-4.7)[g]
Urban areas	**231**	**812,020**	**28.4**	**31.7 (27.6–36.2)**	**1.6 (1.2–2.1)**
A: Wealthy, nuclear families	31	140,588	22.1	22.1 (15–31.4)	1.0[f]
B: Older, wealthy, white	3	36,392	8.2	6.1 (1.2–31.2)	0.3 (0.1–1.5)[f]
C: Wealthy urbanites	12	13,800	87	82.2 (40.1–155.4)[d,h]	3.7 (1.6-8)[e,g]
D: Middle class, single family homes	84	277,936	30.2	30 (23.9–37.1)	1.4 (0.9–2.1)[f]
E: Hispanic, working class	5	30,784	16.2	23.3 (7.1–56.8)	1.1 (0.3–2.8)[f]
F: College towns, students	5	31,432	15.9	23.5 (6.8–58)	1.1 (0.3–2.9)[l]
G: Lower incomes, racial diversity	23	98,540	23.3	34.7 (21.5–52.2)	1.6 (0.9–2.8)[f]
H: Challenging neighborhoods, African American	68	182,548	37.3	64 (44.5–88.6)[h,d]	2.9 (1.7–4.8)[e,g]
State of Delaware	**851**	**3,648,804**	**23.3**	**23.3 (21.8–24.9)**	**Rural-baseline**

[a]The crude overdose death rate is not adjusted for the age, sex, or racial composition of neighborhood types within geographic areas

[b]Adjusted overdose death rates account for the age, sex, and racial composition of neighborhood types within geographic areas. In parentheses, 99% confidence intervals are displayed

[c]Standardized rate ratios show the rate of a neighborhood or geographic area compared to the respective reference group. A rate ratio of two means that that neighborhood or geographic areas has twice the overdose death rate of the reference category. If the 99% confidence intervals of the rate ratio cross the value one, the reader can conclude that there is no significant difference to the reference group

[d]Indicates significant differences from the geographic area a neighborhood type is nested in ($\alpha = 0.01$)

[e]Indicates significant differences from the Middle Income, Single family Homes neighborhood type within the same geographic area ($\alpha = 0.01$)

[f]Indicates significant differences from the Lower Income, Minority neighborhood type within the same geographic area ($\alpha = 0.01$)

[g]Indicates significant differences from the Wealthy Nuclear Families neighborhood type within the same geographic area ($\alpha = 0.01$)

[h]Indicates significant differences from the State of Delaware

rate in Inner Suburban Areas. Type C (Wealthy Urbanites) and type H (Challenging Neighborhoods, African American) have significantly higher rates than the Urban geographic area they are nested in.
2. Moreover, we find variations for neighborhood types if located in differing geographic areas. For example, although neighborhood type D (Middle Class, Single Family Homes) as a group showed a significantly increased rate compared to the state, but when nested into the different geographic areas, only tracts in Inner Suburban areas show a significantly increased rate compared to the state. Moreover, neighborhood type D (Middle Class, Single Family Homes) shows a significantly increased rate over the respective geographic area only in Outer Suburban, and Inner Suburban neighborhoods but no significant differences in Urban and Rural areas.
3. Comparing neighborhood types within the same geographic area, we find up to 13-fold variations between neighborhood types, for instance between type B (Older, Wealthy, White) and type C (Wealthy Urbanites) in Urban areas. Specifically, in Small Towns and Outer Suburban areas type D (Middle Class, Single Family Homes) and type E (Hispanic, Working Class) show rate ratios of 1.9 and 2.2 times of neighborhood type A (Wealthy, Nuclear Families).[7] In Inner Suburban areas neighborhood types show mainly rates between 30 and 40 per 100,000 person-years, except for neighborhood type A (Wealthy, Nuclear Families) which shows an adjusted rate of only 17.7. Here, neighborhood type D (Middle Class, Single Family Homes) and G (Lower Incomes, Racial Diversity) show significantly higher rates than type A (Wealthy, Nuclear Families). As stated, Urban areas show the widest range of adjusted overdose death rates for neighborhood types. Neighborhood type C (Wealthy Urbanites), which is restricted to Urban geographic areas, and neighborhood type H (Challenging Neighborhoods, African American) show, moreover, the highest rates of all neighborhood types across all geographic areas. All other neighborhood types in urban areas show neither significant different rates from the state, the geographic area, the wealthy comparison group A (Wealthy, Nuclear Families), nor compared to the middle-income comparison group type D (Middle Class, Single Family Homes).

To summarize, we find that both classifications, the urban/rural continuum as well as the geodemographic classified neighborhood types, illuminate variations in overdose death rates. Urban areas show the highest overdose death rates for the 4-year study period and are the only areas that show significantly increased rates compared to the State as well as other geographic areas. The classification by neighborhood types revealed even more variation in overdose death rates, with four of the eight neighborhood types showing significant different rates from the State. While overall relations between socio-economic statuses of neighborhoods and overdose death rates were established, the relationship was shown to be more complicated with significant variation within lower income, as well as wealthy neighborhoods. Moreover, a wealthy neighborhood type C (Wealthy Urbanites) and a lower income neighborhood type H (Challenging Neighborhoods, African American) show the highest statewide rates of all neighborhood types. By nesting the neighborhood types within geographic areas, we showed that neither of our previous descriptions covered all variation in overdose death rates in Delaware. For instance, the analysis showed that while Urban areas show significant increased rates, only two neighborhood types within the geographic area actually show increased rates and, accordingly, indicate the 'truly' problematic urban areas. And similarly, we showed that specific neighborhood types that had increased rates when analyzed as a group only showed increased risks in certain geographic areas.

Discussion and Conclusion

Recent claims about the geographic concentration of overdose deaths in rural vs. urban areas challenge our understanding of the problem and justify paying more attention to the communities or neighborhoods in which they occur [11]. The importance of scientific contributions on this matter cannot be overstated, as they promise to improve the delivery of interventions where and to whom they are needed most [10]. To move beyond urban /rural distinctions, we utilized a geodemographic classification approach to investigate differences between rural and urban geographic areas and the unique socio-economic, demographic neighborhoods within them. Geodemographic classification reveals how more complex neighborhood characteristics (e.g., measures of socio-economic status, demographic composition and residential instability) are useful in estimating overdose death rates. Thus, the present study helps advance our understanding of rural and urban differences, and neighborhood effects on overdose deaths, potentially leading to more effective interventions.

Our findings show that understanding overdose death rate differences between rural and urban geographic areas is helpful, but not sufficient for knowing where they are most problematic. We found that contrary to many states in the U.S, Rural areas in Delaware do not show significantly

[7] Neighborhood type A (Wealthy, Nuclear Families) was chosen as the reference category for the presentation of the rate ratios since the type is present in all geographic areas and allows for a quick estimate how a neighborhood fares compared to one of the most economically advantaged neighborhood type.

higher overdose death rates than Urban areas, or the State at large, for our (2013–2016) study period [1]. Instead, Urban areas have significantly higher overdose rates than the State, (i.e., 1.3 times the state rate), and a significantly higher rate than Rural areas, (i.e., 1.6 times). However, our geodemographic approach demonstrated how investigating the unique socio-economic and demographically-based neighborhood types within them is also necessary for understanding the distribution of overdose deaths across place.

Even when located within a specific geographic area, our analysis shows significant (up to 13-fold differences) variations between neighborhood types. Specifically, overdose death rates in Small Town/Outer Suburban and Inner Suburban areas were not significantly different from the state average, but specific neighborhood types within them were. For instance, neighborhood types A (Wealthy, Nuclear Families) and F (College Towns, Students), with overdose death rates of 13.9 and 2.7 per 100,000 person-years respectively, have significantly lower overdose death rates than both the state at large, as well as the geographic area in which they are located.

Among neighborhood types, we expected to find differences by economic status with wealthy neighborhoods showing lower overdose death rates and more disadvantaged neighborhoods showing higher ones [18–22]. We find some support for this prospect. Wealthy, Nuclear Families neighborhoods (A) show some of the lowest overdose death rates across all geographic areas, while lower income neighborhoods tend to have higher overdose death rates. Yet, Wealthy, Nuclear Families (A) neighborhoods only have significantly lower overdose death rates than the state when they are in Small Towns and Outer-Suburban areas. In contrast to the assertion that wealth is unilaterally a protective factor against overdose deaths, we find that Wealthy Urbanite neighborhoods (C) show the highest overdose death rates of all neighborhoods types across the state.

Further, since Wealthy Urbanite (C) neighborhoods are restricted to Urban areas, these findings are highly relevant to refine our understanding of urban overdose deaths. Studies that either compare urban groups below or above the poverty level or based on income quartiles have difficulties identifying this high-risk neighborhood type within urban areas. Figure 1 indicates that while Wealthy Urbanites neighborhoods have high levels of education, home values, and occupational status positions some of the characteristics of this neighborhood type, such as residential instability or percentage of children growing up in female headed households, distinguish it from other wealthy neighborhood types in Urban areas.

But to further complicate the picture of relations between economic neighborhood status and overdose deaths, Middle Class, Single Family Home neighborhoods (D) in Small Town and Outer Suburban areas have higher rates than neighborhood type G (Lower Incomes, Racial Diversity). In Inner Suburban areas they even have a significantly higher rate than the state. Neighborhood type D (Middle Class, Single Family homes) warrants further investigation since this type in each geographic area contains the largest share of the population as well as the largest counts of overdose deaths. Additionally, this neighborhood type is highly relevant since it shows higher rates than the state and wealthy comparison groups in three geographic areas. And, while the rates for this neighborhood type are not the highest in the state or the geographic areas, they indicate the wide spread severity of the current drug epidemic and how it impacts all kinds of communities.

To summarize, our findings underscore the usefulness of geodemographic classification in the study of overdose deaths. Geodemographic classification of neighborhoods aligns closely with our complex models of how places affect residents and health-related consequences. The application of this approach reveals a few important contributions from our study. First, we find variation in overdose death rates not only between geographic areas but within them (e.g. by neighborhood types). This indicates that studying urban and rural areas is necessary to understanding variations in overdose deaths but is not sufficient. A better understanding of the dispersion of overdose deaths across space would follow from a more geo-demographically segmented analysis that also accounted for the unique socio-economic and demographic character of neighborhoods.

Second, as with prior research, we find the economic status of neighborhoods has a significant impact on overdose deaths, e.g., wealthy neighborhood types generally show lower overdose death rates across all geographic areas. Yet, within urban areas we find an increased rate of overdose deaths not only in type H (Challenging Neighborhoods, African American) but also in Wealthy Urbanites (C) neighborhoods. Studies that compare socio-economic status of neighborhoods based on a wealthy vs. disadvantaged spectrum still group together distinct types of neighborhoods. However, not all lower income urban areas have increased overdose death rates and not all higher income neighborhoods have low rates. This approach allowed us to not only confirm findings from previous studies that have found associations between overdose death rates and socio-economic status, but also to draw out variations between neighborhoods with similar socio-economic characteristics.

In sum, geodemographic classification demonstrates the ability to more narrowly identify populations highly impacted by overdose deaths within geographic or wealth-based classifications. It follows that more specific identification of at risk populations will allow for improved capabilities for surveillance of prescribing patterns, identification of illicit drug markets, and provision of more targeted harm reduction efforts. The heterogeneity of neighborhood types shown to be associated with higher rates of overdose deaths speaks to the far-reaching impacts of the latest drug epidemic. Inevitably, this calls for interventions that are equally far reaching, but also tailored to suit the needs of the diverse populations that are disproportionately affected.

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Compliance with Ethical Standards

Conflict of interest None of the authors has a conflict of interest for the subject matter or data used in this paper.

References

1. Center for Disease Control and Prevention (2017). CDC reports rising rates of drug overdose deaths in rural areas. CDC Newsroom. Retrieved May 1, 2018, from https://www.cdc.gov/media/releases/2017/p1019-rural-overdose-deaths.html.
2. Paulozzi, L. J., & Xi, Y. (2008). Recent changes in drug poisoning mortality in the United States by urban–rural status and by drug type. *Pharmacoepidemiology and Drug Safety, 17*(10), 997–1005.
3. Mack, K. A., Jones, C. M., & Ballesteros, M. F. (2017). Illicit drug use, illicit drug use disorders, and drug overdose deaths in metropolitan and nonmetropolitan areas—United States. *Morbidity and Mortality Weekly Report, 66*(19), 1–12.
4. Cicero, T. J., Ellis, M. S., Surratt, H. L., & Kurtz, S. P. (2014). The changing face of heroin use in the United States: A retrospective analysis of the past 50 years. *JAMA Psychiatry, 71*(7), 821–826.
5. Stewart, K., Cao, Y., Hsu, M. H., Artigiani, E., & Wish, E. (2017). Geospatial analysis of drug poisoning deaths involving heroin in the USA, 2000–2014. *Journal of Urban Health, 94*(4), 572–586.
6. Young, A. M., Havens, J. R., & Leukefeld, C. G. (2010). Route of administration for illicit prescription opioids: a comparison of rural and urban drug users. *Harm Reduction Journal, 7*, 24.
7. Dunn, K. E., Barrett, F. S., Yepez-Laubach, C., Meyer, A. C., Hruska, B. J., Petrush, K., Berman, S., Sigmon, S. C., Fingerhood, M., & Bigelow, G. E. (2016). Opioid overdose experience, risk behaviors, and knowledge in drug users from a rural versus an urban setting. *Journal of Substance Abuse Treatment, 71*, 1–7.
8. Dombrowski, K., & Khan, B. (2017) The scope and scale of rural drug use in Nebraska. In K. Dombrowski & K. Gocchi-Carrasco (Eds.), *Reducing health disparities: Research updates from the field* (pp. 59–77) Lincoln, NE: Syron Design Academic Publishing.
9. Cicero, T. J., Surratt, H., Inciardi, J. A., & Munoz, A. (2007). Relationship between therapeutic use and abuse of opioid analgesics in rural, suburban, and urban locations in the United States. *Pharmacoepidemiology and Drug Safety, 16*(8), 827–840.
10. Keyes, K. M., Cerdá, M., Brady, J. E., Havens, J. R., & Galea, S. (2014). Understanding the rural-urban differences in nonmedical prescription opioid use and abuse in the United States. *American Journal of Public Health, 104*(2), 52–59.
11. Cerdá, M., Gaidus, A., Keyes, K. M., Ponicki, W., Martins, S., Galea, S., & Gruenewald, P. (2017). Prescription opioid poisoning across urban and rural areas: identifying vulnerable groups and geographic areas. *Addiction, 112*(1), 103–112.
12. Rigg, K. K., & Monnat, S. M. (2015). Urban vs. rural differences in prescription opioid misuse among adults in the United States: Informing region specific drug policies and interventions. *International Journal of Drug Policy, 26*(5), 484–491.
13. Dombrowski, K., Crawford, D., Khan, B., & Tyler, K. (2016). Current rural drug use in the US Midwest. *Journal of Drug Abuse*, 2(3), 22.
14. Brady, J. E., Giglio, R., Keyes, K. M., DiMaggio, C., & Li, G. (2017). Risk markers for fatal and non-fatal prescription drug overdose: A meta-analysis. *Injury Epidemiology, 4*(1), 1–24.
15. Monnat, S. M., & Rigg, K. K. (2016). Examining rural/urban differences in prescription opioid misuse among US adolescents. *The Journal of Rural Health, 32*(2), 204–218.
16. Rossen, L. M., Khan, D., & Warner, M. (2014). Hot spots in mortality from drug poisoning in the United States, 2007–2009. *Health & Place, 26*, 14–20.
17. Tung, E. L., Cagney, K. A., Peek, M. E., & Chin, M. H. (2017). Spatial context and health inequity: Reconfiguring race, place, and poverty. *Journal of Urban Health, 94*(6), 757–763.
18. Galea, S., Ahern, J., Vlahov, D., Coffin, P. O., Fuller, C., Leon, A. C., & Tardiff, K. (2003). Income distribution and risk of fatal drug overdose in New York City neighborhoods. *Drug and alcohol dependence, 70*(2), 139–148.
19. Hannon, L., & Cuddy, M. M. (2006). Neighborhood ecology and drug dependence mortality: An analysis of New York City census tracts. *The American Journal of Drug and Alcohol Abuse, 32*, 453–463.
20. Visconti, A. J., Santos, G., Lemos, N. P., Burke, C., & Coffin, P. O. (2015). Opioid overdose deaths in the city and county of San Francisco: Prevalence, distribution, and disparities. *Journal of Urban Health, 92*(4), 758–772.
21. Rowe, C., Santos, G., Vittinghoff, E., Wheeler, E., Davidson, P., & Coffin, P. O. (2016). Neighborhood-level and spatial characteristics associated with lay Naloxone reversal events and opioid overdose deaths. *Journal of Urban Health, 93*(1), 117–130.
22. Marshall, J. R., Gassner, S. F., Anderson, C. L., Cooper, R. J., Lotfipour, S., & Chakravarthy, B. (2018). Socioeconomic and geographical disparities in prescription and illicit opioid-related overdose deaths in Orange County, California, from 2010 to 2014. *Substance Abuse, 21*, 1–7.
23. Galea, S., Ahern, J., Tardiff, K., Leon, A., Coffin, P. O., Derr, K., & Vlahov, D. (2003). Racial/ethnic disparities in overdose mortality trends in New York City, 1990–1998. *Journal of Urban Health, 80*(2), 201–211.
24. Denney, J. T., Onge, S., & Dennis, J. A. (2018). Neighborhood concentrated disadvantage and adult mortality: Insights for racial and ethnic differences. *Population Research and Policy Review, 37*(2), 301–321.
25. Hembree, C., Galea, S., Ahern, J., Tracy, M., Piper, M., Miller, T., Vlahov, J., D., & Tardiff, K. J. (2005). The urban built environment and overdose mortality in New York City neighborhoods. *Health & Place, 11*(2), 147–156.
26. Draus, P., & Carlson, R. G. (2009). Down on main street: Drugs and the small-town vortex. *Health & Place, 15*(1), 247–254.
27. Rhew, I. C., Hawkins, J. D., & Oesterle, S. (2011). Drug use and risk among youth in different rural contexts. *Health & Place, 17*(3), 775–783.
28. Spielman, S. E., & Singleton, A. (2015). Studying neighborhoods using uncertain data from the american community survey: A contextual approach. *Annals of the Association of American Geographers, 105*(3), 1003–1025.
29. Longley, P. A. (2016). Geodemographic profiling. International Encyclopedia of Geography, 1–11.
30. Singleton, A. D., & Spielman, S. E. (2014). The past, present, and future of geodemographic research in the United States and United Kingdom. *The Professional Geographer, 66*(4), 558–567.

31. Sleight, P. (1997). *Targeting Customers: How to use Geodemographic and Lifestyle Data in Your Business*. Henley-on-Thames: World Advertising Research Center.
32. Brueckner, J. K., & Rosenthal, S. S. (2009). Gentrification and neighborhood housing cycles: Will America's future downtowns be rich? *The Review of Economics and Statistics, 91*(1), 725–743.
33. Ehrenhalt, A. (2012). *The great inversion and the future of the American City*. New York: Knopf.
34. Folch, D. C., Arribas-Bel, D., Koschinsky, J., & Spielman, S. E. (2014). Uncertain uncertainty: Spatial variation in the quality of American Community Survey estimates. *Demography, 53*(5), 1535–1554.
35. Spielman, S. E., Folch, D., & Nagle, N. (2014). Patterns and causes of uncertainty in the American Community Survey. *Applied Geography, 46*, 147–157.
36. Spielman, S. E., & Folch, D. C. (2015). Reducing uncertainty in the American Community Survey through data-driven regionalization. PLoS ONE, 10(2), e0115626.
37. Theobald, D. M. (2001). Land-use dynamics beyond the American urban fringe. *Geographical Review, 91*(3), 544–564.
38. Housing Assistance Council. (2012). *Taking stock. Rural People, Poverty, and Housing in the 21st Century*. Washington, DC: Housing Assistance Council.
39. Longley, P. (2005). Geographical Information Systems: a renaissance of geodemographics for public service delivery. *Progress in Human Geography, 29*(1), 57–63.
40. Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information science and systems*. New York: Wiley.
41. Reibel, M. (2011). Classification approaches in neighborhood research. *Introduction and Review. Urban Geography, 32*(3), 305–316.
42. Rothman, K. J., Greenland, S., & Lash, T. L. (2008). *Modern epidemiology*. Philadelphia: Lippincott Williams & Wilkins.
43. Consonni, D., Coviello, E., Buzzoni, C., & Mensi, C. (2012). A command to calculate age-standardized rates with efficient interval estimation. *Stata Journal, 12*(4), 688–701.
44. Tiwari, R. C., Clegg, L. X., & Zou, Z. (2006). Efficient interval estimation for age-adjusted cancer rates. *Statistical Methods in Medical Research, 15*(6), 547–569.