A Spatial Cluster and Socio-demographic analysis of COVID-19 infection determinants in Ohio, Michigan and Kentucky

By

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Emmy Soy, Student Date

Approvals:

Dr. Nazanin Naderi, Thesis Advisor

Dr. Peter Kimosop, Committee Member

Dr. Hojjat Mehri, Committee Member

Dr. Salvatore A. Sanders, Dean of Graduate Studies

ABSTRACT

The World Health Organization declared COVID-19 a global pandemic in March 2020. Many countries and economies were greatly affected, including the United States of America. Many people were greatly affected causing them to go into critical care resulting in some eventual fatalities. Some of the factors that could have led to the widespread of infections can be attributed to the socio-demographic determinants, including gender, race/ethnicity, income, urban-rural location, access to healthcare and age.

This study is aimed at exploring and examining patterns of COVID-19 infections by considering age, gender, health insurance coverage, race/ethnicity and income factors. Data from the Center for Disease Control (CDC), Department of Health and Human Services (HSS), the COVID tracking Project, and the U.S. Census Bureau (USCB) were used in this study.

A Bayesian Conditional Autoregressive (CAR) model was used to explore the association between COVID-19 infection rates, hospitalizations and deaths, and socio-demographic variables using Open BUGS for the states of Ohio, Michigan and Kentucky.

At the beginning of March 2020, the number of COVID-19 cases reported by the CDC for the USA was 123,498 infections.

ACKNOWLEDGEMENT

I would like to show my gratitude and appreciation to my thesis advisor Dr. Nazanin Naderi whose attention and guidance was undivided. We began discussing this work in Fall 2020 during the COVID-19 pandemic and she motivated me to think about how we can work together. This was such a great inspiration for me, and I enjoyed every learning moment. I would like to continue with this research and cover other topics in future.

My gratitude goes to Dr. Peter Kimosop for guiding me through the whole process of Geographic Information System mapping of the three states. Am grateful for your support and guidance.

Dr. Hojjat Mehri has always been a pivotal part of my studies at Youngstown State University and his advice and nurturing hand has played a big role in my education. Thank you for all your attention.

DEDICATION

I dedicate this work to my husband Major Robert Butaki, our children Chemutai, Ngeiywa, Chesiro and Chepkech Butaki. My thanks also to our parents Dr. Wilson Soy, Esther Soy, Charles Butaki and Betty Chepkinjo and our siblings. I would not have made it without your full support. And finally, to Everlyn Rono, you remain our rock.

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CHAPTER 1: INTRODUCTION

Since the announcement by the World Health Organization that Coronavirus (COVID-19) is a worldwide pandemic on March 11, 2020, the whole world came to a standstill leading to many disruptions. The rates of infection spread quickly to different regions, causing a strain on many healthcare systems. Globally, positive cases were on the rise and by the end of March 2020, most countries had several confirmed cases. In the US, confirmed cases between January 3,2020 and April 14,2021 increased from 9 to 30,949,496 with 557,415 deaths (WHO, 2021).

1:0 Rational

The burden of the Coronavirus pandemic varies among countries and regions. The spread of COVID-19 occurs when one is physically near (within 6 feet) or have a direct contact with a person with COVID-19 (CDC, 2020). Usually, when someone with COVID-19 coughs or sneezes, they produce respiratory droplets which when inhaled causes infection to anyone in proximity.

Several measures were put in place by the CDC. These included: 1) wearing a mask that covers the nose and mouth, 2) maintaining at least 6 feet from others, 3) avoiding crowds and areas without proper ventilation, 4) washing hands or sanitizing often, 5) cleaning and disinfecting surfaces more often, and 6) getting vaccinated once the vaccine is available.

The disease burden has been attributed to broad environmental, social, and economic factors in addition to the individual level and behavioral risk factors. Health and illness are influenced by a broad spectrum of variables including environmental, social and economic factors (e.g., Evans & Stoddart,1990: Labonte, 1987) and thus the need to conduct an ecologic-level study of COVID-19 infections, hospitalizations and deaths in Ohio, Michigan and Kentucky using a Bayesian

Conditional Autoregression model to examine the pattern of the pandemic and factors that determine them.

There is need to further our understanding in this area to allow for more development of strategic preventive measures that takes environmental, social, economic, healthcare factors into consideration. The infection, hospitalization and death rates of COVID-19 will show the association with population-level indicators measuring socio-economic and healthcare factors.

Since the COVID-19 outbreak in December 2019, there has been significant information examining various outcomes of COVID-19 across the globe. Mortality, hospitalizations and infections rates and causes have been explored. The risk factors associated with COVID-19 have been identified as age, gender, and underlying conditions. The older age group was found to be of highest risk of infection and experiencing the worst outcomes. It has also been examined that people who need extra precautions include people 1) in rural communities 2) with disabilities 3) with developmental and behavioral disorders 4) experiencing homelessness 5) in racial and ethnic minority groups.

The socio-economic, cultural, physical, and environmental factors play a pivotal role in the rate of infections of infectious diseases and other chronic health conditions including heart disease, respiratory diseases, diabetes and mortality (e.g. Kawaki, Kennedy, Lochner & Prothrow 1997; Rosset et al., 2000; Wilkinson, 1996.

1.1 Purpose of Study

The purpose of this study is to understand and explore socio-economic factors that determine the infection, hospitalization, and death from COVID-19 between April 2020 and December 2020 in the states of Ohio, Michigan, and Kentucky.

Due to the burden of the spread of coronavirus, the CDC introduced mitigation activities that can be taken by people and communities to slow the spread of the virus. The introduction of personal preventive practices/actions to enable safe operations and healthy places/environments in workplaces and public facilities were some of the mitigating activities.

Wearing a face mask, handwashing, and sanitizing, staying home when ill and practicing social distancing (6 ft) are some of the examples of how an individual can practice preventive measures. Other COVID-19 mitigation activities have included stay-at-home orders, business and academic closures and travel and gathering restrictions. These were mainly aimed at slowing down the spread of the virus and minimizing infection and fatality rates. However, they could also have some economic, social, and other secondary consequences.

1.2 Background

Social determinants of health (SDOH) are the conditions in the environment where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks (US Department of health and Human services, Social determinants of health (SDOH)). These determinants affect peoples' wellbeing and health and, in this case, could have been the factors that contributed to infections, hospitalizations and deaths due to COVID-19.

1.3 Significance of the Study

Differences in social determinants of health can lead to poor health outcomes. Some of these social determinants include healthcare coverage, community income and education. Inequities related to these social determinants have become more prominent during COVID-19 response, causing more harm to racial and ethnic minority groups. Some of the consequences of the mitigation efforts by the CDC include unemployment, loss of healthcare coverage, stress, social isolation and stigma associated with having the COVID-19. These unintended consequences caused exceptional hardships in communities with limited resources, but especially those where mitigation strategies are more strictly enforced.

1.4 Terminology

Table 1 in APPENDIX A, gives definitions of word or phrases used throughout this paper to maintain consistency.

CHAPTER 2: LITERATURE REVIEW

2.0 Area of Study

A retrospective, population-based, ecological level study to assess spatial patterns of COVID-19 infections, hospitalizations and deaths in Ohio, Michigan and Kentucky and the factors that determine these patterns was done. Using the census division of counties which corresponds to the political regions, this analysis allows for nearly complete coverage of the population in the study area which allow for further work to be conducted in future with regards to policy recommendations. For important determinants of health to work, there is a need for study designs that work at ecological level (Kawachi et al., 1997: MacIntyre & Ellaway, 2000: Wilkinson, 1996)

There were approximately 11.689 million residents in Ohio, 9.986 million in Michigan, and 4.467 million in Kentucky as of July 2019 (Statistics USA, 2019). Access of healthcare services for the three states is through Medicare, Medicaid, employer insured, self-pay and some are not insured (US Department of Health and Human services)

The geographical location of the three states can be seen on Figure 1 (APPENDIX A) -Population Map.

2.1 COVID-19 Service Delivery

The testing and diagnosis of COVID-19 in the US is done in several approved locations. COVID-19 tests are available at no cost nationwide at health centers and select pharmacies. The Families First Coronavirus Response Act ensures that COVID-19 testing is free to anyone in the U.S., including the uninsured (US Department of Health and Human Services)

2.2 Determinants of COVID-19

2.2.1 Age Group

According to the CDC (CDC COVID-19 case-level report forms, March 1–November 14, 2020), the incidence of COVID-19 was highest among adults aged ≥80 years in late March to late May 2020, with a spike in incidence in the week beginning April 12, 2020. In June, incidence increased in all age groups, with the most rapid rate of increase and highest overall incidence among young adults aged 18–24 years; the rate in this group continues to be the highest among all age groups. Incidence steadily increased among children and adolescents (aged 0–17 years). The incidence in high school–aged persons (aged 14–17 years) was markedly higher than that in younger children by early July, then decreased before increasing in September. During late September–early October, weekly incidence decreased among young adults aged 18–24 years only, then continued to steadily increase among all age groups through November 14.

2.2.2 Gender/ Sex Group

Males are more likely to test positive for COVID-19, more likely to have complications and more likely to die from the virus than females, independent of age. This is according to a study by Farhaan Vahidy of Houston Methodist Research Institute, US, and colleagues.

As the COVID-19 pandemic unfolds and evolves across the globe, researchers have identified population sub-groups with higher levels of disease vulnerability, such as those with advanced age or certain pre-existing conditions. Some studies from China and Europe have indicated that males tend to experience higher disease severity compared to females. However, a comprehensive analysis of COVID-19 gender/sex in a large and diverse metropolitan area in the US has been lacking.

The authors conclude that there is a clear and strong independent association between males and SARS-CoV-2 susceptibility, complications, and poor outcomes. They further noted that understanding gender differences in disease infection is a fundamental step toward improved disease management and intervention strategies for both men and women.

2.2.3 Race/Ethnic Group

The U.S Department of Health and Human Services points out that social determinants of Health 2020 (cited 2020 Jan 20), including health and social inequalities have put many people from racial and ethnic minority groups at increased risk of getting sick and dying of COVID-19. The term racial and ethnic minority groups include people of color with a wide variety of backgrounds and experiences. It further identifies the 5 social determinants of health, including 1) economic stability 2) education 3) social and community context 4) health and healthcare 5) neighborhood and built environment. Inequalities in social determinants of health, such as poverty and healthcare access that affect these groups are interrelated and influence a wide range of health and quality-of life outcomes and risks.

2.2.4 Income Group

According to University of Chicago researchers, the lowest-income group had the highest rate of job losses between February 1, 2020 and the end of June, while the highest-income workers had the lowest job loss rate during this period. While the gaps narrowed somewhat by the end of June, the lowest-income group had only 81 percent of the jobs they had on February 1, while the highest-income group had 96 percent of the jobs they had pre-pandemic.

2.2.5 Healthcare Insurance Coverage Group

Current Population Survey Annual Social and Economic Supplement (CPS ASEC) and the American Community Survey (ACS) report that in 2019, 8.0 percent of people, or 26.1 million, did not have health insurance at any point during the year. The percentage of people with health insurance coverage for all or part of 2019 was 92.0 percent. Most people had Private health insurance coverage, covering 68.0 and 34.1 percent of the population at some point during the year, respectively. In 2019, 9.2 percent of people, or 29.6 million, were not covered by health insurance at the time of interview, according to the ACS, up from 8.9 percent and 28.6 million.

CHAPTER 3: METHODOLOGY

3.0 Procedure

The objective of this study was to evaluate how the determinants of COVID-19 affected the infections, hospitalizations and deaths of populations in Ohio, Michigan and Kentucky. To achieve this, county shapefiles were obtained from the U.S. Census Bureau and mapped using the ArcGIS software. These shapefiles were subsequently joined with the COVID-19 data from the CDC. The data was then analyzed statistically with Conditional Autoregression (CAR) Model in Open BUGS.

3.1 Data Collection and Sources

The data used in this study was obtained from the American Community Survey (ACS), the CDC, the US Department of Health and Human Services, Centers for Medicare and Medicaid Services, US Census Bureau, and the COVID Tracking Project. These data gave figures for infections, hospitalizations, discharges and deaths of COVID-19 patients by age, gender, race /ethnicity, income and health care coverage. The data obtained was from April 2020 to December 2020 for the three states. All records with a principal discharge diagnosis of COVID-19 were selected. The 2019 American Community Survey 5-year estimate (Table S2701) provided data on population and residency.

3.2 ArcGIS

The total number of counties for the three states is 291: 88 in Ohio, 83 in Michigan and 120 in Kentucky. For this study, the county was used as the unit for analysis.

To map county datasets for the 3 states, polygon shapefile obtained from the U.S. Census Bureau were mapped using ArcGIS Pro. Data from COVID-19 cases from July 2020 to December 2020 all aged 15 and over were obtained from the Center for Disease Control (CDC) website and joined with the polygon shapefiles representing different counties. A total of 291 counties were included in the analysis.

3.3 Conditional Autoregression Model

The Spatial analyses of COVID-19 were conducted in two phases. First, county boundaries were geo-referenced and linked to the county COVID-19 infection rates for April 2020 to December 2020 and maps were developed for visualization.

3.4 Analysis of Research Questions

3.4.0 Problem Description

The infections, hospitalizations and deaths due to COVID-19 in the 3 states was dependent on several factors which, according to the CDC are called determinants of health. These determinants bring about the inequities and inequalities that different groups experienced. The question therefore is, how can we identify the most prominent factors? Which group is mostly affected? The analysis that follows will attempt to answer these questions.

3.4.1 Impact Analysis of Covid-19 on Different Age Groups?

The age groups to consider are 0-17 years, 18-49 years, 50-64 years, and 65+ years. Individuals of 65+ were more vulnerable to infections and deaths primarily due to several underlying health issues as indicated by the CDC. However, from the analysis, those more affected were those between 18-49 years.

	Infections	SD	LCL	UCL	Min	Max
0-17 years	180.95	163.99	103.6	258.29	11	1250
18 - 49 years	1236.56	962.18	1162.05	1311.06	127	5974
50 - 64 years	493.59	348.78	419.09	568.09	22	2035
65+ years	441.45	299.68	366.755	516.14	54	1731

3.4.2 Impact analysis of Covid-19 on Different Gender/Sex

Females and males responded differently to COVID-19 making the males more vulnerable to infections and deaths.

MI		**Mean**	**SD**	**Median**	**Start**	**Sample**
	M	1.11875	252.75	0.4805	10001	3000
	F	-1.5765	248.275	-5.2475	10001	3000

KY		**Mean**	**SD**	**Median**	**Start**	**Sample**
	M	1.491667	337	0.6406667	10001	3000
	F	-2.102	331.0333333	-6.996667	10001	3000

OH		**Mean**	**SD**	**Median**	**Start**	**Sample**
	M	0.92775	253.5	1.8685	10001	4000
	F	-3.93	249.25	-0.86225	10001	4000

3.4.3 Impact Analysis of Covid-19 on Different Races/Ethnic Groups

Individuals have been categorized as either of white race or non-white race (Black, Hispanic, Asian and Others)

From our results, individuals of a white race were less infected with COVID-19 as compared with non-white race.

OH		Mean	SD	Median	Start	Sample
	M	-4.315	0.1427	-4.315	1	3000
	T	-0.7161	102.1	1.239	1	3000

MI		Mean	SD	Median	Start	Sample
	M	-4.113	0.1044	-4.112	1	3000
	T	-0.1776	101.6	-1.01	1	3000

KY		Mean	SD	Median	Start	Sample
	M	-4.361	0.1537	-4.362	1	3000
	T	1.862	100.8	1.698	1	3000

From our results, individuals of a white race had lower number of deaths due to COVID 19 as compared with non-white race.

OH		Mean	SD	Median	Start	Sample
	M	-7.912	0.08853	-7.913	1	3000
	T	-1.234	99.1	-0.5128	1	3000

MI		Mean	SD	Median	Start	Sample
	M	-7.171	0.05094	-7.171	1	3000
	T	-1.945	97.74	-2.559	1	3000

KY		Mean	SD	Median	Start	Sample
	M	-8.3	0.09354	-8.297	10001	3000
	T	1.948	102	1.172	10001	3000

3.4.4 Impact of Covid-19 on Different Income Groups

Individuals from low-income (L) communities were more vulnerable to infection and death than those from median income (M) communities.

MI		Mean	SD	Median	Start	Sample
	L	4.375	1010	1.822	10001	3000
	M	-6.806	995.1	-19.99	10001	3000

KY		Mean	SD	Median	Start	Sample
	L	4.475	1011	1.922	10001	3000
	M	-6.306	993.1	-20.99	10001	3000

OH		Mean	SD	Median	Start	Sample
	L	3.711	1014	7.474	10001	4000
	M	-15.72	997	-3.449	10001	4000

3.4.5 Impact of Covid-19 on Different Healthcare Coverage Groups?

Individuals have been categorized under Insured and Uninsured of different race and ethnic groups.

Analysis of the data shows that access to healthcare coverage is more prominent with individuals of the white race while there is a disparity for those from minority groups.

OH		Mean	SD	Median	Start	Sample
	Hispanic	2.128	1001	5.069	10001	4000
	Black	10.88	1004	-0.5185	10001	4000
	White	3.486	995.3	-12.48	10001	4000

MI		Mean	SD	Median	Start	Sample

	Hispanic	29.21	999.4	20	10001	3000
	Black	-11.96	1028	-7.136	10001	3000
	White	10.41	995.3	1.187	10001	3000

KY		**Mean**	**SD**	**Median**	**Start**	**Sample**
	Hispanic	29.21	999.4	20	10001	3000
	Black	-11.96	1028	-7.136	10001	3000
	White	10.41	995.3	1.187	10001	3000

Analysis of uninsured persons shows that majority of those who had limited access to healthcare were of minority groups.

OH		**Mean**	**SD**	**Median**	**Start**	**Sample**
	Hispanic	0.532	250.25	1.26725	10001	4000
	Black	2.72	251	-0.129625	10001	4000
	White	0.8715	248.825	-3.12	10001	4000

MI		**Mean**	**SD**	**Median**	**Start**	**Sample**
	Hispanic	7.3025	249.85	5	10001	3000
	Black	-2.99	257	-1.784	10001	3000
	White	2.6025	248.825	0.29675	10001	3000

KY		**Mean**	**SD**	**Median**	**Start**	**Sample**
	Hispanic	9.736667	333.1333333	6.6666667	10001	3000
	Black	-3.98667	342.6666667	-2.378667	10001	3000
	White	3.47	331.7666667	0.3956667	10001	3000

CHAPTER 4: RESULTS

4.0 Analysis

The data collected was used to map using ArcGIS. Shapefiles representing the counties in the three states were joined with the COVID-19 data.

Model adequacy ensured through various diagnostic tests using burn-in and convergence test. The statistical analysis was performed using OpenBUGS.

Of the three states, Ohio was most affected by COVID-19. A further analysis would be able to show why this was so.

CHAPTER 5: DISCUSSION

SDOH plays a vital role in healthcare of individuals in a society. The 5 determinants discussed contributed to the COVID-19 infections and deaths in the 3 states. Although more research needs to be done to get more data, it is important to note that other factors could also have caused the infections and spread of COVID-19.

The practice of wearing a mask and social distancing played a major role in curbing the spread of COVID-19 in populations (CDC).

Other possible factors include community practices, housing, immigration status, underlying health issues, smoking, employment and culture. These could be investigated further in more depth.

APPENDIX A

TABLE 1

Terminology

CDC	Center of Disease Control
WHO	World Health Organization
SDOH	Social Determinants of Health
ACS	American Community Survey
OH	Ohio
MI	Michigan
KY	Kentucky
SD	Standard Deviation

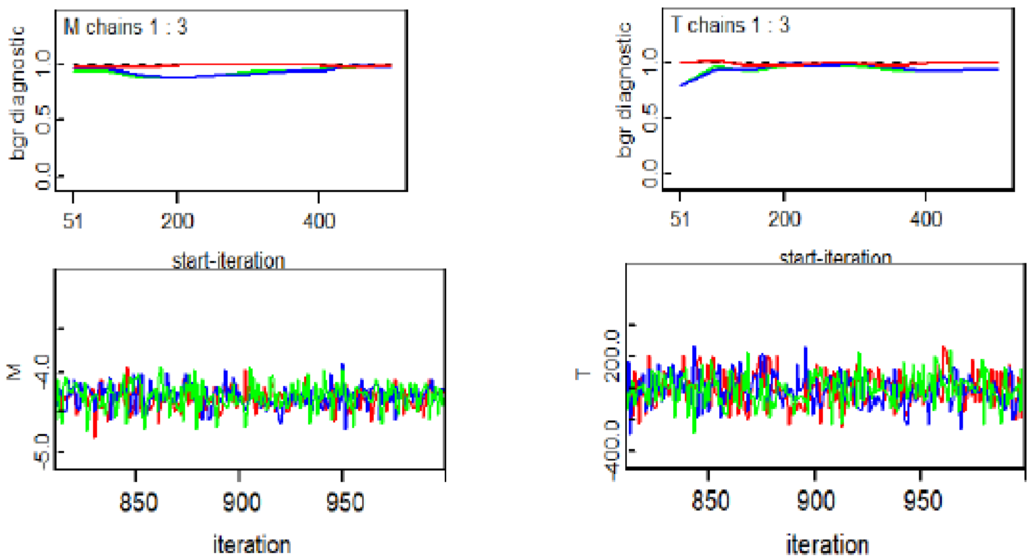
TABLE 2

Data Sources

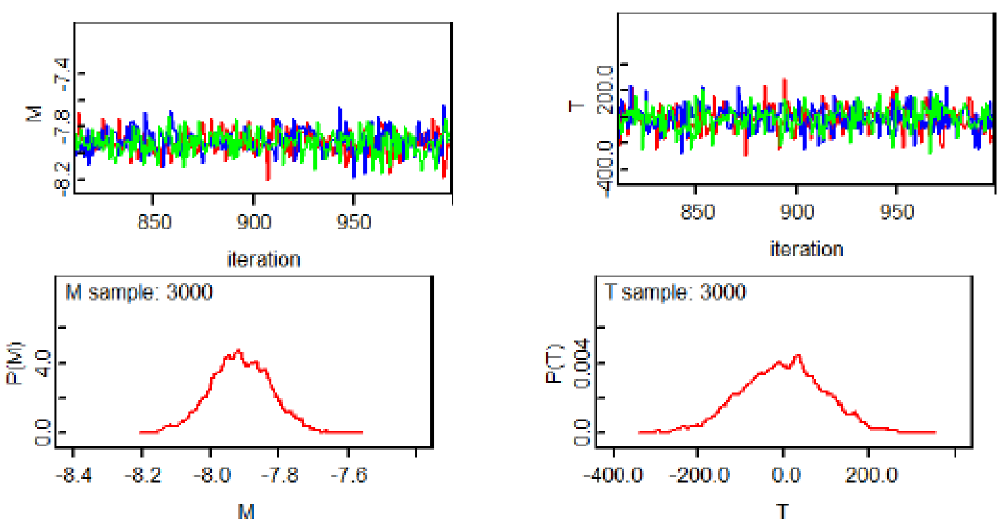
DETERMINANT	SOURCE
Age, Sex, Race	The CDC (Center for Disease Control)
Race/Ethnicity Data	The COVID Tracking Project
Community Income	US Census Bureau
Healthcare Coverage	US Department of Health and Human Services
Population	American Community Survey
COVID-19 Infections	The COVID Tracking Project
COVID-19 Hospitalizations	The COVID Tracking Project
COVID-19 Deaths	The COVID Tracking Project

APPENDIX B

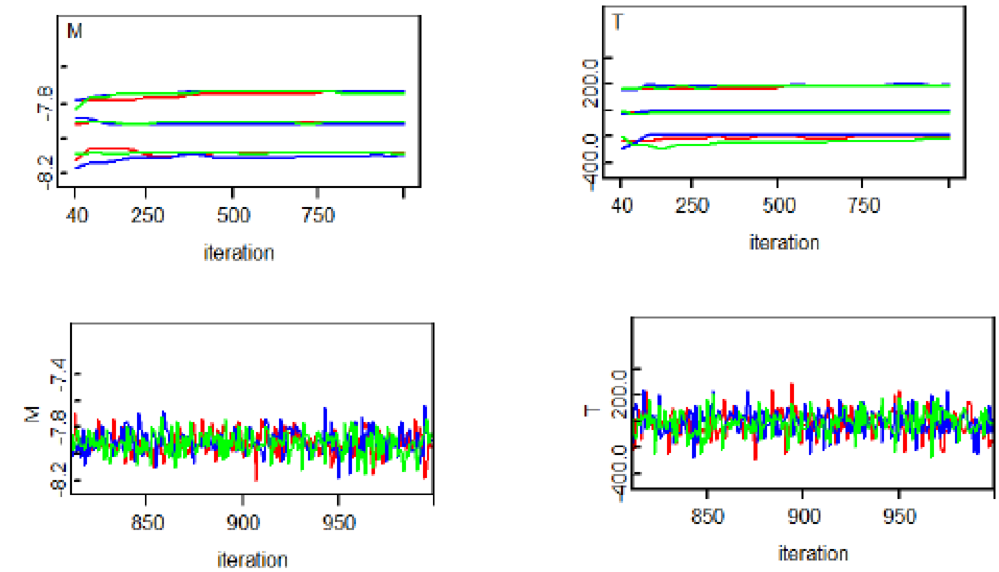
Ohio Infections Graph



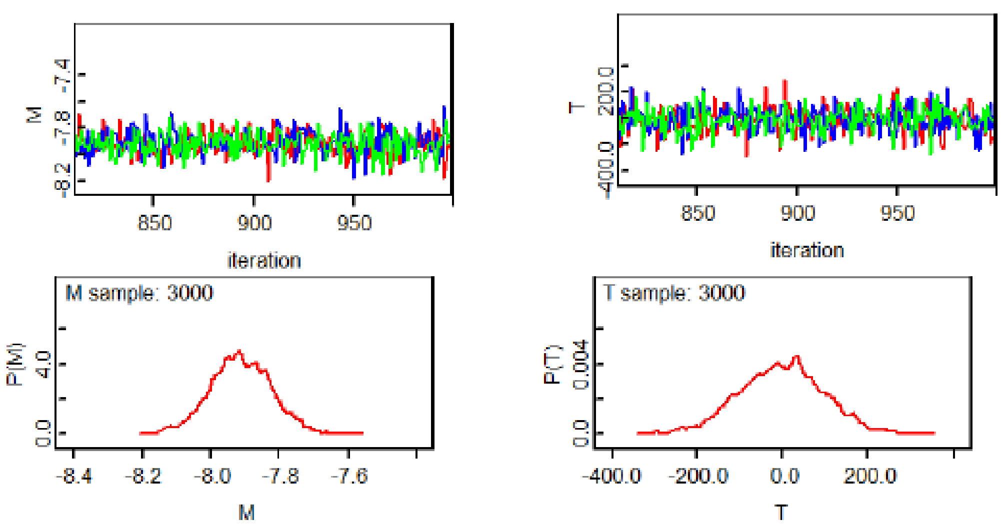
Ohio Deaths Graph



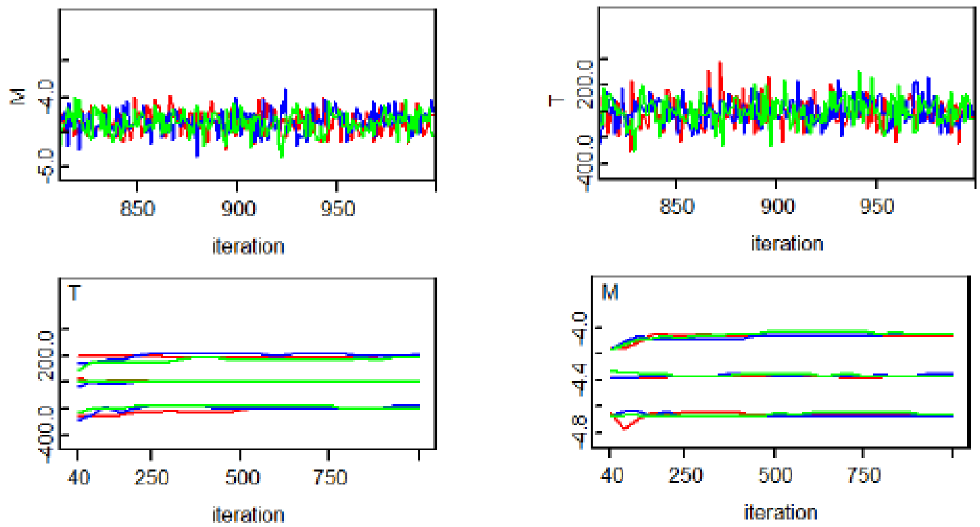
Michigan Infections Graphs



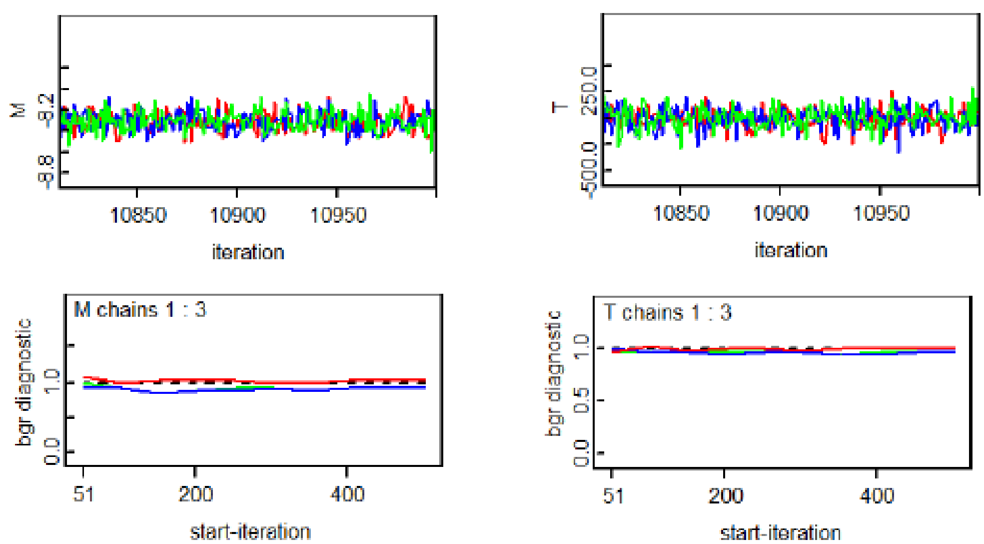
Michigan Deaths Graphs

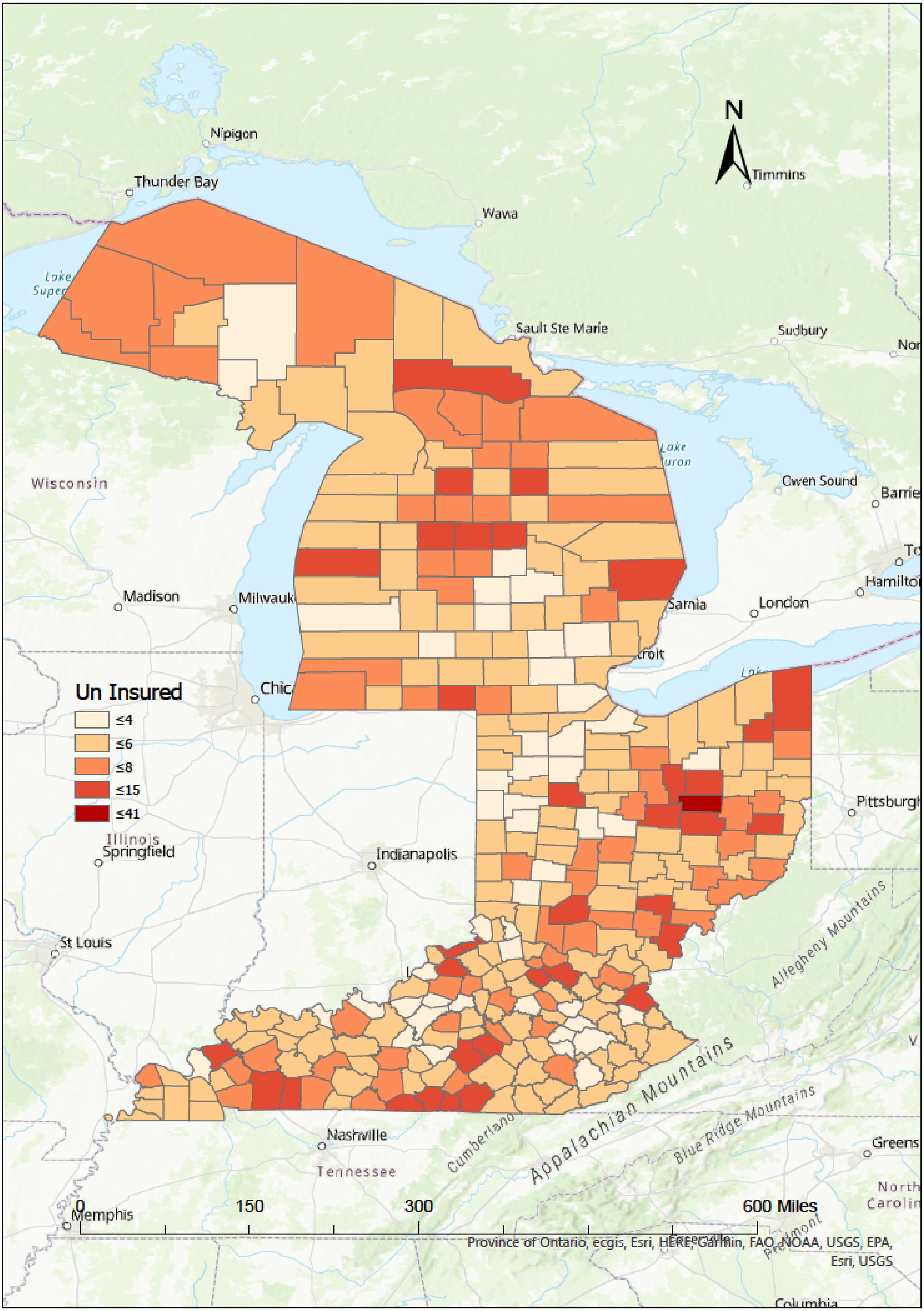


Kentucky Infections Graph



Kentucky Deaths Graphs





Un Insured
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≤6
≤8
≤15
≤41
N
0
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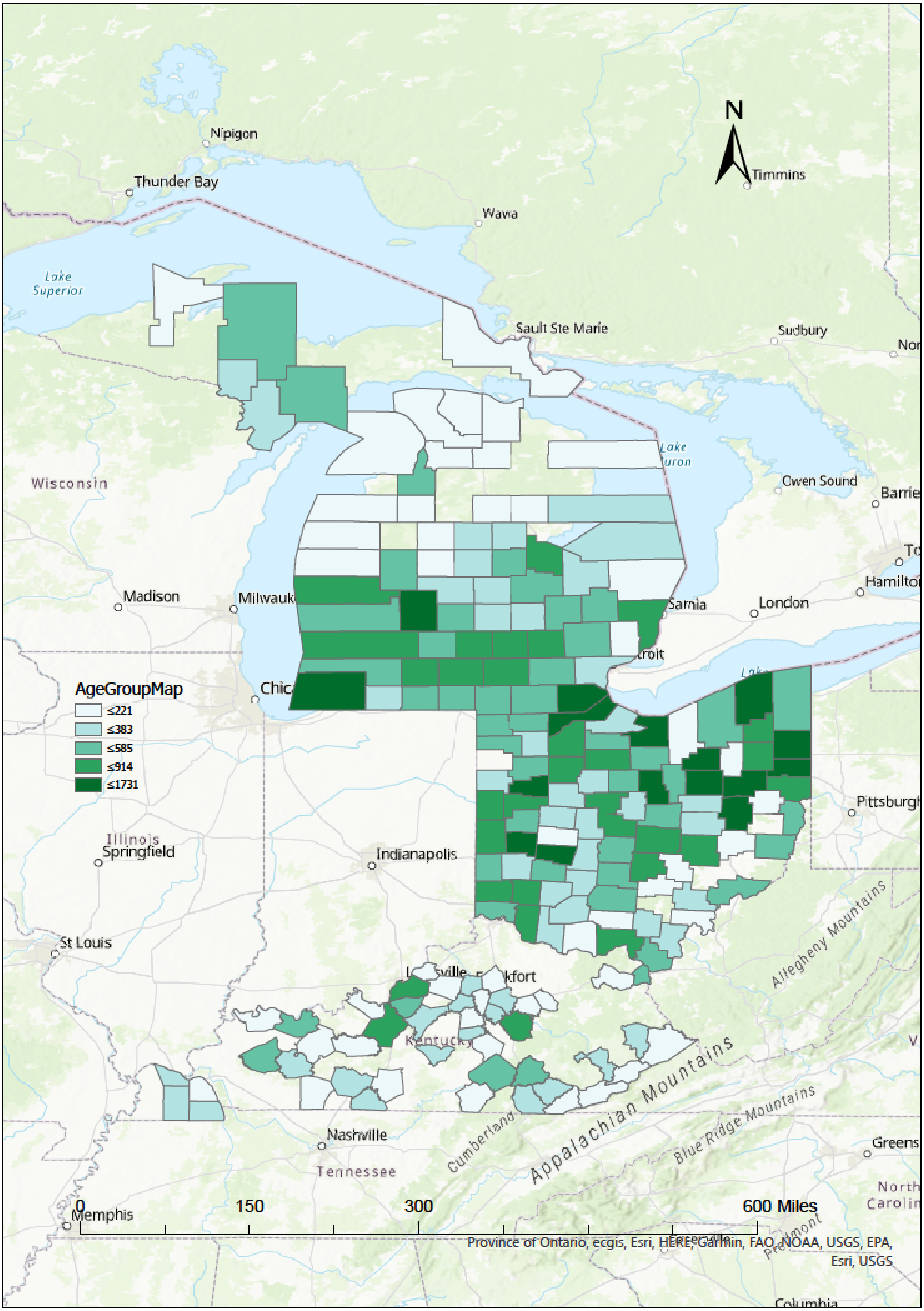
300
600 Miles
Province of Ontario, ecgis, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, Esri, USGS



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Wawa
Timmins
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Sudbury
Owen Sound
Barrie
Hamilton
London
Sarnia
Wisconsin
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St Louis
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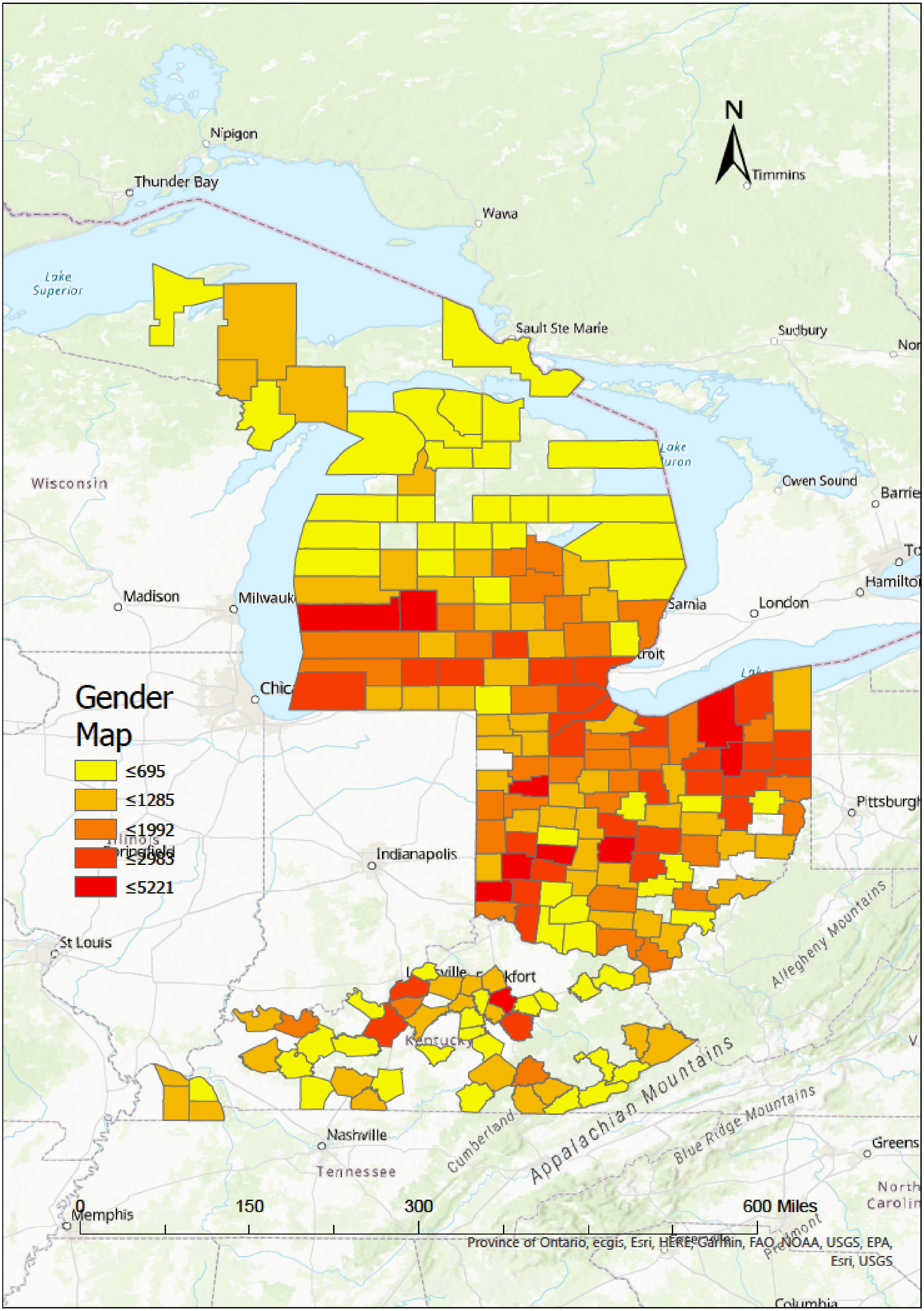
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Tennessee
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Timmins
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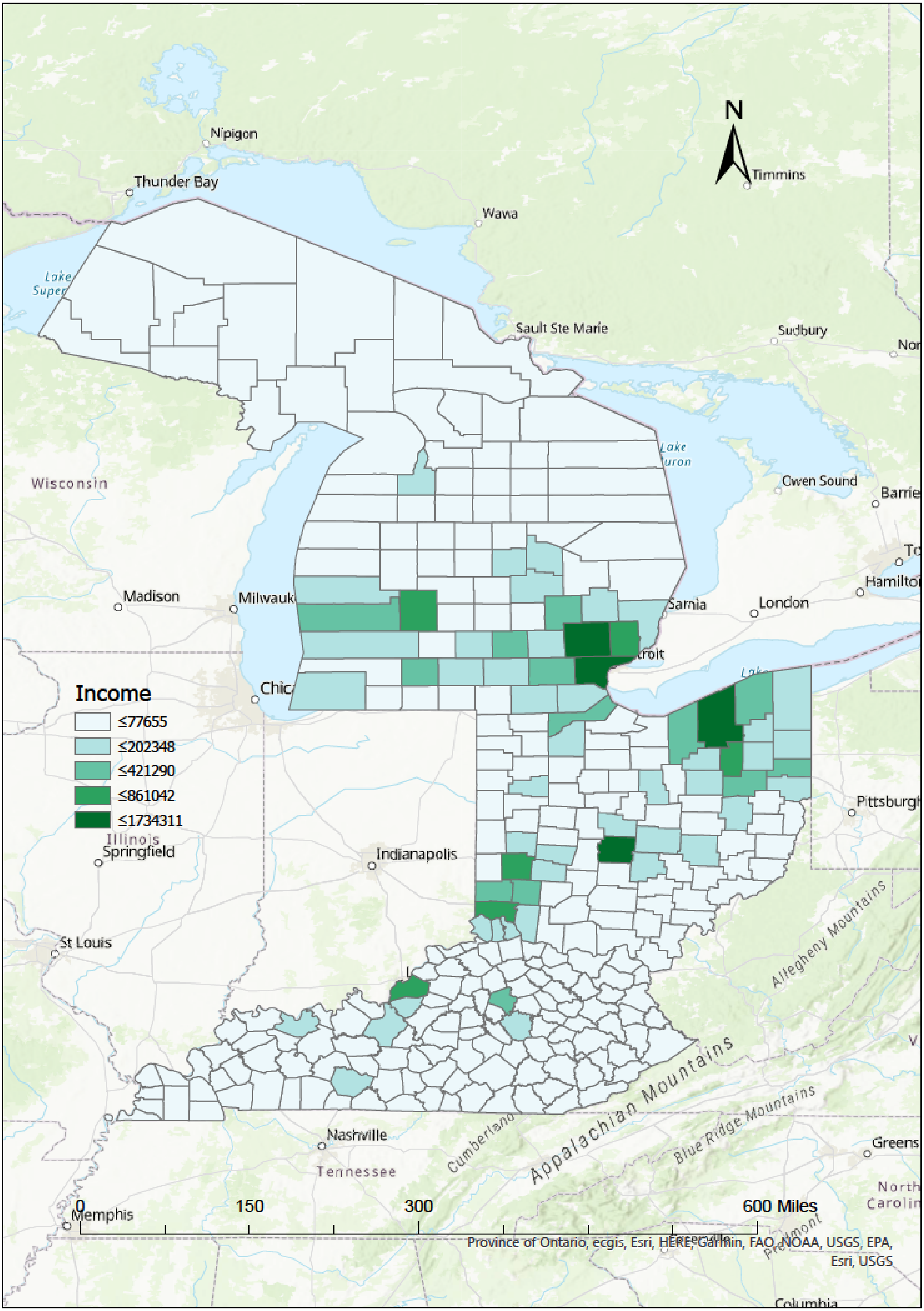

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Wawa
Timmins
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Hamilton
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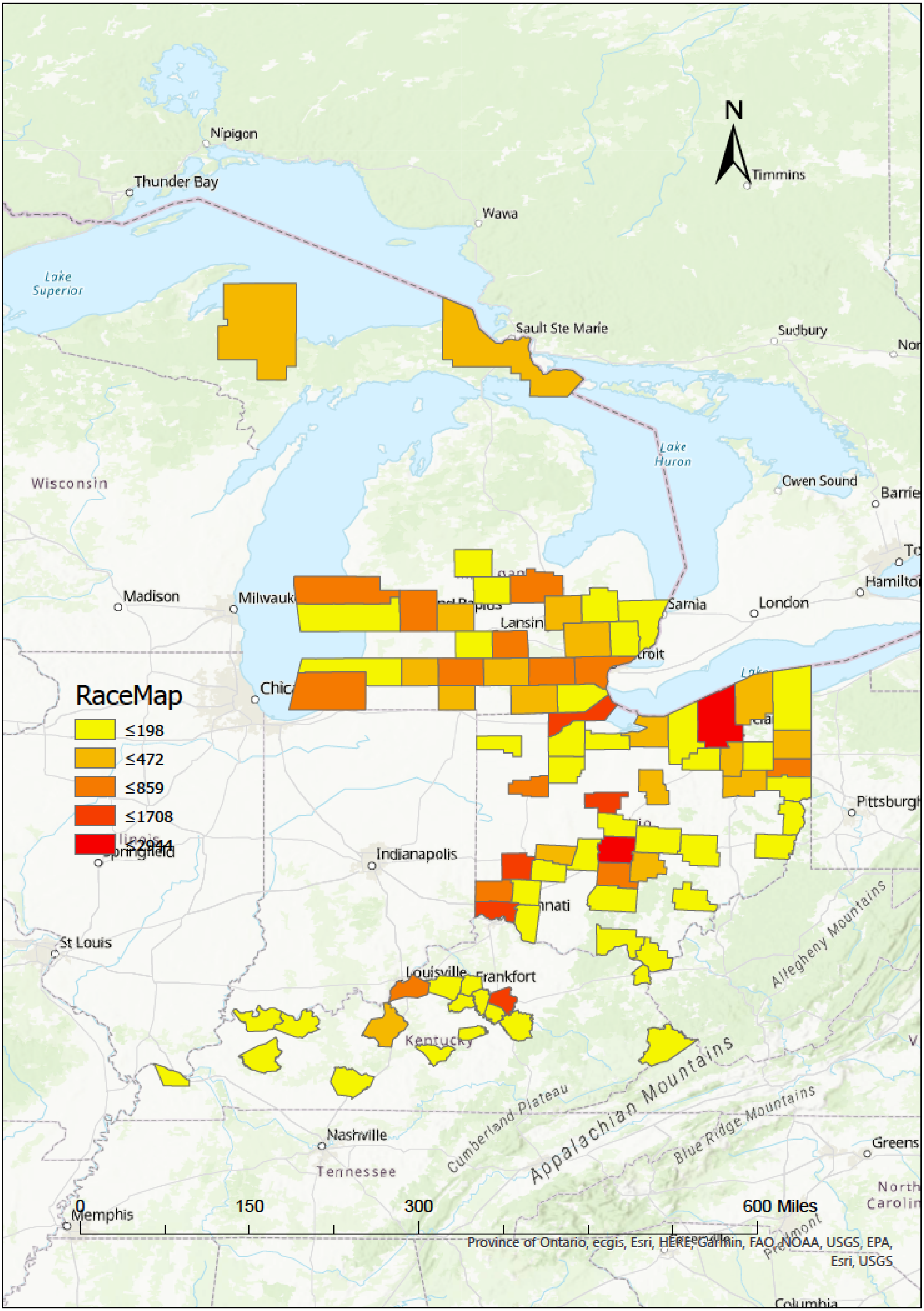
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Sudbury
Lake Huron
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Louisville
Frankfort
Kentucky
Allegheny Mountains
Appalachian Mountains
Cumberland Plateau
Blue Ridge Mountains
Nashville
Tennessee
Greens
Memphis
Columbia

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