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**Appendix Table 1.** NCHS Urban-Rural Classification Scheme.

**Appendix Table 2.** Number and percent of counties with suicide rates >20 per 100,000, by urban-rural classification, 2005 and 2015.

**Appendix Table 3.** Model covariates, data sources, and specifications.

**Appendix Figures 1–11.** Annual model-based county-level estimates of suicide rates across the U.S., 2005–2015.

**Appendix Figure 12.** Deciles of model-based suicide rates in 2005 and 2015, U.S. Decile 1 corresponds to the lowest suicide rates, while Decile 10 corresponds to the highest.

**Appendix Figure 13.** Coefficients of variation (i.e., relative standard error/deviation) of county-level suicide rates in the U.S., 2005 (top) and 2015 (bottom).

**Appendix Figure 14.** Percentage of counties with greater than 20%, 30% or 40% increases in model-based suicide rates over the time period from 2005–2015, by urban-rural classification.

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**Appendix Table 1.** NCHS Urban-Rural Classification Scheme[a]

| Urban-rural classification | Definition |
|---|---|
| Metropolitan (urban) | |
| Large central metro (i.e., most urban) | Counties located in a metropolitan statistical area (MSA) of at least 1 million population and meet one of three conditions: (1) contain the entire population of the largest principal city of the MSA, (2) are completely contained within the largest principal city of the MSA, or (3) contain at least 250,000 inhabitants of any principal city of the MSA. |
| Large fringe metro (i.e., suburban) | Counties in MSAs of 1 million or more population that do not qualify as large central metro counties |
| Medium metro | Counties in MSAs of populations between 250,000 and 999,999 |
| Small metro | Counties in MSAs of fewer than 250,000 population |
| Nonmetropolitan | |
| Micropolitan | Counties in micropolitan statistical areas (population 10,000–49,999) |
| Noncore (i.e., most rural) | Nonmetropolitan counties that do not qualify as micropolitan |

[a]Urbanization level was determined using the NCHS Urban-Rural Classification Scheme for Counties from 2006 (applied to data years 2005–2012) and 2013 (applied to data years 2013–2015).

NCHS, National Center for Health Statistics

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**Appendix Table 2.** Number and Percent of Counties With Suicide Rates >20 per 100,000,[a] by Urban-Rural Classification,[b] 2005 and 2015

| Urban-rural classification | Total number of counties | | Number of counties with model-based suicide rates >20 per 100,000 | | Counties with model-based suicide rates>20 per 100,000, % | |
|---|---|---|---|---|---|---|
| | **2005** | **2015** | **2005** | **2015** | **2005** | **2015** |
| Metropolitan (urban) | | | | | | |
| Large central metro (most urban) | 63 | 68 | 0 | 2 | 0.0 | 2.9 |
| Large fringe metro (suburban) | 354 | 368 | 5 | 53 | 1.4 | 14.4 |
| Medium metro | 332 | 372 | 9 | 83 | 2.7 | 22.3 |
| Small metro | 340 | 358 | 17 | 96 | 5.0 | 26.8 |
| Non-metropolitan | | | | | | |
| Micropolitan | 694 | 641 | 49 | 181 | 7.1 | 28.2 |
| Noncore (most rural) | 1,357 | 1,333 | 175 | 600 | 12.9 | 45.0 |
| Total | 3,140 | 3,140 | 255 | 1,015 | 8.1 | 32.3 |

[a]Based on model-based suicide rates, with 20 corresponding roughly to the 90th percentile in 2005.
[b]Urbanization level was determined using the NCHS Urban-Rural Classification Scheme for Counties from 2006 (applied to data years 2005–2012) and 2013 (applied to data years 2013–2015).

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**Appendix Table 3.** Model Covariates, Data Sources

| Covariate | Data source |
|---|---|
| Land area (square mile) | Area Resource Files,[1] Decennial Census |
| Mean household size | Area Resource Files,[1] Decennial Census |
| Housing unit density per square mile | Area Resource Files,[1] Decennial Census |
| Median age | Area Resource Files,[1] Decennial Census |
| Median household income | Area Resource Files,[1] American Community Survey (ACS) |
| Median home value | Area Resource Files,[1] ACS |
| Median gross rent | Area Resource Files,[1] ACS |
| % Housing units with more than 1 person/room | Area Resource Files,[1] ACS |
| Percent American Indian or Alaska Native | Area Resource Files,[1] Decennial Census |
| Median per capita income | Area Resource Files,[1] Regional Economic Information (REIS) |
| Percent Asian | Area Resource Files,[1] Decennial Census |
| Percent non-Hispanic black | Area Resource Files,[1] Decennial Census |
| % Persons aged $\geq$25 years with $\geq$4 years college | Area Resource Files,[1] ACS |
| Percent of females divorced | Area Resource Files,[1] ACS |
| Percent female headed household | Area Resource Files,[1] Decennial Census |
| Percent foreign born | Area Resource Files,[1] ACS |
| Percent Hispanic | Area Resource Files,[1] Decennial Census |
| % Persons aged $\geq$25 years with high school diploma | Area Resource Files,[1] ACS |
| % Persons aged $\geq$25 years with less than high school diploma | Area Resource Files,[1] ACS |
| Percent in owner-occupied housing | Area Resource Files,[1] Decennial Census |
| Percent below the poverty level | Area Resource Files,[1] Census SAIPE |
| Percent rural population | Area Resource Files,[1] Decennial Census |
| Percent urban population | Area Resource Files,[1] Decennial Census |

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| | |
|---|---|
| Percent non-Hispanic white | Area Resource Files,[1] Decennial Census |
| Percent workers in agriculture/forestry/fishing/hunting/mine work | Area Resource Files,[1] ACS |
| Percent workers in construction | Area Resource Files,[1] ACS |
| Percent workers in education/healthcare/social assistance | Area Resource Files,[1] ACS |
| Percent workers in manufacturing | Area Resource Files,[1] ACS |
| Percent workers in other industries | Area Resource Files,[1] ACS |
| Unemployment rate, $\geq 16$ | Area Resource Files,[1] Bureau of Labor Stats (BLS) |
| Veteran population estimate | Area Resource Files,[1] Department of Veteran's Affairs |
| Number of violent crimes | Uniform Crime Reporting Program Data: County-Level Detailed Arrest and Offense Data[2] |
| Number of property crimes | Uniform Crime Reporting Program Data: County-Level Detailed Arrest and Offense Data[2] |
| Number of drug abuse violations–total | Uniform Crime Reporting Program Data: County-Level Detailed Arrest and Offense Data[2] |
| All other offenses except traffic | Uniform Crime Reporting Program Data: County-Level Detailed Arrest and Offense Data[2] |
| Estimated number of foreclosure starts divided by number of mortgages times 100 | Housing and Urban Development Small Area Foreclosure Rates[3] |
| U.S. Postal Service data from June 2008 on residential addresses vacant 90-days or longer | Housing and Urban Development Small Area Foreclosure Rates[3] |
| Estimated high cost loan rate: percent of loans shown to be high cost according to Home Mortgage Disclosure Act data | Housing and Urban Development Small Area Foreclosure Rates[3] |
| Illicit drug or alcohol abuse/dependence in past year | National Survey of Drug Use and Health Substate Estimates[4] |
| Any mental illness in past year | National Survey of Drug Use and Health Substate Estimates[4] |
| *Nonmedical use of pain relievers in the past year* among individuals aged $\geq 12$ years | National Survey of Drug Use and Health Substate Estimates[4] |
| *Major depressive episode in the past year* among adults aged $\geq 18$ years | National Survey of Drug Use and Health Substate Estimates[4] |

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| | |
|---|---|
| *Marijuana use in the past year* among individuals aged ≥12 years | National Survey of Drug Use and Health Substate Estimates[4] |
| *Serious mental illness in the past year* among adults aged ≥18 years | National Survey of Drug Use and Health Substate Estimates[4] |
| Had serious thoughts of suicide in the past year among adults aged ≥18 years | National Survey of Drug Use and Health Substate Estimates[4] |
| Illicit drug use in the past month among individuals aged ≥12 years | National Survey of Drug Use and Health Substate Estimates[4] |
| Tobacco product use in the past month among individuals aged ≥12 years | National Survey of Drug Use and Health Substate Estimates[4] |
| Treatment gap for alcohol – Needing but not receiving treatment for alcohol use in the past year among individuals aged ≥12 years | National Survey of Drug Use and Health Substate Estimates[4] |
| Treatment gap for drug use – N*eeding but not receiving treatment for illicit drug use in the past year* among individuals aged ≥12 years | National Survey of Drug Use and Health Substate Estimates[4] |
| Percent of deaths with underlying cause of R99 code (state-level): ill-defined and unknown cause of mortality | Mortality Data[5] |
| Percent of deaths pending (state-level) | Mortality Data[5] |
| Model-based age adjusted death rates due to drug poisoning | Model-Based Drug Poisoning Estimates[6] |

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## MODEL SPECIFICATIONS

Hierarchical Bayesian models were implemented incorporating fixed covariates and spatiotemporal random effects. The posterior distributions were estimated via Integrated Nested Laplace Approximation (INLA) in R (www.r-inla.org/). These models borrow strength across both counties and years to produce smoothed annual county-level suicide rates. The model is described below, for $i = 1, ..., m$ counties and $t = 1, ..., T$ years:

$$\text{logit} (p_{it}) = \alpha_0 + X_{it}'\beta + u_i + v_i + \varphi_{1t} + \psi_{it}$$

This model includes:

a) A logit link function $\log (p_{it}/(1 - p_{it}))$; where, $p_{it}$ is the probability of suicides in county $i$ and time $t$.

b) An overall intercept term $\alpha_0$. The intercept, $\alpha_0$ was assigned a flat prior: $P(\alpha_0) \propto$ constant, (where P indicates probability).

c) A set of fixed effects, $X_{it}'\beta$, where $X_{it}$ : is the $i$ th row and $t$ th column of the covariates matrix $X$ and $\beta$ is a vector of regression parameters. The $\beta$ for fixed effects $(X_{it}'\beta)$ were assigned Normal priors. $\beta \sim N(0,100)$

d) A spatial random effect, $u_i$, to account for county-level spatial dependence (e.g., clustering). This term was modeled using conditionally autoregressive priors (CAR)[7] where weights were assigned to each county according to adjacency; neighboring counties receive a weight of one while non-neighboring counties receive a weight of zero. Delaunay triangulation was used to establish spatial weights. This method generates Voronoi triangles from county centroids, where nodes connected by a triangle edge are considered neighbors.[8] Each county has at least one neighbor, and the number of neighbors is determined empirically based on the spatial distribution of the counties. The conditional precision of the spatial random effect was assigned $\tau_u \sim$ Gamma (1, 0.001) prior.

e) A non-spatial random effect, $v_i$, to account for residual county-level variation that is not spatially dependent. This term was assigned a Normal prior, $v_i \sim N(0, \frac{1}{\tau_v})$, with precision, $\tau_v$. The conditional precision of the non-spatial random effect was assigned $\tau_v \sim$ Gamma (1, 0.001) prior.

f) An overall temporal random effect, $\varphi_{1t}$ , to account for temporal autocorrelation. This term was modeled via a first order random walk,[9] where the values in a given year depend upon the values observed in the prior year plus a residual error term, $\varphi_{1t} \sim N(\varphi_{1,t-1}, \frac{1}{\tau_{\varphi 1}})$. The conditional precision of the random effect was assigned $\tau_{\varphi 1} \sim$ Gamma (1, 0.001) prior.

g) A space-time interaction term, $\psi_{it}$, which is a county- and year- specific random effect included to account for any residual spatiotemporal variation that was not captured by the spatial or temporal main effects. This term was assumed to be independently and identically distributed,[10,11] $\psi_{it} \sim N(0, \frac{1}{\tau_\psi})$. The conditional precision of the random effect was assigned $\tau_\psi \sim$ Gamma (1, 0.001) prior.

The Deviance Information Criterion (DIC)[12] was used to determine the best fitting model among a larger set of models including the above terms and a variety of covariates and subsets of covariates. Sensitivity analyses were also conducted to examine the effect of different priors and different spatial weighting schemes. Residuals, posterior predicted means, and 95% credible
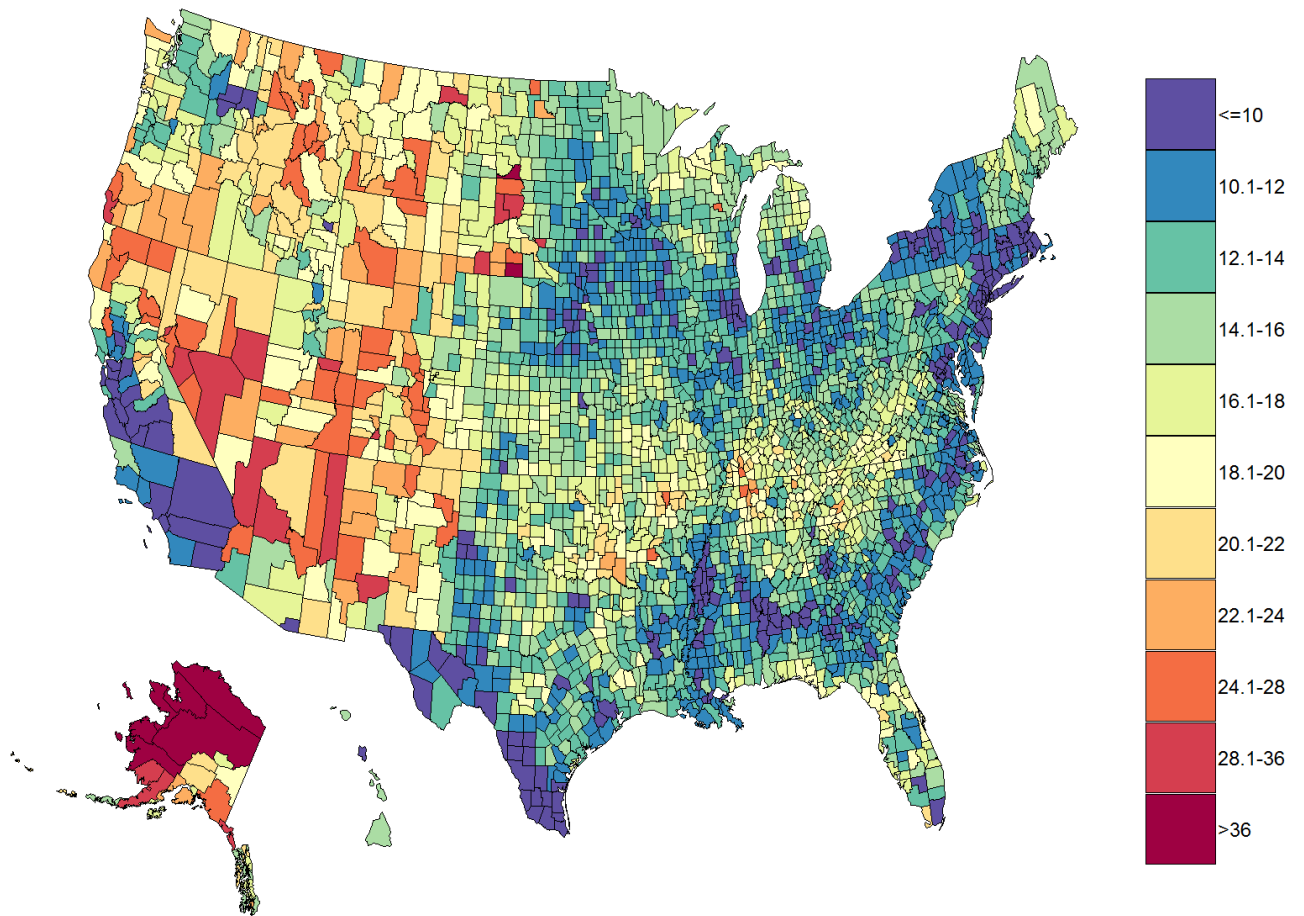
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intervals were examined. Additionally, model-based estimates were aggregated by year, state, and urban-rural classification and compared with direct estimates. Posterior predictions from models with no covariates were highly correlated with the predictions from models with the full set of covariates described above ($R^2$=0.88), but the full model did have a substantially lower DIC. The below scatter plot shows the estimates from the model without covariates and the full model presented in the manuscript. More detail can be found in Khan et al.[13]
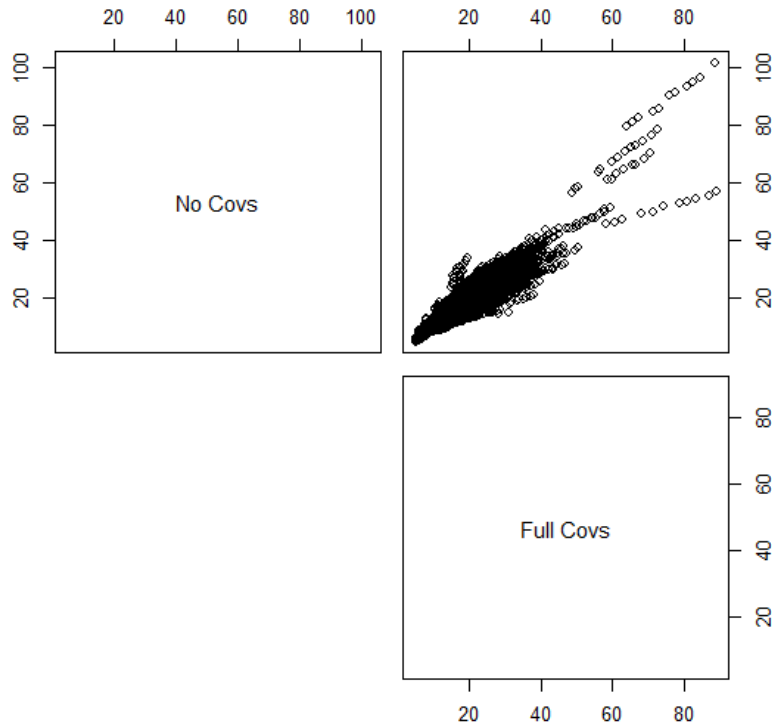
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**Appendix Figure 1.** Model-based estimates of county-level suicide rates in the U.S., 2005.
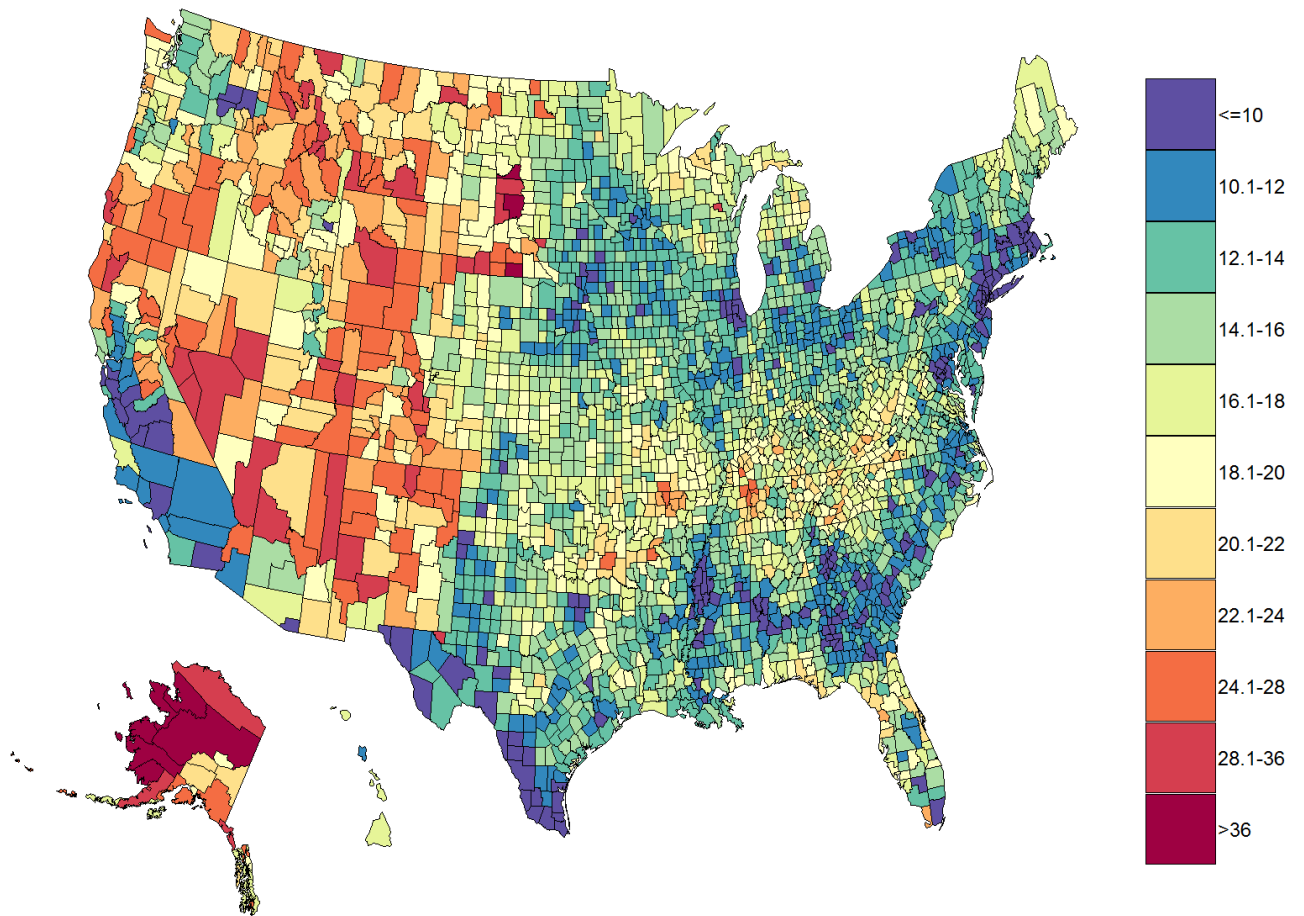


| | |
|---|---|
| | <=10 |
| | 10.1-12 |
| | 12.1-14 |
| | 14.1-16 |
| | 16.1-18 |
| | 18.1-20 |
| | 20.1-22 |
| | 22.1-24 |
| | 24.1-28 |
| | 28.1-36 |
| | >36 |

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**Appendix Figure 2.** Model-based estimates of county-level suicide rates in the U.S., 2006.
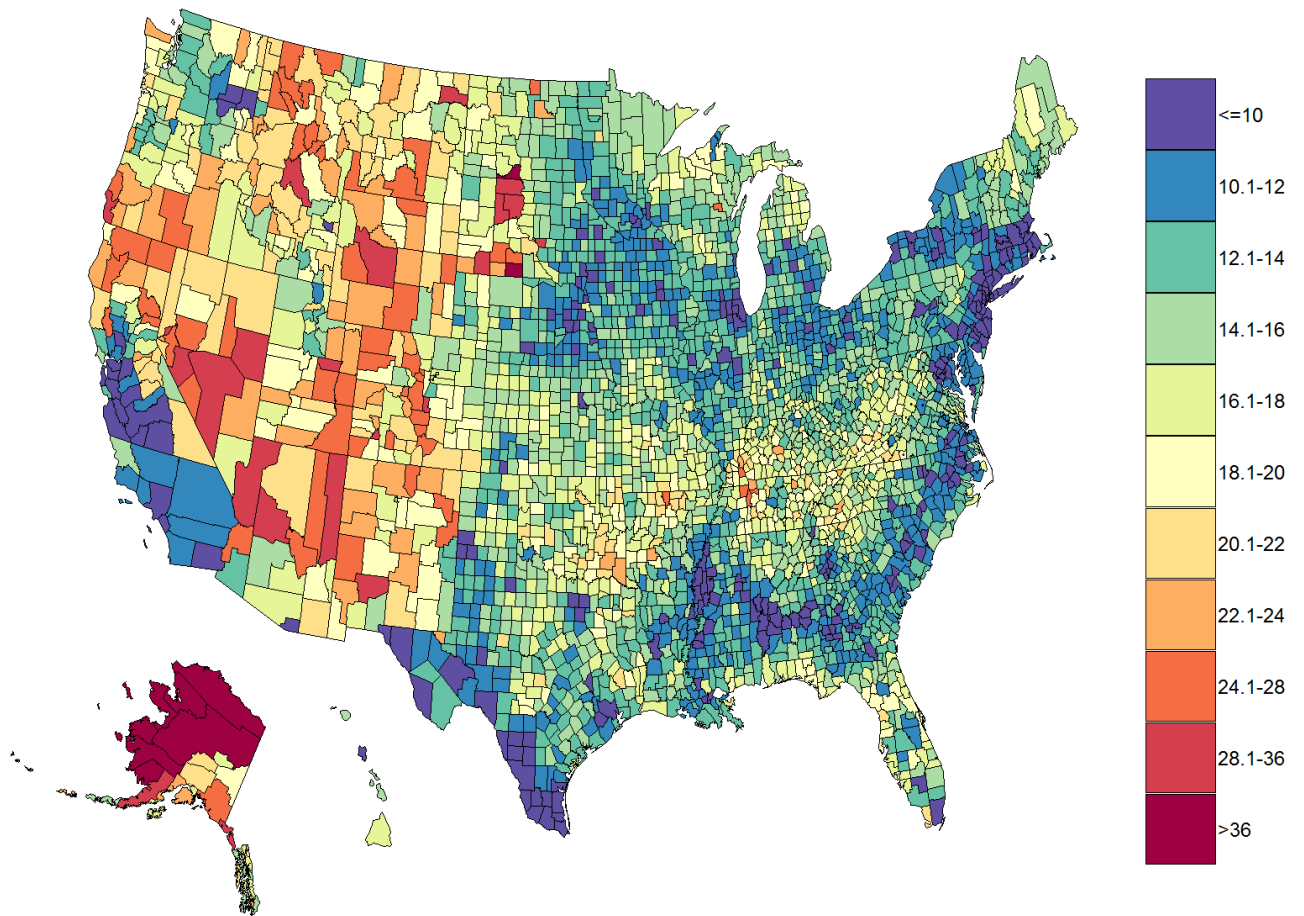
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**Appendix Figure 3.** Model-based estimates of county-level suicide rates in the U.S., 2007.
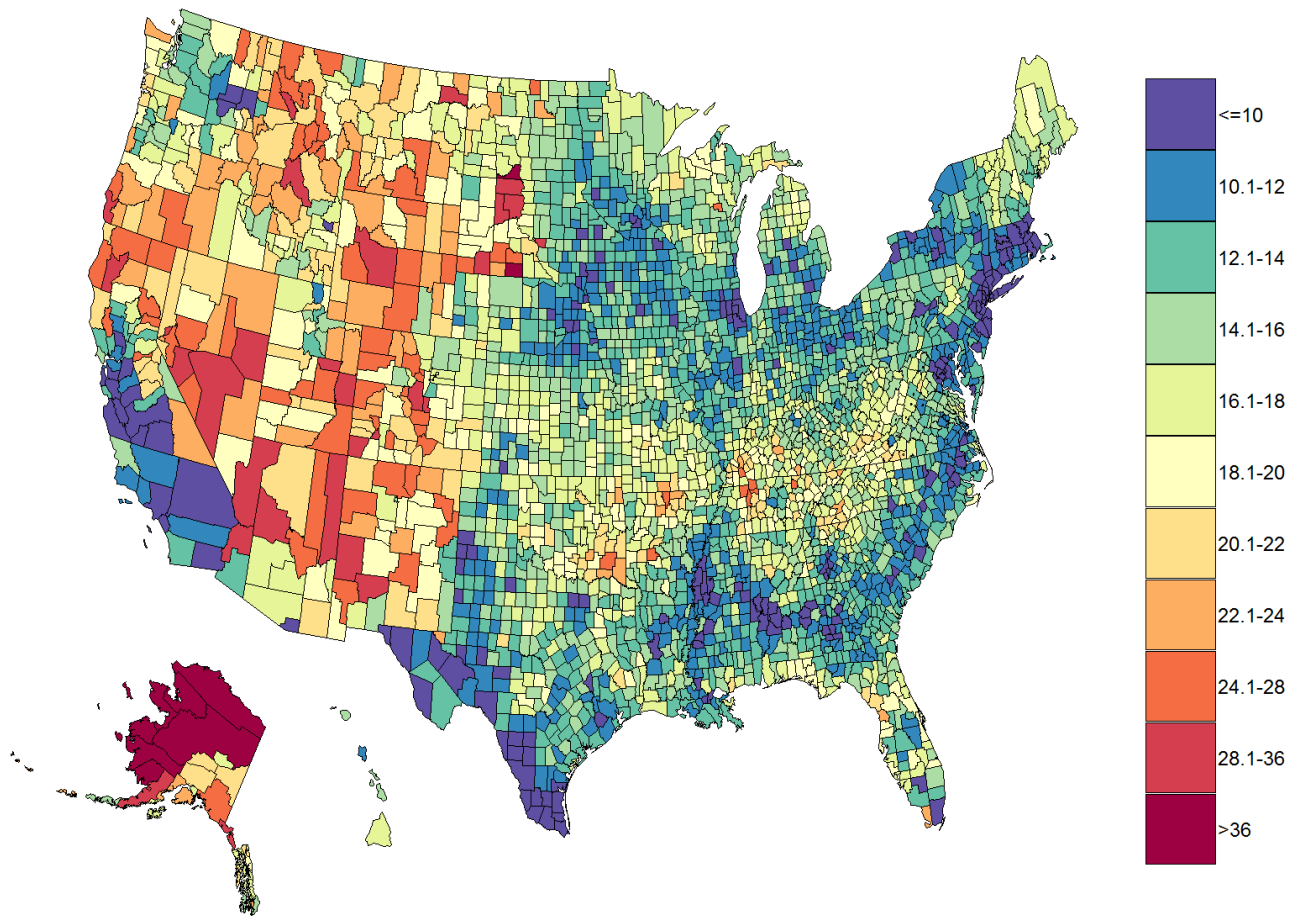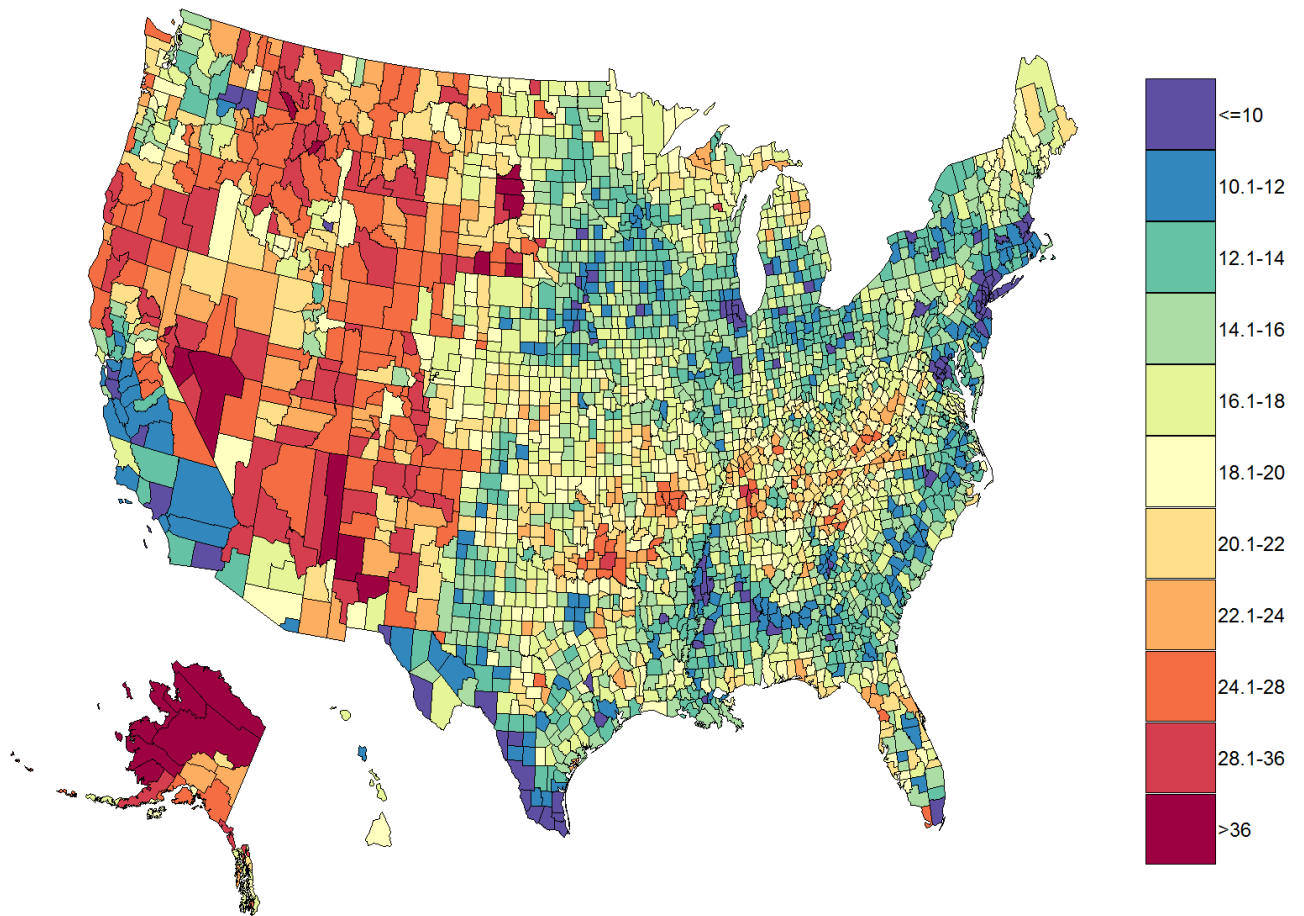
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**Appendix Figure 4.** Model-based estimates of county-level suicide rates in the U.S., 2008.



| | |
|---|---|
| | <=10 |
| | 10.1-12 |
| | 12.1-14 |
| | 14.1-16 |
| | 16.1-18 |
| | 18.1-20 |
| | 20.1-22 |
| | 22.1-24 |
| | 24.1-28 |
| | 28.1-36 |
| | >36 |

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**Appendix Figure 5.** Model-based estimates of county-level suicide rates in the U.S., 2009.
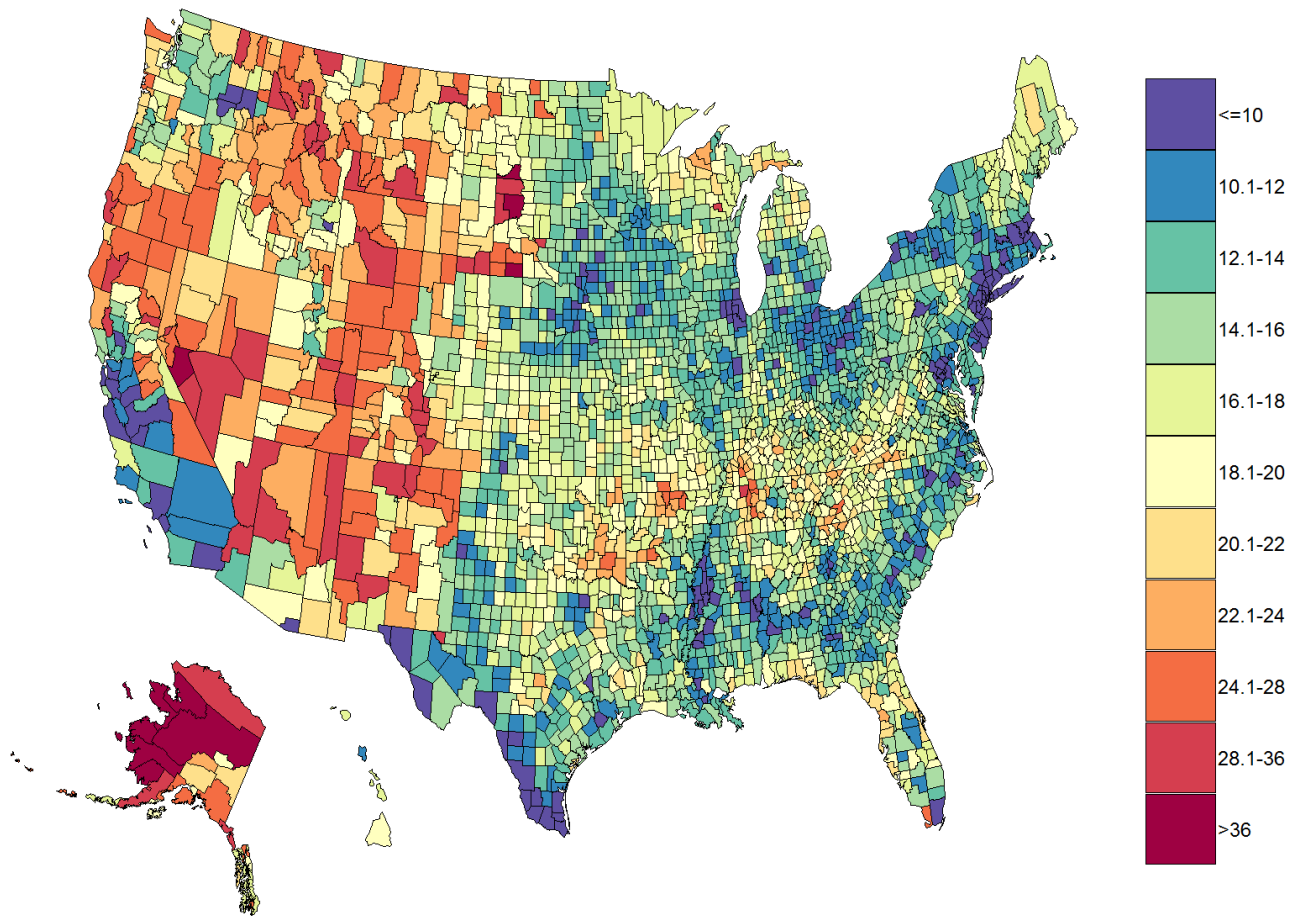
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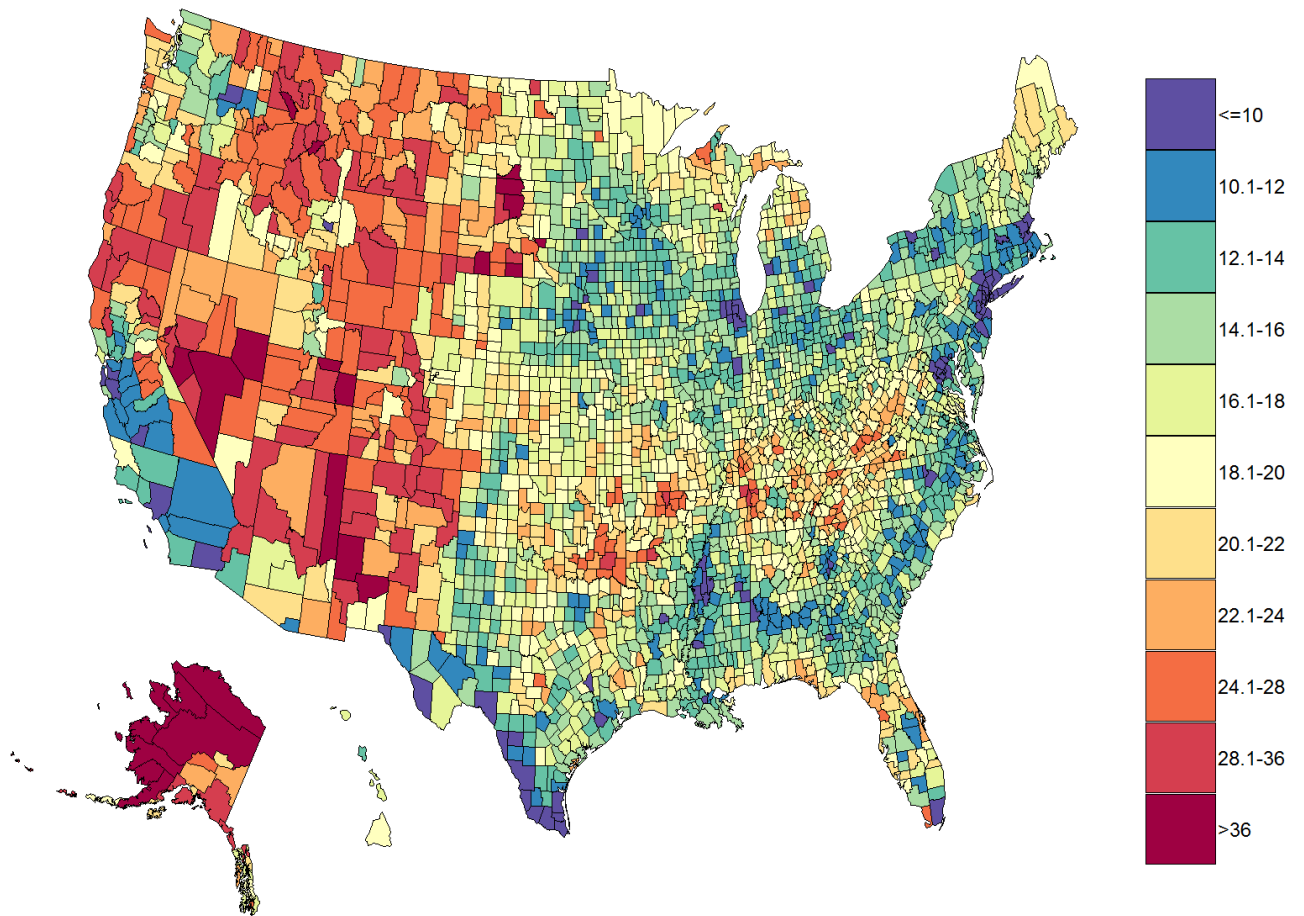**Appendix Figure 6.** Model-based estimates of county-level suicide rates in the U.S., 2010.
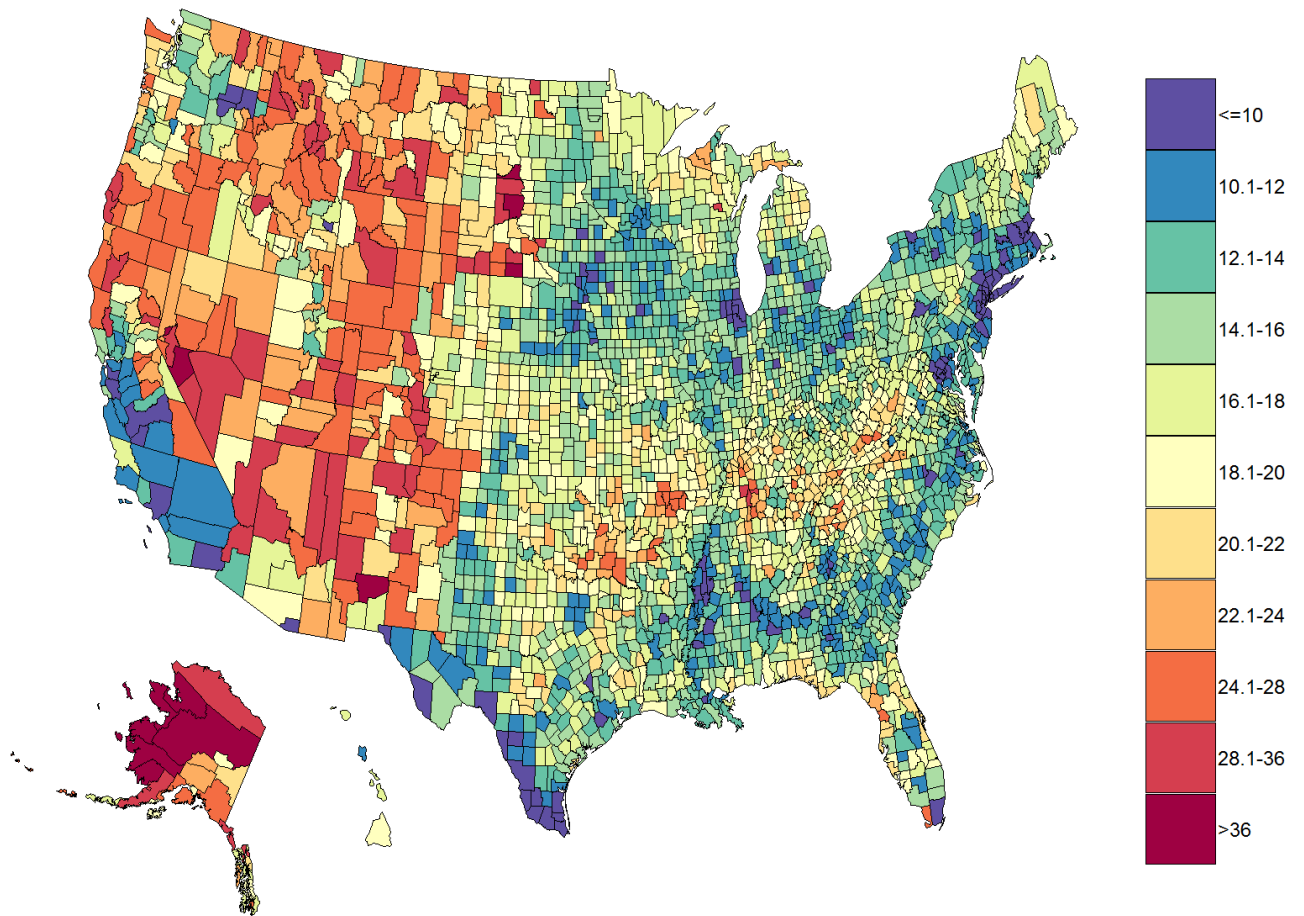
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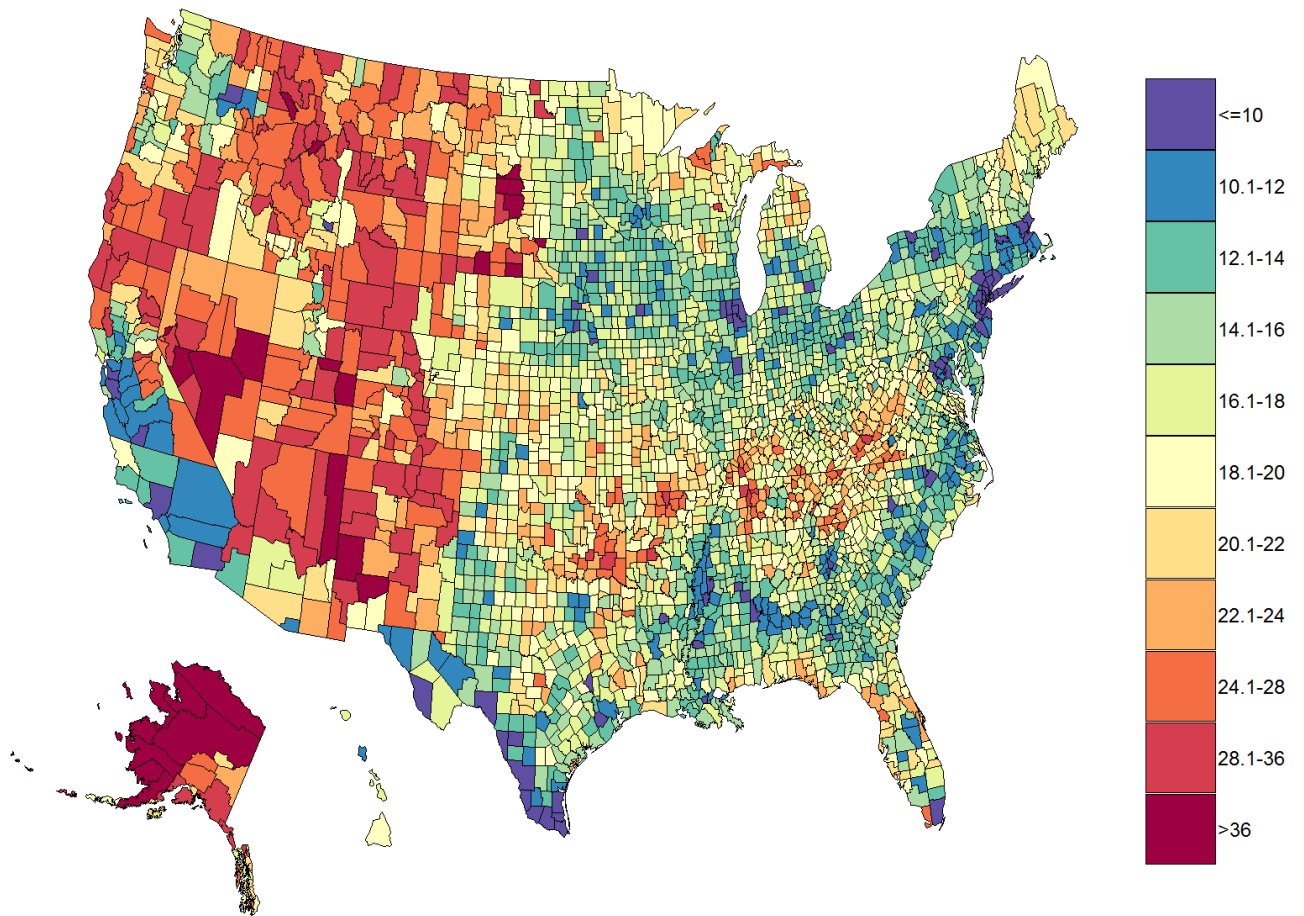**Appendix Figure 7.** Model-based estimates of county-level suicide rates in the U.S., 2011.

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**Appendix Figure 8.** Model-based estimates of county-level suicide rates in the U.S., 2012.
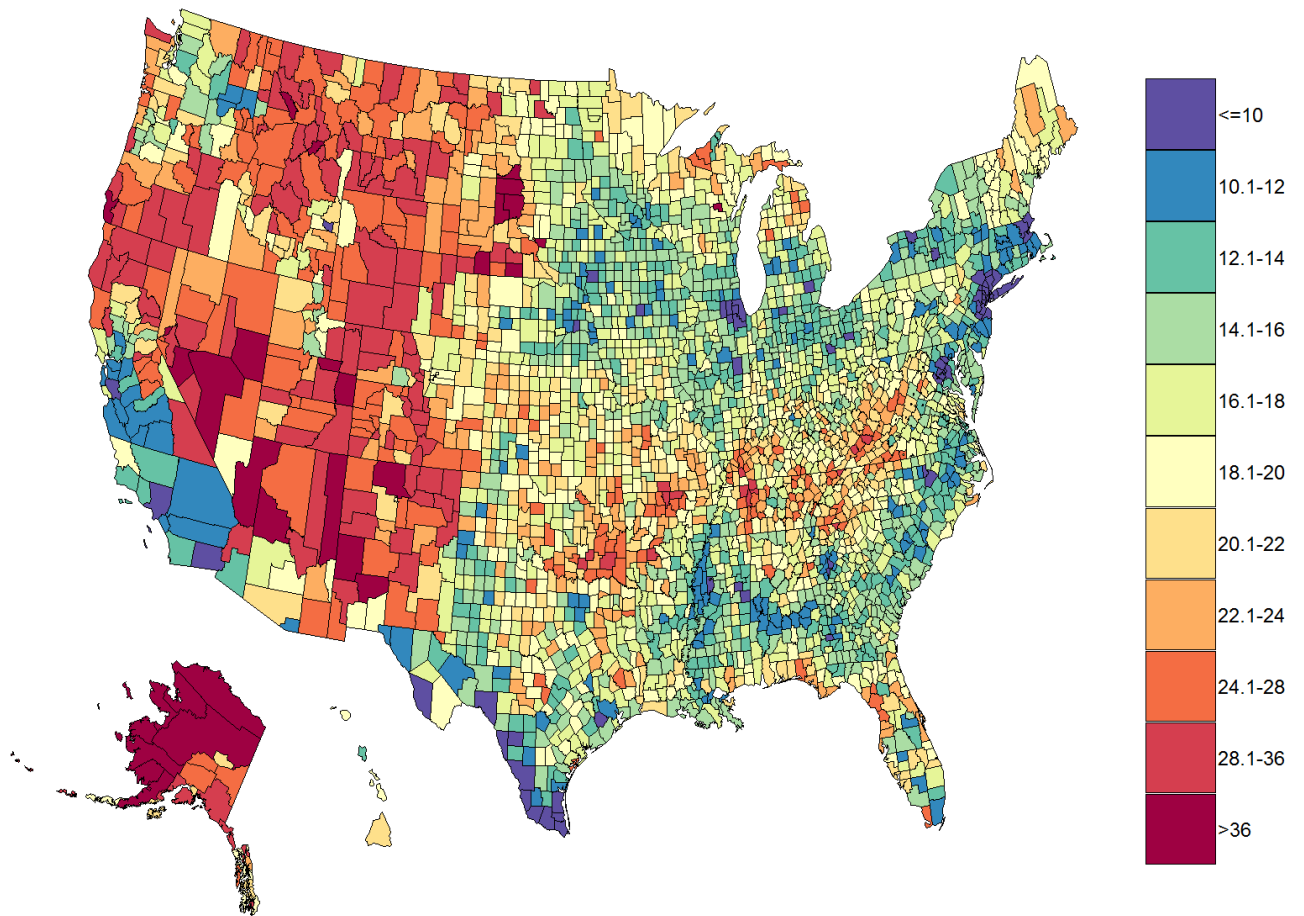
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**Appendix Figure 9.** Model-based estimates of county-level suicide rates in the U.S., 2013.



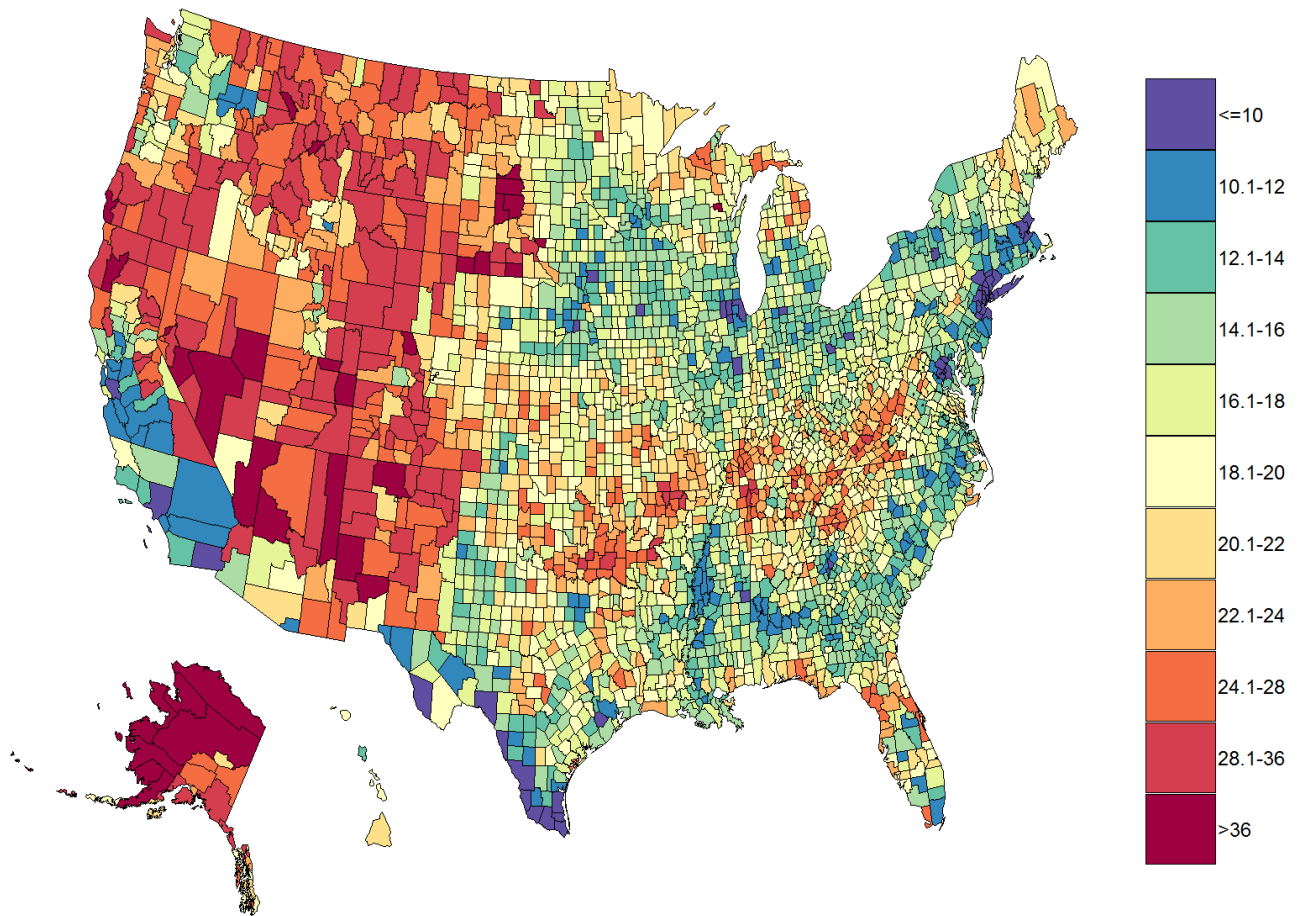| Legend |
|---|
| <=10 |
| 10.1-12 |
| 12.1-14 |
| 14.1-16 |
| 16.1-18 |
| 18.1-20 |
| 20.1-22 |
| 22.1-24 |
| 24.1-28 |
| 28.1-36 |
| >36 |

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**Appendix Figure 10.** Model-based estimates of county-level suicide rates in the U.S., 2014.



| | |
|---|---|
| | <=10 |
| | 10.1-12 |
| | 12.1-14 |
| | 14.1-16 |
| | 16.1-18 |
| | 18.1-20 |
| | 20.1-22 |
| | 22.1-24 |
| | 24.1-28 |
| | 28.1-36 |
| | >36 |

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**Appendix Figure 11.** Model-based estimates of county-level suicide rates in the U.S., 2015.



| | |
|---|---|
| | <=10 |
| | 10.1-12 |
| | 12.1-14 |
| | 14.1-16 |
| | 16.1-18 |
| | 18.1-20 |
| | 20.1-22 |
| | 22.1-24 |
| | 24.1-28 |
| | 28.1-36 |
| | >36 |

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**Appendix Figure 12.** Deciles of model-based suicide rates in 2005 (top) and 2015 (bottom), U.S. Decile 1 corresponds to the lowest suicide rates, while Decile 10 corresponds to the highest.
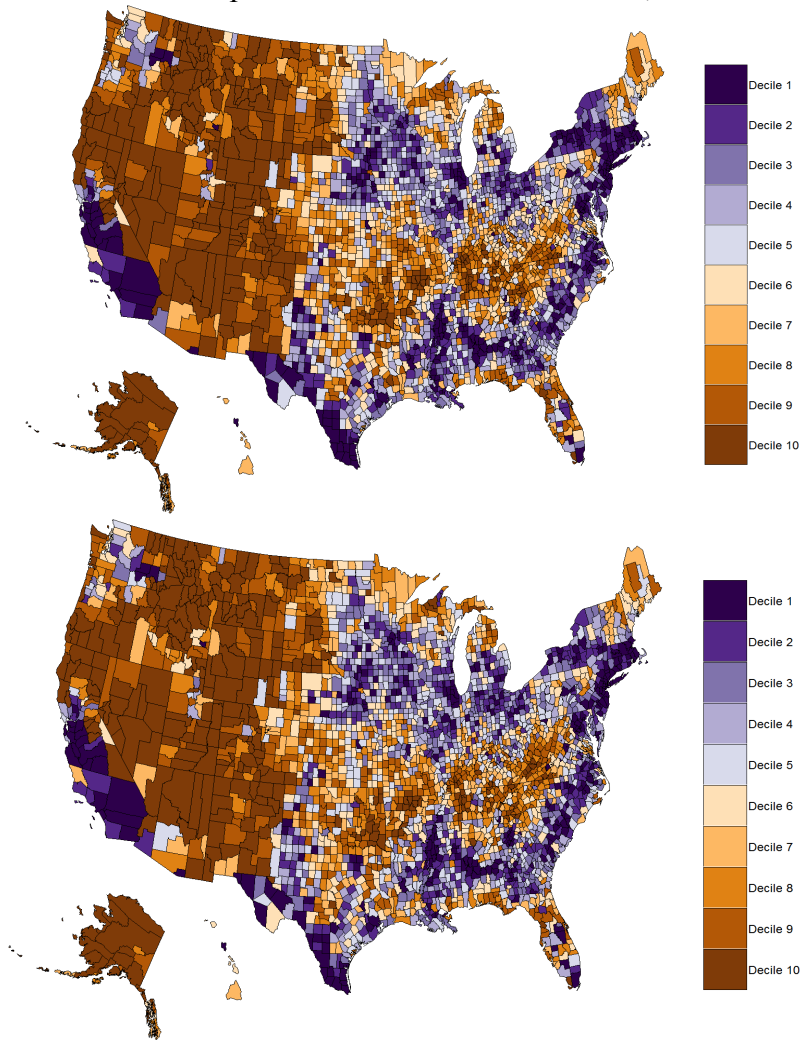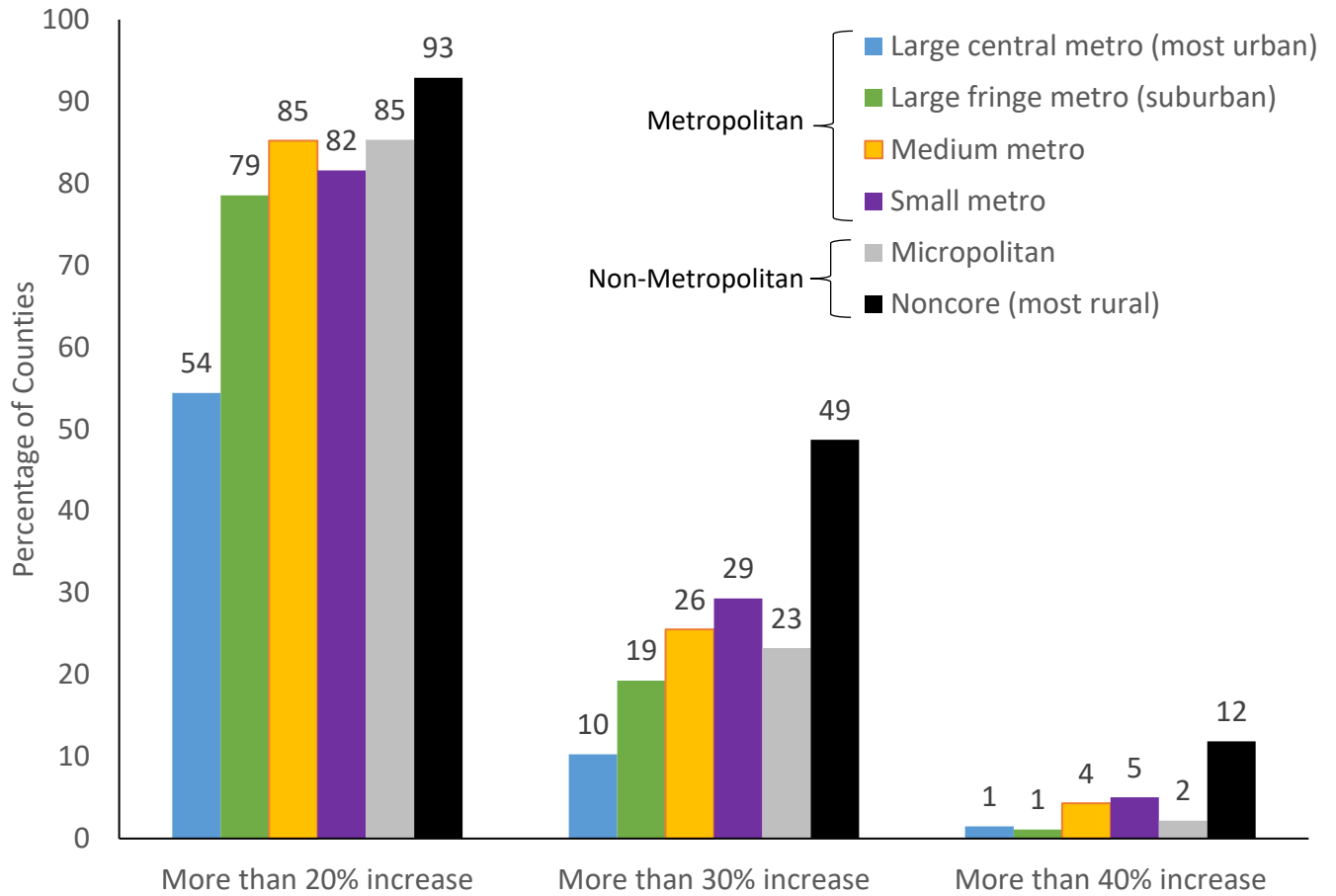
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**Appendix  Figure 13.** Coefficients of variation (i.e., relative standard error/deviation) of county-level suicide rates in the U.S., 2005 (top) and 2015 (bottom).
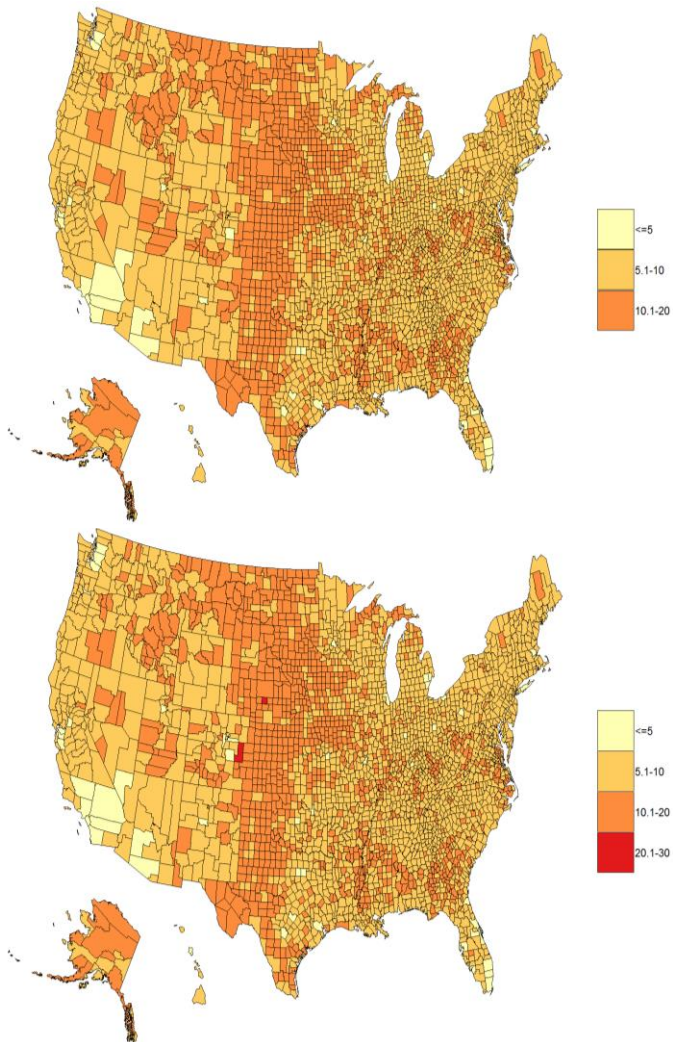
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**Appendix Figure 14.** Percentage of counties with greater than 20%, 30% or 40% increases in model-based suicide rates from 2005 to 2015, by urban-rural classification.



*Note*: Categories of >20%, >30% and >40% increase are not mutually exclusive.

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