Pharmacy Shortage Areas Across the United States: A Visual Representation by a Web Mapping Application

by

Taylor Corrin Robinson

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To My Parents

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Table of Contents

List of Tables

List of Figures

Abbreviations

ACS	American Community Survey
AMPAC	Access to Medicines and Pharmacies Advisory and Advocacy Committee
BG	Block Group(s)
CMS	Centers for Medicare and Medicaid Services
DEA	Drug Enforcement Agency
DHHS	Department of Health and Human Services
FDA	Food and Drug Administration
FPL	Federal Poverty Level
GEOID	Geographic Identifier
GIS	Geographic Information Systems/Science
HPSA	Health Professional Shortage Area
MUA	Medically Underserved Area(s)
NAD	North American Datum
NCPA	National Community Pharmacist Association
NCPDP	National Council for Prescription Drug Programs
PAI	Pharmacy Access Initiative
RUCA	Rural-Urban Commuting Area
USC	University of Southern California
2SFCA	Two-Step Floating Catchment Area

Abstract

Pharmacies are one of the most used healthcare facilities across the nation due to of the number of services provided within a retail setting. The services provided by a retail pharmacy include dispensing of medications, vaccines, diagnostic testing, counseling, and more, all of which are pertinent to creating and maintaining a healthy community. A pharmacy shortage area is a location or area with an inadequate number of pharmacies available to a community leading to residents traveling far distances to their nearest pharmacy. Determining states or parts of the country that have a large number of these shortage areas provides a blueprint of where pharmacies are greatly needed. This project provides a national distribution of the accessibility of pharmacy locations by census tract for 2018 and 2020. These results are presented in a web mapping application through ArcGIS Pro. By presenting pharmacy shortage areas by census tract and over time, policymakers have highly relevant information. Given this information, there is a better chance for federal, state, and local policy changes that may improve pharmacy accessibility overall.

Chapter 1 Introduction

Pharmacies are a healthcare facility which provide access to medications, treatments, and other primary care services. Compared to other types of healthcare facilities such as emergency care, primary care, etc., pharmacies provide their amenities with more convenience, such as with drive-through access, longer hours and weekends, and sometimes more locations. Better access to pharmacy locations is important to medical equity across the nation. Especially for low-income neighborhoods and neighborhoods with low-vehicle ownership, the need for adequate access is extremely important because these services are sometimes an alternative to higher priced healthcare facilities.

This study aims to analyze what types of populations are affected by adequate or inadequate pharmacy access across the United States. The analysis is done using a calculation based on the nearest pharmacy to the centroid of a census block group. The pharmacy data years include 2018 and 2020 pharmacies with indicators of which pharmacies have closed between the two years and which were newly opened by 2020. Using population density, to determine urbanicity at the census block group level, all block groups within an urban, suburban, or rural census tract are considered a shortage area based on distance thresholds. For each year, using the distance to nearest pharmacy from each census block group, a census tract is considered a shortage area if an area of over 500 residents or over 33% of the tract's population is further than a given distance from the nearest pharmacy. Following existing literature on pharmacy deserts, the distance thresholds are set based on whether tracts are urban, suburban, or rural and for characteristics of the populations in each tract (Guadamuz, et al. 2021).

Figuring out the locations of these pharmacy shortage areas can provide statistics of who is being affected by a lack of access to pharmacies and their services. Applying this across a large study area, such as the United States, shows at the national level just how many people and places are affected. This project shares these areas in an interactive map, which can serve as a blueprint for policy makers and pharmacy executives to make decisions on where pharmacy locations are needed.

This project was completed by the author working with the Pharmacy Access Initiative group which includes four other members within the University of Southern California (USC) Spatial Sciences Institute and School of Pharmacy. In addition to the author, the group's members included in this project were the Director Dima Qato, PharmD, MPH, PhD; Robert Vos, PhD, GISP; Post-Doctoral Research Fellow Jenny Guadamuz, PhD; and Research Project Specialist/Data Analyst Andrew Shooshtari, MS. The Pharmacy Access Initiative is community-based public health research, and this project was partnered with the National Community Pharmacists Association (NCPA). In addition, feedback was solicited from an Advisory and Advocacy Committee (AMPAC) made up of clinicians, elected officials, and federal and state policymakers.

1.1. Pharmacy Importance

Pharmacies play a vital role in providing healthcare services to the general public. The standard services provided by pharmacies include prescription, over the counter and behind-the-counter medications, patient consultations, and some vaccines, which are also available within primary health care facilities. These services provided by pharmacies are convenient for patients because of the ability to receive these services, usually without having to wait for weeks for an appointment, as compared to some primary care facilities. Along with the convenience of pharmacy hours, the vaccines available also can be given at reduced prices with coupons that might not be offered in primary care facilities. Also, pharmacist consultation includes advice on what medications to take based on symptoms and help with compliance and use of medications which are offered for free in a pharmacy setting. These services being offered at pharmacies, that would otherwise cost at other health care facilities, is why adequate pharmacy access is necessary to all.

Management of common health conditions in the US, such as heart disease and diabetes, require regular access to the types of services provided by pharmacies. Medications, including insulin for diabetes, are one of the main factors for a patient to remain compliant in maintaining their health condition. Heart disease and diabetes account for two of the top ten leading causes of death by the Centers for Disease Control in the United States as of 2020, with heart disease ranking highest in mortality rates (Centers for Disease Control and Prevention 2022). Both heart disease and diabetes cause those diagnosed to rely heavily on pharmacies to receive most of their medications and treatments and to remain compliant. Conditions which lead to heart disease include high cholesterol which is a condition that can cause the arteries leading to the heart to be clogged and can be treated with various medications and changes in diet. Failure to consistently treat high cholesterol, for example, can cause heart disease and may cause heart attacks as well. Being compliant with receiving and taking medications to reduce cholesterol is very important to the reduction of a heart disease diagnosis. Having adequate access to pharmacies can result in better compliance amongst a community.

1.2. Pharmacy Deserts

The term “pharmacy desert” has become popular for describing a location with poor access to pharmacies and their services. The addition of the word “desert” comes from the term “food desert” which describes a location with scarce access to healthy food options or any food locations in general (Alkon and Agyeman 2011). The definition of food desert locations is similar to pharmacy desert locations in that they do not provide adequate availability of what is needed for the community. Healthy food options and pharmacy services should be available and accessible to all.

Pharmacy deserts can be defined as locations of populations with little to no access to pharmacies and their services based on many factors, one being distance traveled by a person to their pharmacy. Another definition includes areas of populations that have pharmacy locations available in their neighborhoods, but these pharmacies are not in their insurance network, making it nearly impossible to receive certain available care (Kelling 2015). Insurance companies often have multiple plans from which beneficiaries can choose what will benefit them best. Insurance companies decide for their pharmacy plans which locations and companies to create contracts with, which reduces the amount of freedom patients have to receive care from pharmacies. Previous small-area studies that focused on the spatial accessibility of pharmacies or healthcare facilities within certain distances from populations or neighborhoods, (Wisseh, et al. 2020; Pednekar and Peterson 2018; Bonner 2015) provide information on the social inequities within certain locations. Overall, mostly minority populations and lower income populations are affected the most by inaccessibility to healthcare facilities and pharmacies. Basic healthcare services should be accessible to all and determining where there are locations that lack this access is a way of showing social inequities within the healthcare system.

The income of a location or neighborhood has a great influence on whether or not a pharmacy desert might exist. Low-income census tracts or neighborhoods might not be able to provide the necessary financial resources needed to keep community pharmacies in business (Gebhart 2019). Independent pharmacies are privately owned, often pharmacist-owned, businesses which are single store operations (Riemschneider 2010). A chain pharmacy is an organization in which more than two pharmacies are operating under the same name (Miller and Goodman 2017). Independent pharmacies, which generally do not have a budget as large as their chain company counterparts, receive the same reimbursement amounts for government insurances such as Medicare and Medicaid. Medicare and Medicaid reimbursements, which are the amounts that the federal government is willing to pay a pharmacy for the medications of beneficiaries of Medicare or Medicaid insurances, are beneficial to pharmacies which have other sources of income for their business. For independent pharmacies, many of which are in neighborhoods with populations that have a large amount of Medicaid or Medicare beneficiaries, the reimbursement rates alone are not enough to keep the business running, hence the need for better and higher reimbursement rates. For an independent pharmacy to thrive as well as the chain pharmacies, the community around the pharmacy is needed to do their part in keeping the business running monetarily, even with products other than pharmaceuticals. There is a correlation between low-income populations and populations with majority government insurance, therefore, these pharmacy locations would not receive the monetary income from their residents that they would in higher income locations (Keisler-Starkey and Bunch 2021). Therefore, determining where these pharmacy desert locations are can provide a better understanding of the needs and potential improvements of the neighborhood.

Identifying what qualifies a neighborhood to be a pharmacy desert has been studied and grouped by a plethora of topics. Previous studies on pharmacy deserts focused on social determinants and inequities of accessible pharmacies (Guadamuz, et al. 2021; Wisseh, et al. 2020; Ikram, Hu and Wang 2015), spatial accessibility of pharmacies based on travel time (Ouma, et al. 2021; Weiss, et al. 2018), and distribution of pharmacy types (i.e., community, retail, etc.) (Jagadeesan and Wirtz 2021; Kelling 2015). The inequities of pharmacy access are most prevalent in areas where there are low-income populations and low rates of vehicle ownership. Both of these factors contribute to the fact that pharmacy shortage areas can occur from the lack of financial support from the community. Communities which have a higher percentage of the population enrolled in government insurances affect the monetary intake of pharmacies, especially independent pharmacies, because of the Medicare and Medicaid reimbursement rates. Not only will having a lack of vehicle ownership within a census tract affect the accessibility of pharmacies for the population but also the extended travel times and distances to reach the closest pharmacy has an effect on the accessibility of those living in these neighborhoods or census tract as well.

In this work, the term “pharmacy shortage area” will be used rather than “pharmacy desert”. Using the term shortage area allows for locations to be considered in this category if the distance to the nearest pharmacy is larger than a certain threshold for the type of tract it is (i.e., urban, rural, or suburban). Rather than considering a tract as a desert, the term shortage area allows for the presence of pharmacies within or near the shortage areas but an inadequate access to these locations based on the distance traveled by residents of these tracts.

1.3. Study Area

To present the data on pharmacy shortage areas, where they are, what they mean, and who are affected, the study area needed to be large and include a wide range of locations. Starting from the tract level and increasing in size to the national level can provide locations of shortage areas which is of importance to deciding where there should be increased pharmacy locations. Having the study area reach the entire nation informs all those living in the United States of their status of whether they are living in a shortage area or not and can give insight to those who depend on pharmacies of whether their neighborhood is medically beneficial to them or not. The study area of this project includes the contiguous United States, Alaska, Hawaii, and the District of Columbia. The US territories are not included in this project's study area.

1.4. Federal Policies

There are federal policies that apply to pharmacies and pharmaceutical services or products which can affect pharmacy patients and how they receive or interact with these products. The United States Food and Drug Administration (FDA) and the Drug Enforcement Agency (DEA) are both federal administrations and agencies which monitor the distribution of pharmaceutical products in order to provide safety and reduce harm for those receiving such products. Many of the policies created within this administration and agency are still active within pharmacies and affect how drugs are sold and what services are provided within pharmacies. Consultation with a pharmacist is a free pharmacy service that is useful to those who do not have insurance or would have to pay copays and large payments to a primary healthcare facility for such service. Federal policies allow for patient consultation by a pharmacy to be accessible and free to the public.

The Food and Drug Administration (FDA) regulates policies which pertain to pharmacies because pharmacies sell of pharmaceutical drugs. Specifically, the Food, Drug and Cosmetic Act was put into place to replace and strengthen past legislation on product branding and misleading food and drug labels (Leelamanthep and Sergent 2021). The Food, Drug, and Cosmetic Act allows for the criminalization of false claims and creates a requirement of ingredients, indications, and warnings to be listed on the product's label. Other policies including the Durham-Humphrey Amendment separate drugs into two categories: over the counter and prescription drugs. The Kefauver-Harris Amendment establishes a framework process in order to get a drug approved to be consumed. This framework includes multiple phases of trials and lengthy research done by the FDA. The Comprehensive Drug Abuse Prevention and Control Act, which initiated the creation of the Drug Enforcement Administration (DEA), separates all drugs into six classes. Beginning with schedule (class) one drugs which have a high potential for abuse and are illegal in the United States (i.e., Marijuana, Heroin, and LSD), reducing in abuse potential to schedule five drugs which include limited levels of narcotics (i.e., cough suppressants with <200mg of Codeine per 100mL) (Diversion Control Division - Drug Enforcement Agency, n.d.).

Amendments and Acts which apply directly to the pharmacies include the Omnibus Reconciliation Act which allows individual states to create local standards on pharmacists providing patient consultation on medications. The goal of this amendment is to increase pharmacy-patient interactions through algorithms which detect drug interactions, allergies, dose, duration, and duplications in the medications given to a patient (Leelamanthep and Sergent 2021). The pharmacist, through this act, is allowed the final say in determining what is best for each patient, whether that be a change in dosing, therapeutic substitution, etc. Another act which directly affects pharmacies is the Medicare Modernization Act which, funded by the government, provides an opt-in option for patients who are “economically struggling” to pay reduced costs for medications, subject to annual check-ups (Leelamanthep and Sergent 2021).

All of the aforementioned laws and policies have shaped the way medications are legally distributed in the US. The process in which medication compliance is conducted, the goal of which is to prevent patients from being harmed by medications, is a strategy that is currently used in pharmacies, hospitals, and doctors’ offices and is used to prioritize the patient’s overall wellbeing.

1.5. Thesis Structure

This thesis consists of five chapters including this Introduction, Related Work, Data and Methods, Results, and Conclusions, all of which provide background information, analysis, and explanation of results of the web application presenting pharmacy shortage areas.. Chapter 2 provides description and analysis of previous studies which on pharmacy deserts and inadequate access to pharmacies and healthcare and how they compare to this project. Chapter 3 explains the data preparation, geospatial analyses, and creation of the web mapping application. Chapter 4 presents the results of the analysis that are shared via the web mapping application which include the national distribution of pharmacy locations which closed from 2018 to 2020, the newly opened locations nationally, the pharmacies that stayed active both years nationally, along with the tracts that are considered shortage areas and the demographics of those areas. Chapter 5 includes discussion of results, potential future work that could be done using the information found in this study, and limitations of the project.

Chapter 2 Related Work

This chapter presents a literature review of past articles which studied pharmacy deserts and how the studies relate to and differ from the pharmacy shortage areas studied in this project. The analyses differ from study to study allowing for a well-rounded understanding of the different types of pharmacy deserts and how the definition of a pharmacy desert can be applied to the classification of a pharmacy shortage area. Along with the comparison of past articles on pharmacy desert studies, this chapter describes how urbanicity is categorized in the US and within this project, the definition of areas that are medically underserved, and the travel distances to the nearest pharmacy that are considered acceptable by Centers for Medicaid and Medicare Services (CMS) which is being compared to the travel distances found in this project. This chapter also discusses methods and issues relating to the creation of web maps and web mapping applications.

2.1. Pharmacy Access

A "desert" in the context of accessibility refers to a location with little or no accessibility to a particular social service, due to either limited availability of the service or limitations in the ability of nearby populations to actually receive the benefit of that service. The different types of deserts, when applied to pharmacy access, include spatial and physical access, location availability, and insurance or benefit access. Each of these definitions of a social service "desert" is distinguished by different service thresholds and methodologies for measuring where the pharmacy locations are able to be accessed adequately and where they are not. Many previous research projects done on pharmacy deserts present their own definition of how they determine a pharmacy desert and their methods to find them.

2.1.1. Pharmacy Desert Definitions

Determining the distance to a pharmacy can be found using a nearest within a radius, a radius which can be set to see what the closest location of a pharmacy is, which can give a neighborhood an idea of what the general nearest pharmacy location is to them. Wisseh, et al. (2021), define a pharmacy desert as a location in which the distance to the nearest community pharmacy is longer than one mile. A community pharmacy can be any pharmacy that is able to serve a community as opposed to those locations that might not be publicly available such as a hospital pharmacy. The radius chosen for analysis includes not only distance taken by car but also by foot. This radius can be changed by different residential categories (i.e., rural, urban, suburban, etc.), which may be appropriate since there are different typical expectations of travel distances across rural, urban, and suburban places.

Wisseh et al. (2021) define a pharmacy desert as a location with a distance longer than one mile to the nearest pharmacy. This comes from the concept of a food desert and has been altered to work for pharmacy access. Wisseh et al. (2021) also determine pharmacy desert subtypes which consisted of type one having denser communities than type two. Type one also includes more Hispanic and non-Hispanic Black residents than type two communities. Not only was this study the first of their knowledge to present pharmacy deserts within Los Angeles County based on their definition, but it also was the first to provide analysis on the composition of these communities.

A one-mile radius can be utilized to define a reasonable distance to travel to a pharmacy. (Wisseh et al. 2021; Pednekar and Peterson 2018). Pednekar and Peterson (2018) utilize the same definition of a longer than one mile radius while also adding in that if more than 33% of residents within a census tract have to travel the full distance of one mile, that census tract is considered a pharmacy desert. The authors consider a pharmacy desert a location where geographic access to a pharmacy or pharmacy services are lacking or scarce. In addition to using a one-mile radius, Pednekar and Peterson (2018) assess pharmacy deserts using hot spot analysis. A hot spot analysis identifies areas of clustering of what is being analyzed, in this instance pharmacy deserts. Using hot spot analysis and their definition of a pharmacy desert, they find that every county in Pennsylvania includes at least one census tract that meets their definition of a pharmacy desert.

Qato et al. (2014) study pharmacy access in Chicago, along with characteristics of populations with poor access to pharmacies. They define a pharmacy desert using population income levels and physical access to the nearest pharmacy. Their two-part define requires that first, at least 20% of a census tract's residents have a household income below federal poverty level, and second, that more than 33% of residents within a census tract are more than a mile from the nearest pharmacy or more than 33% of residents are considered "low vehicle access" (Qato et al. 2014). Finding a percentage range to determine whether a tract is considered to have low vehicle ownership or to be considered low income is important to the terminology of a pharmacy desert. Not only do the residents within pharmacy deserts have a lack of access to the pharmacy locations and their services, but these locations also have to provide for more residents than those within locations of adequate pharmacy availability. Qato et al. (2014) find that segregated Black communities, low-income communities, and federally designated Medically Underserved Areas (MUAs) disproportionately include more pharmacy deserts in their communities. They suggest that policies regarding prescription access should not only focus on insurance or prescription prices but also incorporate pharmacies more in locations of pharmacy deserts and MUAs.

2.1.2. Pharmacy Closure

All pharmacy locations, including independent, grocery, chain, or even hospital pharmacies, can open and close locations and change their services over periods of time similar to other retail type stores and chain locations. Loss of pharmacy locations could turn a community or location which already had poor availability to pharmacy locations and services to a location or community with no availability. Guadamuz et al. (2020) assess the closing of pharmacy locations in the US from 2009 to 2015. They find that the risk of closures in urban areas is significantly higher than in suburban or rural areas. The risk of closure for urban and non-urban locations is higher for independent pharmacies. Low income, uninsured, and publicly insured residents and their communities are at high risk for closures as well. These risks are signs that show the community could become a pharmacy desert if the trends of pharmacy closures continue.

2.1.3. Insurance Access

Pharmacy closures can be caused by a variety of reasons including funding, reimbursement costs for Medicare, and sales. Klepser et al. (2011) study whether closures in pharmacy locations are related to the implementation of Medicare Part D. Implementation of Medicare Part D allows for the lowering of reimbursement rates for pharmacies which affected the sales of medications and profits of pharmacies. These lowered reimbursement rates affect independent pharmacies the most and show that before Medicare Part D, there was a steady increase of locations, after the implementation of this Medicare plan, there was a significant decrease in the number of independent locations.

2.1.4. Medication Access

Pharmacies in some states within the US provide behind-the-counter medications which are open to the public and do not require a prescription for purchase. Some of these medications are emergency contraceptives, Narcan, insulin, Pseudoephedrine, syringes, and Schedule V cough syrups. Each of these drugs may be purchased without a prescription because each is used in an emergency and the availability of pharmacist consultation minimizes the risk in taking these drugs incorrectly (Pray and Pray 2011). In some states, non-prescription behind-the-counter drugs including Pseudoephedrine products and syringes require the patient to present a government-issued ID before sale.

Foster et al. (2006) survey 426 women via 25 independent pharmacies in California. California was chosen because it was one of only eight states at the time which provided emergency contraceptives without a prescription. The goal was to tell if there were any boundaries to accessing emergency contraceptives and how the women found out about receiving these emergency contraceptives from their community pharmacies (Foster et al. 2006). The study finds that over 80% of those surveyed thought it was very important to be able to have access to these contraceptives and that speaking to a pharmacist was also very helpful. Being able to access these behind the counter medications without a prescription could decrease the time between the patient receiving the medication. Some drugs are life threatening if taken improperly, and others have short efficacy periods, such as emergency contraceptives which are only effective within 72 hours after unprotected intercourse or failure of birth control, hence the need for these medications without requirement of prescription (Weismiller 2004). Pharmacies providing these medications are also more convenient for those who need them with the amenities provided such as longer hours and drive thru access.

2.2. Spatial Accessibility to Healthcare Services and Facilities

Geographic information-based analysis methods (i.e., cluster/hot spot, provider to population, etc.) are useful ways of determining pharmacy access and pharmacy deserts when analyzing the pharmacy locations spatially. Some of these analyses, which can be used to determine and present pharmacy deserts, include Euclidean distance, two-step floating catchment area, three-step floating catchment area, and more. Each of these different analysis methods could be more beneficial depending on what outcome is needed.

2.2.1. Methods

When determining spatial accessibility to healthcare facilities and resources, geographic information analysis methods are prominent in providing this information. Provider-to-population ratio provides a ratio which details whether an area is considered a shortage of healthcare providers or resources based on the population size of the area and the number of physicians in the area. This ratio does not, however, account for the actual interaction between specific providers and individuals in the population, making them a rough estimate of shortage areas. Ouma et al. (2021) applies the provider-to-population ratio to accessibility to Ugandan healthcare facilities and presents the disparities between the areas with lack of provider service and the already drawn administrative boundaries. For the purposes of the study herein, applying a provider-to-population ratio across the study area of the entire US would not be beneficial. With patients crossing health districts at a small scale, as in Ouma et al. (2021) the ratio may be minimally skewed, however, with a large-scale study area, this method would not be best for producing accurate results. Some patients who suffer from severe diseases are willing to travel to other states or across the country to receive treatment. Using provider-to-population ratio across the nation would affect the outcome of the ratio being that populations as a whole might not use the providers in their areas due to various circumstances, including health insurance network definitions.

A gravity model is a model used to predict behaviors in an analysis such as volume of the flow of goods, for example provider to population flow. A two-step floating catchment area (2SFCA) analysis is a version of a gravity model which measures spatial accessibility. The 2SFCA first assesses physician availability to its population, then added in are the population values, supplies and the area in which the physician would be providing their services. The ratios of these interactions are summed while travel time and physician demand (Luo and Wang 2003). While the provider-to-population ratio does not account for a patient potentially going to a provider outside of their health district, utilizing this method within a 2SFCA analysis can increase the trustworthiness of the resulted values. Rekha et al. (2017) assign a spatial accessibility value when combining the provider-to-population ratio into the 2SFCA.

The various different versions of the floating catchment area methods are best for smaller study areas and projects with extended time and resources. This project incorporates a national-level study area and applying these methods to this large study area would require more time and resources than were available during the time of this project.

Using a Euclidean distance within a method finds the straight-line distance between two points. Euclidean distances can be used to find spatial accessibility to healthcare facilities by finding the nearest location to a neighborhood or household. This method does not, however, account for the road network nor any travel barriers (Ouma et al. 2021). This method also does not account for the curvature of the earth which is best when the study area is smaller and does not reach a wide distance. Applying a Euclidean distance measure to an analysis applied to very long distance is not accurate because it does not account for how the earth curves and assumes a flat surface. There may be errors in results of using this method because the distance may be shorter or longer depending on geographic barriers within the area (Jagadeesan and Wirtz 2021). However, Euclidean distance is a relatively faster measurement in a GIS than a network analysis using a road network. For this project, which covers the entire nation but measures many relatively short distances, using the Euclidean distance measurement rather than distance along a road network is much more feasible and offers adequate accuracy for the estimates required herein.

A fourth method to determine spatial accessibility to healthcare facilities involves finding clusters of healthcare locations, socioeconomic factors which affect accessibility to these locations, or even clusters of areas with minimal or adequate access to these healthcare facilities. Hot spot analysis is used to define areas of high or low values for a given topic, for example pharmacy access. Pednekar and Peterson (2018) use hot spot analysis to determine where the areas of high concentrations of pharmacy deserts are and the racial/ethnic groups present at these clustered locations along with what type of pharmacy, chain or independent, are most prevalent as well. They found that rural areas of predominately White populations are more likely to be pharmacy deserts. This hot spot analysis method is useful to show where there is a lack of pharmacy locations and who are affected, however, to determine pharmacy access across the entire nation, this method would not be best. Spatial access includes variables other than pharmacy placement and the population surrounding these locations, not only distance to these healthcare locations but also the socioeconomic factors present (i.e., vehicle availability, income, etc.) that could affect a patient's access to their local healthcare facility.

Oliveira, Singletary, and Lu (2021) study pharmacy location distribution in Georgia by using cluster analyses. Their hot spot analysis showed a cluster of pharmacy locations in and surrounding the state capital, Atlanta. This method provides an accurate representation of where pharmacy locations may be needed and where there are already enough to service a community. However, because as mentioned previously, the other factors of accessibility are not implemented in these methods which would not be best for a spatial access study such as this one.

2.3. Urbanicity

Rural-Urban Commuting Area (RUCA) Codes are used to define metropolitan and micropolitan areas by urbanization, population density, and commuting. RUCA codes consist of primary and secondary codes as shown in Table 1. Primary codes refer to the primary commuting share of the location meaning, in a metropolitan area, when divided into smaller sections, these smaller sections have a majority of one of the primary code designations. Secondary codes are subdivisions of the primary codes which is where the classifications may overlap for the areas and the second largest commuting share. The designation of the categorizing of a census tract is done using these codes by US Department of Agriculture. Code one of the primary RUCA codes relate roughly to metropolitan core areas, or urban areas, codes two through nine consist of locations where there were high commuting areas within a small-town core or “nonmetropolitan adjacent” codes, or suburban areas, and code 10 being the rural areas (U.S. Department of Agriculture 2020). After studying the location of these designations overlayed on a base map of the US, many locations which fell into codes two through nine were found to be more rural than suburban. This led to the determination of what this project would use to categorize the census tracts into urban, suburban, and rural areas.

Table 1: Primary and Secondary RUCA codes from the US Department of Agriculture. (U.S. Department of Agriculture 2020)

Code	Classification
1	Metropolitan, primary urbanized area
1.0 1.1	No additional code Secondary flow (30%-50%) to larger urban area
2	Metropolitan, high commuting (>30%) to an urbanized area
2.0 2.1	No additional code secondary flow (30%-50%) to larger urban area
3	Metropolitan, low commuting (10%-30%) to an urbanized area
3.0	No additional code
4	Micropolitan area, primary flow within large urban cluster
4.0 4.1	No additional code Secondary flow (30%-50%) to an urbanized area
5	Micropolitan area, high commuting (>30%) to large urban cluster
5.0 5.1	No additional code Secondary code (30%-50%) to an urbanized area
6	Micropolitan area, low commuting (10%-30%) to large urban cluster
6.0	No additional code
7	Small town, primary flow within small urban cluster
7.0 7.1 7.2	No additional code Secondary flow (30%-50%) to an urbanized area Secondary flow (30%-50%) to a large urban cluster
8	Small town, high commuting (>39%) to small urban cluster
8.0 8.1 8.2	No additional code Secondary flow (30%-50%) to an urbanized area Secondary flow (30%-50%) to a large urban cluster
9	Small town, low commuting (10%-30%) to small urban cluster
9.0	No additional code
10	Rural areas, primary flow to tracts outside urban area or urban cluster
10.0 10.1 10.2 10.3	No additional code Secondary flow (30%-50%) to an urbanized area Secondary flow (30%-50%) to a large urban cluster Secondary flow (30%-50%) to a small urban cluster
99	Not coded: zero population, no rural-urban identifier

The shortage area designation within this project is done on the census tract level which caused the need to determine which tracts are considered urban, suburban, and rural. For the use of this project, it was determined that population density measures were best to apply classifications of urbanicity more correctly to the census tracts for shortage area designation using the formula:

$$\frac{Total\ Population\ of\ Block\ Group}{Total\ Square\ Miles\ of\ Block\ Group} = Population\ Density$$

These population density measures, as shown in Table 2, used the total population and total square miles of each census block group. With this new measure of urbanicity, a population of over 3000 per square mile were considered urban, block groups with populations from 1000-3000 per square mile were considered suburban, and block groups with a population less than 1000 per square mile were considered rural. The census tracts urbanicity is then decided based on the majority urbanicity at the block group level.

Table 2: Population Density examples for a few selected census tracts

FIPS	Total Population	Population Density (Per Sq. Mile)	Area (Sq. Mile)
1001020100	1993	525.7633	3.790678953
1001020200	1959	1525.639	1.284052281
1001020300	3507	1698.004	2.06536594
1001020400	3878	1573.236	2.464982849
1001020500	10596	2405.455	4.404987977
1001020600	3668	1181.366	3.104880795
1001020700	3586	414.4332	8.652782175
1001020801	3196	66.60838	47.98194586
1001020802	11142	151.2318	73.6750039
1001020900	6143	54.34644	113.0340866
1001021000	2527	16.91777	149.369526

2.4. MUAs and CMS

MUAs are government-recognized areas which have a shortage of medical professionals. Medical professionals can include doctor, nurses, and pharmacists. Hospitals or health clinics in these locations can apply to be a Federally Qualified Health Center which can receive increased Medicare reimbursements (Health Professional Shortage Area - HPSA Acumen, n.d.). MUAs can include areas as small as a group of counties to an area as large as an entire country (Heath Resources and Services Administration 2021). Within this study, MUAs are compared to the locations of shortage areas to determine if there is a correlation between higher travel distances to pharmacies and locations of shortage of medical professionals.

CMS have distance thresholds that Medicare Part D sponsors must adhere by establishing pharmacy networks with enough conveniently located retail pharmacies to ensure sufficient access to its beneficiaries. A pharmacy network is a group of pharmacies which have a contract with an insurance plan. Those who are enrolled in that insurance plan can receive reduced prices for their prescriptions at those pharmacies which are included in the contract. Medicare part D is an insurance plan in which the beneficiary pays an insurance carrier a premium to receive reduced copays on prescriptions. Medicare Part D, like other insurance plans, requires a deductible and initial coverage copay until a certain amount is reached. Unfortunately, within the Part D plan there is a coverage gap which is implemented once the initial coverage is reached. This coverage gap requires the patient to pay 25% of the retail price of all medications until the out-of-pocket limit is reached (Boomer Benefits 2011). Medicare Part D beneficiaries living in the sponsor's service area should live certain distances from a retail pharmacy that participates in the sponsor's network depending on urbanicity of the area. For urban areas, on average, 90% of the beneficiaries in the sponsor's service areas should live within two miles from a retail pharmacy that participates in the sponsor's network. For suburban areas, on average 90% of the beneficiaries should live within five miles from a retail pharmacy that participates in the sponsor's network. For Rural areas, on average, 70% of the beneficiaries should live within

15 miles from a retail pharmacy that participates in the sponsor's network (Department of Health and Human Services and CMS 2008).

The distances that CMS considers reasonable distances for their Medicare part d beneficiaries to travel to the nearest pharmacy are what are being applied to create CMS shortage areas. In this project, the distances of 2 miles for urban, 5 miles for suburban and 15 miles for rural tracts are what are considered the thresholds for what is considered a census tract a shortage area or not for CMS. This is not to be confused with the shortage areas designations that CMS has created within their own projects and analyses.

2.5. Web Maps and Applications

Web mapping was introduced in the early 1990s with a website that provided an interactive map for the user with characteristics much like the current web maps but with much slower speeds and less manipulations. The Xerox Palo Alto Research Center initiated a web mapping movement with their Map Viewer which had minimal manipulation by the user other than zooming and adjusting the visibility of rivers and borders (Haklay, Singleton, and Parker 2008). With the era of technology in 1993, when this Map Viewer was implemented, navigating through the map included delays for the user. The speed of the Map Viewer tool would be prevalent for the next decade with web mapping technologies. With the development of web mapping increasing, locations and directions were brought to the forefront with the implementation of Multimap.com, MapQuest, StreetMap, Yahoo Maps, and others. At the time of implementation, these websites incurred limitations for the user because the sites could only provide pre-loaded information. Bt 2005, internet GIS had become more refined, however the limitations prevented the expansion and growth of these maps (Haklay, Singleton, and Parker 2008). The complexity of using these web maps was still present because when these technologies were introduced, internet services were not as advanced as they are now. These web mapping sites and creators would become increasingly more advanced and intricate as time went on.

Web mapping provides different user manipulation depending on the type of service indicated for the client (Adnan, Singleton, and Longley 2010). With thin client architecture, majority of the processing is done on the side of the processor which allows the client to take requests of the mapping tool and receive HTML responces (Agrawal and Gupta 2017). This type of architecture does not utilize the client as much as it could and results in a limitation in functionality of the server being that any request made by the client, including zooming, is done through the server. With thick client architecture, the client has more ability to processes with plug-ins and can reduce the utilization of the processors side. With the client having more abilities, this could be beneficial if there are connection issues with the server. A hybrid architecture of these two include data related tasks done by the processor and user interaction tasks done by the client (Agrawal and Gupta 2017).

A benefit of web maps includes information being updated in real time and no need to create a paper or stagnant map. An example of this is being able to show real time changes in an event like an election. With the advantage of the 'refresh' button, users are able to receive information as it is uploaded (Neumann 2017). Digital or web mapping allows an unexperienced user to create a map using something as simple as an excel worksheet into an Esri online map (Totman 2012). Another advantage of web mapping is having the ability to alter the privacy of the map. These maps, through Esri's online mapping software, can be closed off to only allow certain members of your organization or be made open to the public. Lastly, an aspect of web mapping that may not be available on paper maps is the ability to place oneself in the first person view of the map. If zoomed in far enough on a web map, the user can reach the street level, such as in Google Maps, you can travel down a street at eye level.

With web mapping, creation involves multiple layers of data along with the availability of zooming in and out to different extents. Designing a web map allows for a more flexible focus area because of the ability to update the map and allows the user to decide where to zoom in or out. The ability to turn on and off certain data layers can allow the user to adjust the hierarchy of the map and benefit their specific goals of the map. With designing a static or paper map, there is usually one goal in mind and it is portrayed on the map. One aspect of the map, whether that be the streets, localities, businesses, or other attractions, is the focus. Visual hierarchy is also important in static maps because showing streets rather than attractions can move the user's attention in the wrong way depending on the focus of the map (Code 2020).

Web mapping has advanced significantly since its implementation and has become an application for purposes other than just providing a visualization of an area. Interactive web maps allow the user to manipulate a map to benefit their needs. Different from a static web map, interactive maps allow for the changing of features on the map, scales, base maps, and adjust features. This type of mapping is beneficial to this study by allowing the user to navigate the map to any location within the country to visualize the local pharmacy shortage areas.

Chapter 3 Data Sources and Methods

This chapter provides the step-by-step methodology of the analysis used to find pharmacy shortage areas across the study area if the US and the creation of the web mapping application. The data's origin, preparation, and use are provided here as well. An explanation of the approach used is described here as well as how a shortage area is defined.

3.1. Overview of Methods

The methodology approach used in this study follows the workflow as shown in Figure 1. The process starts at the census block group level and expands to the national level. Each census block group is given a centroid point which is then used to find the nearest pharmacy location for both 2018 and 2020. After determining the urbanicity of each tract (i.e., urban, rural, or suburban) by using a population density measure, each category of urbanicity is given a threshold of what considers the tracts a shortage area or not based on the majority at the block group level.

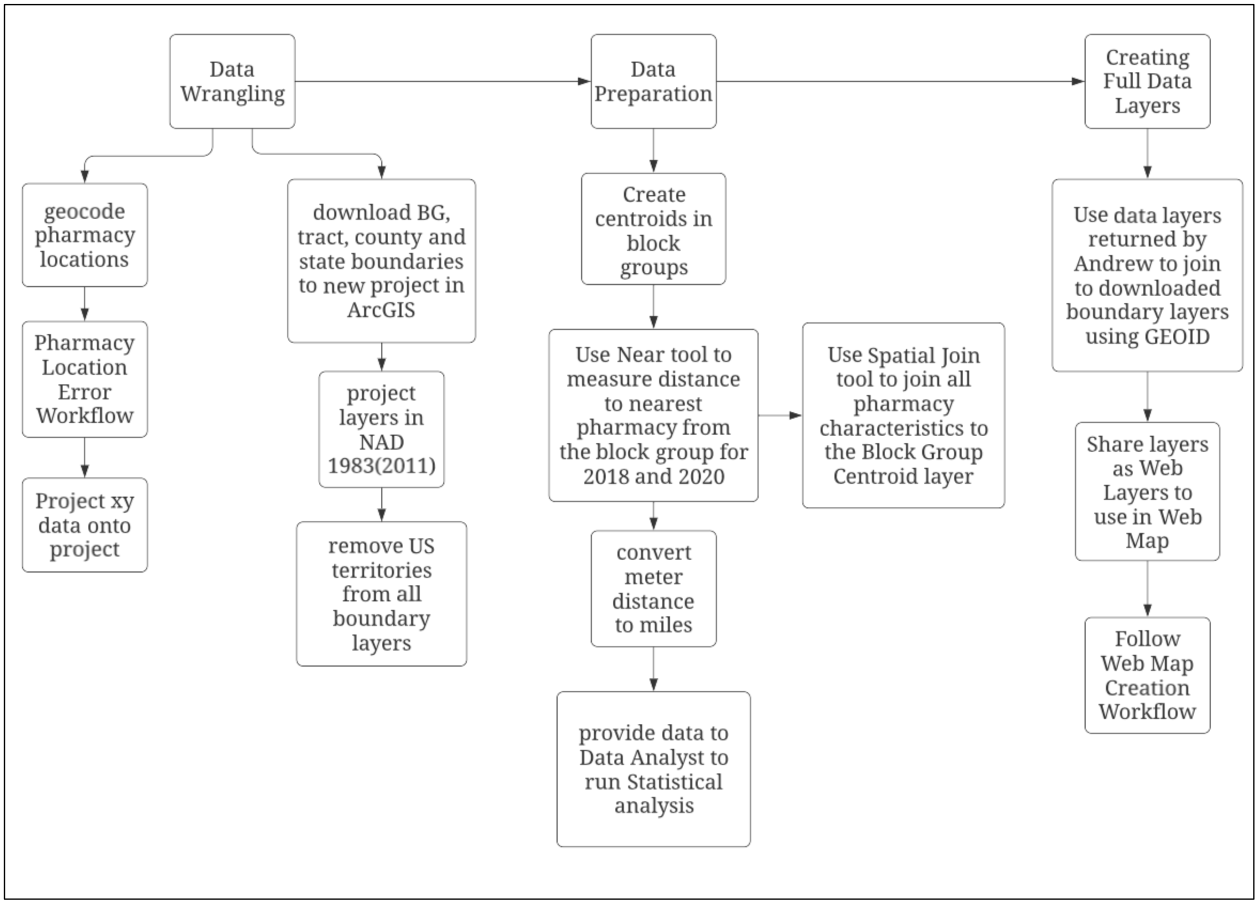

Figure 1:Workflow diagram of the full methodology process of analysis

Once each tract is given an urbanicity category, based on the distance to nearest pharmacy of the block group centroid, if more than 500 residents or more than 33% of the tract's population has a travel distance to the nearest pharmacy over a certain threshold, the tract is considered a pharmacy shortage area. For urban tracts, over 500 residents or over 33% of the population traveling a distance of over 1 mile, for suburban a distance over 2 miles, and for rural a distance of over 10 miles considers the tract a shortage area for pharmacies. Disregarding the urbanicity, if a tract is considered low vehicle (i.e., over 100 households within a tract do not own a vehicle) or low income (i.e., over 20% of the population lives under the poverty line (<100% FPL)) it is considered a shortage area if the distance for over 500 residents or over 33%

of the population has a travel distance farther than ½ mile. Data from the Health Resources and Services Administration identify areas designated as Medically Underserved Areas (MUAs). MUA is a federal designation used to identify a shortage of primary health care services for residents within a geographic area. These include areas that have too few primary care providers, high infant mortality, high poverty or high elderly population.

Once each tract is given a shortage area or a non-shortage area designation, statistics are then produced at the block group, tract, county, and state levels to provide analysis of what groups of demographics are affected by a shortage of pharmacies. Finally, a web map is created using all data layers including pharmacy point data, block group, tract, county, and state level boundaries.

3.2. Data

The different data layers used in this project included table data, polygon data and point data as shown in Table 3. The pharmacy data used in this study came from the National Council for Prescription Drug Programs dataQ®. This data was received with attributes including pharmacy name, type (independent or chain), address, amenities (drive thru access, walk in clinic, etc.), year opened, and provider ID. This data was received for the years 2018 and 2020. The data within dataQ® is updated weekly and monthly for up-to-date changes with ownership or closings. The pharmacy data used was from July of both years 2018 and 2020.

Table 3: Data types and sources that are used in this project

Dataset	Type	Source
Pharmacy Locations	Table	National Council for Prescription Drug Programs dataQ®
Census Block Group Boundary Layer	Polygon	U.S. Census Bureau TIGER/LINE Shapefiles
Census Tracts	Polygon	U.S. Census Bureau TIGER/LINE® Shapefiles
County Boundary Layer	Polygon	U.S. Census Bureau TIGER/LINE® Shapefiles
State Boundary Layer	Polygon	U.S. Census Bureau TIGER/LINE® Shapefiles
American Community Survey (ACS) demographic and economic characteristics	Table	American Community Survey (2015-2019)
MUAs	Table	Health Resources and Services Administration

The boundary layers for the census block groups, tracts, counties and states are shapefiles which were retrieved from TIGER/Line® shapefiles from the Census Bureau for 2019. The TIGER/Line® data boundaries do not include demographic information, but information of the size and contents of the boundaries such as amount of land or water within the boundaries. The census boundaries are chosen every 10 years, however, the TIGER/Line® files through the census bureau are updated yearly to adjust for legal boundaries as of January 1, 2019 (TIGER/Line® Shapefiles). This data was downloaded in shapefile form.

The data used to populate the boundary layers came from the American Community Survey (ACS) 5-year estimates from 2015-2019. These estimates were used to provide population data and demographic information at all levels. Some of the attributes in these layers included number of and percentage of population with Medicare, Medicaid or public insurance, no insurance, percent Black, White, or Latinx, and other demographic and population data. The attributes used in this project are shown in Table 4 below.

Table 4: Attributes used from the ACS 2015-2019 estimates in this project

Attribute	Type	Use
Population	Number	Population of the block group, tract, county or state
100% FPL	Percentage	Percent of population making an income under 100% of the federal poverty level
150% FPL	Percentage	Percent of population making an income under 150% of the federal poverty level
Percent White, Black, Latinx	Percentage	Percent of the population that is White, Black, or Latinx
Percent no vehicle	Percentage	Percent of population without a vehicle
Percent no insurance	Percentage	Percent of population without insurance
Median Household Income	Number	Median household income at the tract level
Percent Medicare, Medicaid	Percentage	Percent of population with Medicare or Medicaid
Medically Underserved Areas	Number	Number of tracts that re considered MUAs
Population Over 65	Number	Population of persons 65 years and older

The NAD 1983 (2011) datum and geographic coordinate system are used throughout this study for all data layers. This choice provides reasonably accurate geodesic distances over a larger study area, as opposed to a projected coordinate system which would be beneficial for smaller-sized study areas. A North American datum and coordinate system accounts for the curvature of the earth in this region.

3.3. Data Preparation

The data used within this project required data wrangling and management before being used to run analysis. The pharmacy data required the most manipulation with its geographic location with 68,590 locations. Once the addresses of the pharmacy data were provided from the NCPDP, the file of these pharmacy locations for both 2018 and 2020 were downloaded into a new project in ArcGIS Pro. The locations were then geocoded using the geocoder tool in ArcGIS Pro and a coordinate was provided for each of these locations. Through the geocoding process, 102 locations in the 2018 and 105 in the 2020 datasets were found unmatched. The locations which were not found automatically using the geocoding tool and were placed manually by typing in the address into Google Maps and comparing the base map from Google Maps to the base map in ArcGIS Pro.

Some locations of pharmacies may have closed in one location and reopened in another location with the same provider ID and were counted as one pharmacy. Some pharmacy locations contained an address spelling error, for example one year the street address being spelled “moffett” and the next “mofat”. Lastly, some pharmacy locations had the same address but different coordinates for both years. To account for these errors in the data, Data Analyst Andrew Shooshtari applied a workflow to combat the errors in the changes over the years for the pharmacy locations as shown below in Figure 2.

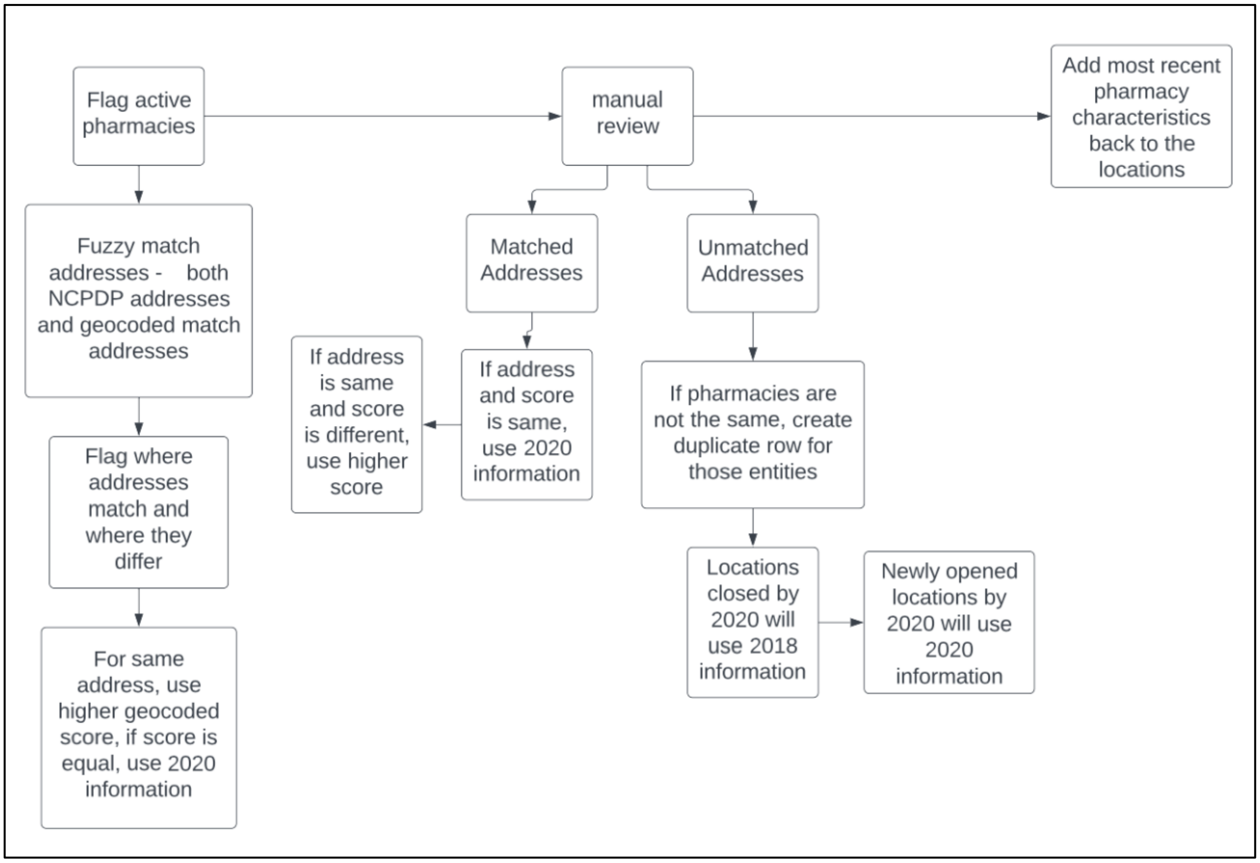

Figure 2: Workflow used to remove geographic errors from pharmacy locations (Source: Data Analyst, Andrew Shooshtari).

Once the pharmacy locations were run through the error removal workflow, the file was returned and placed back into ArcGIS Pro. The pharmacy location data layer was then downloaded and displayed in the project using the Display XY Data tool for each year.

The block group, tract, county, and state layers were then downloaded from the TIGER/Line® Shapefile website into the ArcGIS project with the pharmacy data. Centroids of the block group layer were created by adding two fields to the attribute table labeled 'x' and 'y' and were made to be a 'double' field type. Both the 'x' and 'y' fields were used in the Create Geometry tool as the x-coordinate of centroid and y-coordinate of centroid respectively. The coordinate system was set to NAD 1983 (2011). Once the coordinates were placed for the centroid of each block group, the attribute table of the block groups was then exported as a table in the same project content pane. Once exported, the XY data was displayed into the NAD 1983 (2011) coordinate system to place point data of the centroid points.

The centroid points of the block group were used in the near tool to find the nearest geodesic pharmacy point location. Using this tool added a field to the attribute table which contained the distance in meters to the nearest pharmacy location. This field was then converted to miles by adding an additional field and calculating the field in meters by dividing the original distance field by 1,609. This was applied to both the 2018 and 2020 pharmacy point data locations.

The centroid point data layer, now with additional fields of the distance to nearest pharmacy for 2018 and 2020, was run through the Spatial Join tool to join the pharmacy characteristics including name, amenities, status, etc. This was done twice, separately, to join the GEOID of the block group to its nearest pharmacy information and the results were separate. The results of each of the spatial join layers were then joined back to the original block group centroid layer using the Join Field tool. This tool allowed for the joining of specific fields to reduce duplication of fields and add all pharmacy characteristics of each location nearest to each block group by its GEOID.

The Geographic Identifiers or GEOIDs are numbers that range from two to 12 digits that are assigned to a specific block group, tract, county, or state. As shown in Table 5, at the block group level there are 12 digits which includes two digits for the state, five digits for the county, six digits for the tracts, and one for the block group. In the United States, every state has their own specific GEOID or FIPS code. Within each state the counties have an assigned three-digit number which when paired with the state digits leads to that specific county. The same is done at the tract and block group level adding six and one digit respectfully (US Census Bureau 2021).

Table 5: GEOID Structure for Geographic Areas. (Source: Census.gov)

Area Type	Geoid Structure	Number of Digits	Example Geographic Area	Example GEOID
State	State	2	Texas	48
County	State+County	2+3=5	Harris County, TX	48201
County Subdivision	State+County+Cousub	2+3+5=10	Pasadena CCD, Harris County, TX	4820192975
Places	State+Place	2+5=7	Houston, TX	4835000
Census Tract	State+County+Tract	2+3+6=11	Census Tract 2231 in Harris County, TX	48201223100
Block Group	State+County+Tract+Block Group	2+3+6+1=12	Block Group 1 in Census Tract 2231 in Harris County, TX	482012231001
Block*	State+County+Tract+Block	2+3+6+4=15 (Note – some blocks also contain a one character suffix (A, B, C, etc.)	Block 1050 in Census Tract 2231 in Harris County, TX	482012231001050
Congressional District (113th Congress)	State+Cd	2+2=4	Connecticut District 2	0902
State Legislative District (Upper Chamber)	State+Sldu	2+3=5	Connecticut State Senate District 33	09033
State Legislative District (Lower Chamber)	State+Sldl	2+3=5	Connecticut State House District 147	09147
ZCTA **	Zcta	5	Suitland, MD ZCTA	20746

* The block group code is not included in the census block GEOID code because the first digit of a census block code represents the block group code.

** ZIP Code Tabulation Areas (ZCTAs) are generalized areal representations of United States Postal Service (USPS) ZIP Code service areas.

The file of information with each block groups nearest pharmacy and all of the characteristics of that pharmacy for years 2018 and 2020 were then sent to Data Analyst Andrew Shooshtari. An API pull of the census data were done using an R package called ‘tidycensus’ with R Studio by Post-Doctoral Research Fellow, Jenny Guadamuz. The summary statistics provided from the demographic and population information were done through SAS 9.4 by Data Analyst Andrew Shooshtari.

3.4. Analysis of Shortage Areas

For this project, the definition of a ‘pharmacy shortage area’ is a census tract in which more than 500 residents or over 33% of the tract’s population have to travel a distance farther than one mile for urban classified census tracts, two miles for suburban classified tracts, and ten miles for rural classified tracts. The urbanicity of the tracts is based off of the population density found at the block group level. Tracts with a population density of over 3000 persons per square mile are considered urban, 1000-3000 persons per square mile are considered suburban and less than 1000 persons per square mile are considered rural tracts. Tracts which are defined as low income and low vehicle ownership are considered shortage areas if the distance to the nearest pharmacy is longer than one-half mile. A tract is considered low vehicle if more than 100 households in the tract do not have vehicles. A tract is considered low income if 20% of the population within the tract lives below the poverty line (<100%FPL). It should be noted that although this data used ACS data, not full decennial census information, margins of error for the population and social attributes within the ACS data were not put into consideration.

Only retail pharmacies were used within this study. Of those retail pharmacies, only pharmacies with a provider type of 1 and a dispenser class of 1, 2 or 5 were used. Pharmacies with a provider type of 1 are community or retail pharmacies, and pharmacies with a dispenser class of 1 are independent pharmacies defined as one to three pharmacies with common ownership, dispenser class 2 are chain pharmacies defined as a group of four or more pharmacies under common ownership, dispenser class 5 are franchise pharmacies defined as independently owned pharmacies with a single franchise agreement with a franchisor where the franchisee receives training and support from the franchisor. (Research Data Assistance Center (ResDAC) 2013)

To create a centroid for the census block group layer, two fields labeled 'x' and 'y' were added to the attribute table of the block group layer within ArcGIS pro. The Create Geometry tool was used to populate the 'x' and 'y' fields with coordinates of the centroid point of each block group. For each block group and census tract, Data Analyst Andrew Shooshtari joined together ACS population and demographic information. Using SAS 9.4, Data Analyst Andrew Shooshtari produced the statistical results and merged to the GEOID of the tract and block group layers. This analysis was then taken back into ArcGIS Pro to build the web application.

Once all points were present for both years of pharmacy data, pharmacies with a provider type of 1 and a dispenser class of 1, 2, and 5 were separated and to be used for the rest of the analysis. These pharmacies were chosen to be separated to remove those pharmacies that are not open to the public. Removing those pharmacies which are not accessible to the public eliminates the possibility of a block groups nearest pharmacy not actually being able to be accessed by its residents. The centroid point of the block group was used in the "Near" tool to find the geodesic distance to the nearest pharmacy location for both 2018 and 2020 pharmacy locations.

The three levels of urbanicity used in this study are urban, suburban, and rural, with population density levels described above. With each tract having an urbanicity classification, thresholds are applied for an acceptable distance traveled by residents to the nearest pharmacy. If the closest distance to a pharmacy was greater than this distance threshold, the tract was considered to be a pharmacy shortage area for those who lived in these areas. For urban census tracts, any distance traveled to the nearest pharmacy farther than one mile is considered a shortage area, farther than two miles for suburban tracts and farther than 10 miles for rural tracts. For tracts considered low vehicle or low income, no matter the urbanicity, having to travel farther than a half mile to the nearest pharmacy labels that tract as a pharmacy shortage area. A tract is considered a shortage area if over 500 residents, or over 33% of a tract's residents, are within a shortage area based on the distances to nearest pharmacy at the block group level. This means that at the block group level, which is smaller regions than the census tracts, if over 33% of the populations within the block groups that have to travel farther than one mile for urban block groups, two for suburban and 10 for rural, at the tract level, the tract is considered a shortage area. An indicator for each tract was added to the attributes of the tract GEOID with a text of 'yes' or 'no' for tracts determined as pharmacy shortage areas or not, respectively.

Once the attributes for each layer, including statistical measures, were joined, and applied to the GEOID of the block group, tract, county, and state layers, these data were then transferred into an Excel file. The excel files were then placed within an ArcGIS Pro map project to join to the 2019 Census boundaries. Joining ACS population and demographic information to the census boundaries, multiple polygon files, allows for the geographic location of these GEOIDs to be placed amongst the study area. With each block group, tract, county, and state, once the ACS information is joined to the polygon boundary layers, these layers are then saved as web layers to be used in the web tool in ArcGIS Online.

3.5. Web Map Creation

Creating a web mapping application through ArcGIS online begins with creating an online map or a web map. The workflow of this creation is shown in Figure 3. This map includes the layers that can be visible within the application. The data layers which were managed and edited within ArcGIS Pro and shared to a web layer were added to the web map. These layers included block group, tract, county, and state boundaries. Within each boundary layer, each individual county, state, tract, or block group included its own data and statistical information. The tract layer was duplicated twice to represent the shortage areas in both 2018 and 2020 and to present the CMS thresholds for 2018 and 2020 as well. Once these data layers were added to the web map, the title of the fields which include the data were manipulated to provide a "plain word" description of each field. This step was one to make sure the pop-up window at each layer was understandable to the viewers of the application. For the state, county and tract levels, the statistical information includes some percentage results which require a percentage output. Some fields within these layers were presented as a decimal instead of a percentage. To fix this, the individual web layers were opened in the contents pane of the ArcGIS and each field presented as a decimal was multiplied by 100 using the "calculate field" tool. For the pop-up views, in the field editor, commas to separate thousands were turned on for all fields which weren't percentages. All fields with percentages were allowed two decimal places.

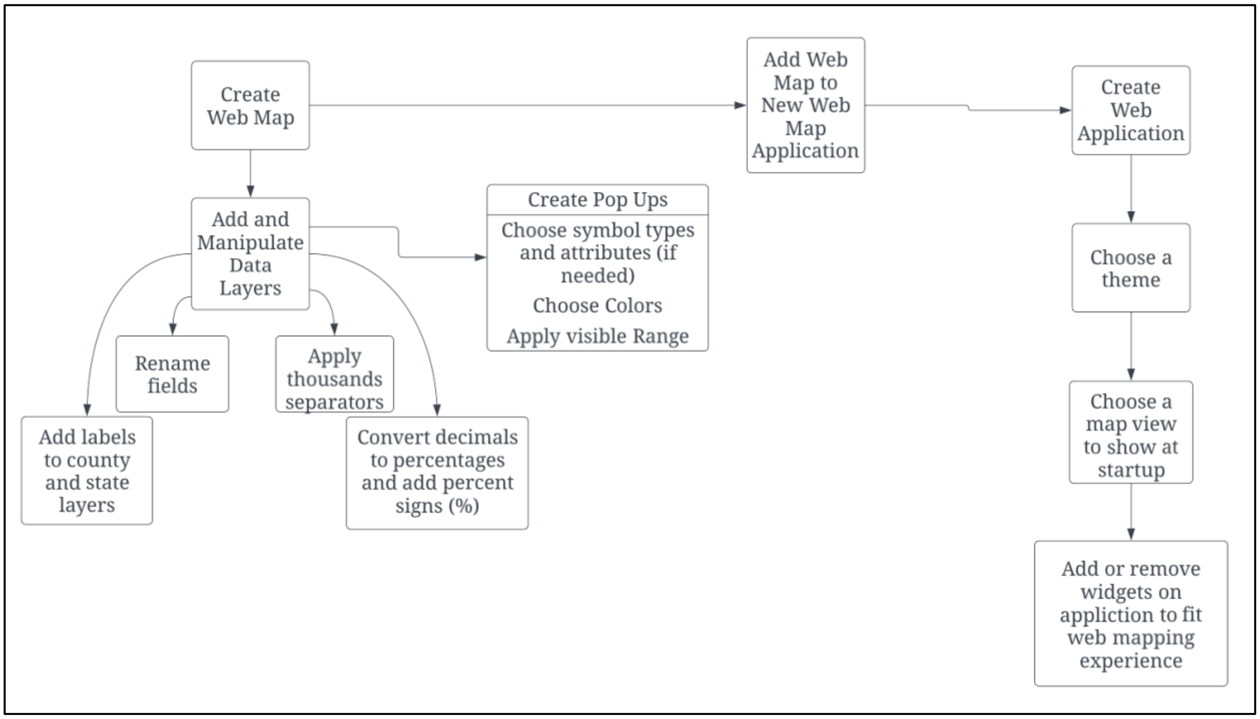

Figure 3: Workflow to Create Web Map and Web Mapping Application

To create the pop up for each data layer, the "enable pop ups" was turned on for all layers. The title was changed for each data layer depending on the data present. For the county layer was coded to provide the county name followed by "county". The state layer was given the state name as the title. For the tract layers, two were labeled as "Shortage Areas – 2020" and "Shortage Areas – 2018" to differentiate between the two separate years. The other two tract layers were labeled as "CMS Shortage Areas - 2018" and CMS Shortage Areas - 2020" to present what would be considered a shortage area for both years under the CMS thresholds applied to this project's methods for shortage area designation. The pharmacy layer was given the title of the type of pharmacy (chain or independent) to show what each point was. After the titles were chosen, each layer's pop-up fields were chosen for what was needed to be presented. The chosen fields were then organized from top to bottom of in the order of what should be shown first to last.

To present the data layers on the map, colors and styles were chosen. The tract layers were color coded by the attribute (or field) which provided the urbanicity and shortage status of each tract. Three colors were chosen for the six possible outputs of the urbanicity and shortage status. The shortage areas for each urbanicity type (urban, suburban, and rural) were all fully opaque for the color chosen. For the non-shortage areas of the three urbanicity types, the colors were put at 70% transparent to differentiate between shortage areas and non-shortage areas while still being able to tell the urbanicity of each tract. For the state layer, a single symbol type was used in order to have all states the same color. The labels for the states were enabled and the name field was used for the labels. This allowed for each state to have its name presented within its boundaries. The same was applied to the county layer as was done for the states layer. The block group layer was presented using a single symbol style without labels. A visible range was applied to the block group, state and county layers, this visible range allowed for the disappearance of one layer when zoomed in to a certain extent. This was done to reduce confusion of what layer was being presented and to allow for an easier flow of data visualization. For the pharmacy points, the layer was presented using unique symbols and the colors were chosen by attribute. The attribute (or field) chosen for the pharmacy layer was the status of the pharmacy, whether the pharmacy was active for 2018 and 2020, closed by 2020 or newly opened by 2020. This was done to provide a visual representations of which pharmacy locations have been created, closed or always active; red for closed, orange for newly opened, and blue for active throughout both years.

The next and final step in building the web mapping application is to create the actual application. Using the Create Web Map tool in ArcGIS online, the theme of Launch Pad was chosen because of the layout which seemed most appropriate for the data being presented. This theme provides the widgets to sit along the bottom, a search bar at the top, and the zoom near the top left. This layout allows for the data presented to be the main focus. after the theme was chosen, the map which was edited previously was added to the map. The widgets were chosen and the ones included were the legend, the layer list, and the swipe tool. Once these were all added, the application was saved and a run through was done to make sure everything was shown as it was supposed to.

Chapter 4 Results

This chapter presents the results of the analyses of the distribution of shortage areas nationally and the web mapping application in which they are displayed. It also shows how the application works and is used for the goal of this project.

4.1. Shortage Area Results

Census tracts were considered shortage areas if the distance to the nearest pharmacy for an urban tract is farther than one mile, for suburban tracts farther than two miles, for rural tracts farther than 10 miles, for low income and low vehicle tracts farther than one-half mile no matter the urbanicity of the tract. These distances as compared to CMSs reasonable travel distances, applied as shortage area designation distances, to the nearest pharmacy are shown in Table 6.

Table 6: Shortage Area Designation Distances for Census Tracts

	Urban	Suburban	Rural	Low Income and Low Vehicle
Current Project	>1 mile	>2 miles	>10 miles	>1/2 mile
CMS	>2 miles	>5 miles	>15 miles	N/A

In order to show the distribution of shortage areas and provide analysis on where these are mostly located, the web mapping application was manipulated to show many different analyses. The distribution of majority Black, White and Latinx populations across the nation and those that are living in a shortage area are also shown within the web map. A view of shortage area distribution by race is shown at the national level to show what populations are being affected most and where. This map also shows the comparison in the shortage area distribution in the project compared to the CMS distance thresholds. A census tract is considered to be predominately one race or ethnicity when one race or ethnicity represents over 50% of the total tract population, as shown in Table 7. For a tract to be considered diverse, not one race or ethnicity constitutes a majority. The percentages used in the categorization of majority White, Black or Latinx populations do not account for the margins of error in the ACS demographics data.

Table 7: Racial and Ethnic Composition of Census Tracts

Majority Black	>50% of the tract population is considered non-Hispanic Black
Majority White	>50% of the tract population is considered non-Hispanic White
Majority Latinx	>50% of the tract population is considered Hispanic
Diverse	No single race/ethnicity holds majority of the tract's population

On the home view of the web map, the distribution of pharmacy shortage areas is seen nationally by urbanicity. As shown in Figure 4, the web map shows the urban shortage areas in a darker pink, and the urban non-shortage areas in a lighter more transparent pink, the suburban shortage areas in a brown, and the suburban non-shortage areas a lighter more transparent brown, the rural shortage areas in green, and the rural non-shortage areas in a lighter more transparent green. The transparency is used to show where the different tracts are by urbanicity while also showing where the shortage areas are.

The pharmacy shortage areas cover a large portion of the United States when the distance thresholds are applied. With a large portion of the western half of the nation being considered rural areas, the shortage areas are very prominent. There are also spots within the large cities across the nation (Houston, Dallas, Chicago, Los Angeles), where the urban and suburban shortage areas are visible at the national level. It is easier to see the rural shortage areas being that the rural tracts are usually much larger than the urban tracts. Being able to see the urban and suburban shortage areas at the national level shows there is an abundance at those locations.

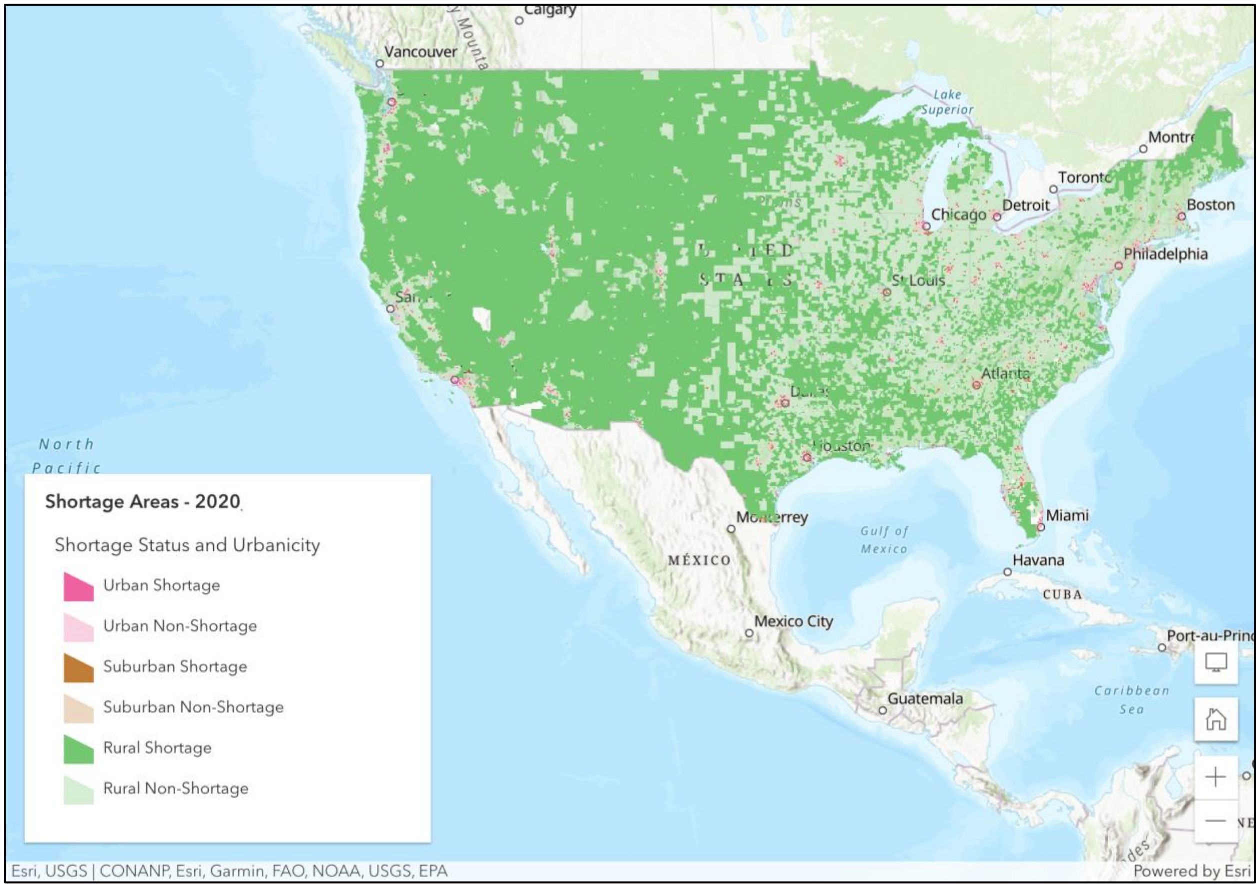

Figure 4:Web app showing the shortage area distribution nationally

Compared to the CMS distance thresholds, if applied as pharmacy shortage area designations, the presentation of shortage areas is significantly less. Within this project, as shown in Table 4, the distances to be considered a shortage area are a few miles less than compared to CMS distances for what is a reasonable distance to travel to a pharmacy. The CMS thresholds do not catch nearly as many shortage areas with what they consider a reasonable distance, as seen in Figure 5.

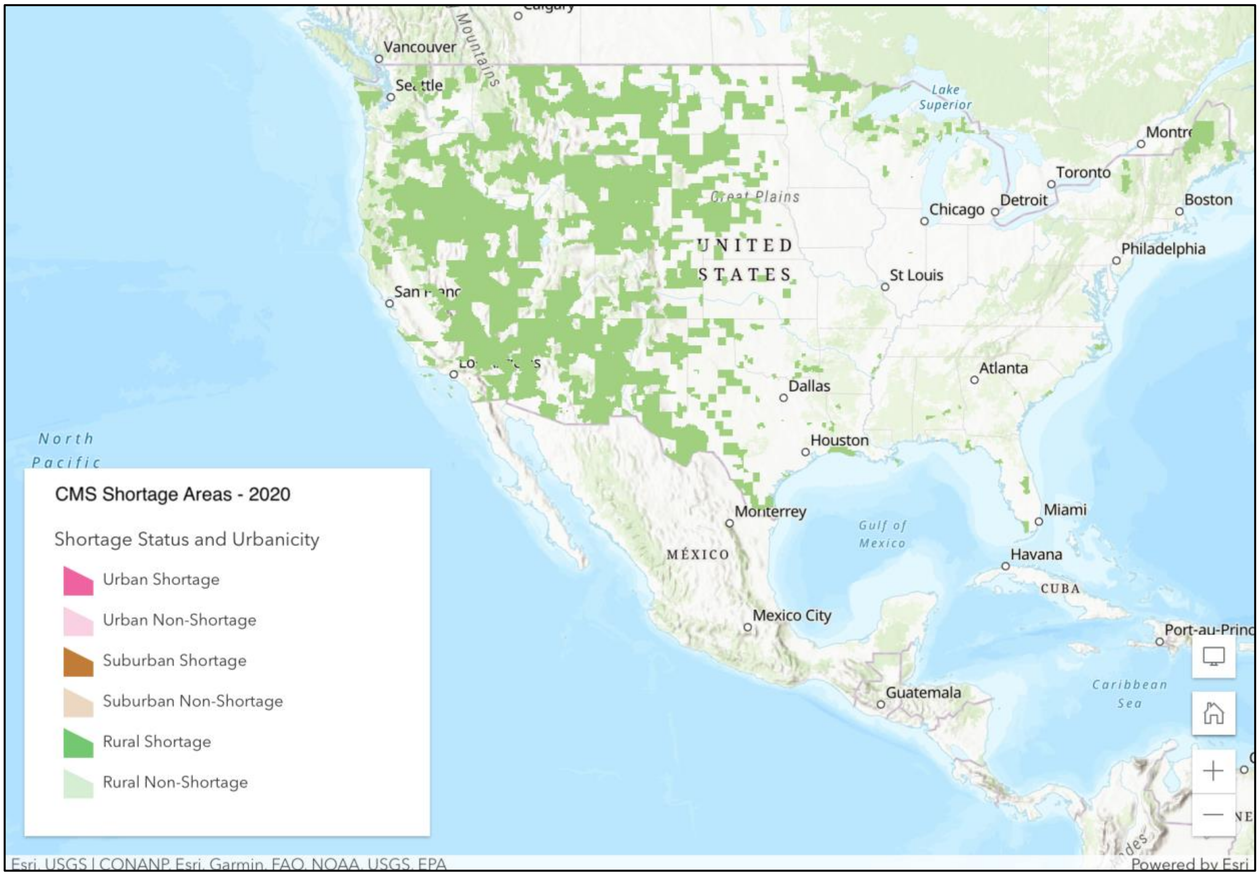

Figure 5: Shortage areas using CMS distances

The web map showing the CMS shortage areas show the distribution of rural shortage areas prominently, however, the suburban and urban shortage areas are not visible at the national view. There are significantly fewer shortage areas captured using CMS thresholds which shows that across the nation, majority of the population should not have an issue finding a pharmacy location near them. The main issue with the CMS thresholds is the assumption that urban, suburban, and rural populations are able to travel these distances without putting into account the fact that some of the population might not have transportation able to travel these distances. With the travel distance thresholds chosen for this project, low income and low vehicle tracts are considered and a shorter distance of one-half mile is applied.

The distribution of White, Black, and Latinx populations across the nation are shown in Figure 6 with the dark opaque colors portraying the shortage areas and light and transparent colors showing the non-shortage areas. Like the rural shortage areas in the home view of the web map, the distribution of White populations is very prominent as well. The rural areas in the western portion of the nation show predominately White populations and diverse populations that are considered shortage areas. Black populations living in a shortage area are more prevalent in the southeastern regions while the Latinx populations living in a shortage area are most prominent in the southwestern and western regions. The Black and Latinx populations as seen at the national view are more prominent and visible where there are shortage areas, as compared to the White populations where the visibility of shortage and non-shortage majority White areas are almost equally visible. The visual analysis shows that where there are Black and Latinx populations, these two groups are more likely to live in a shortage area than White populations. The difference between the White population living in a shortage area compared to the Black population living in a shortage area is much more prevalent than between the Black and Latinx populations.

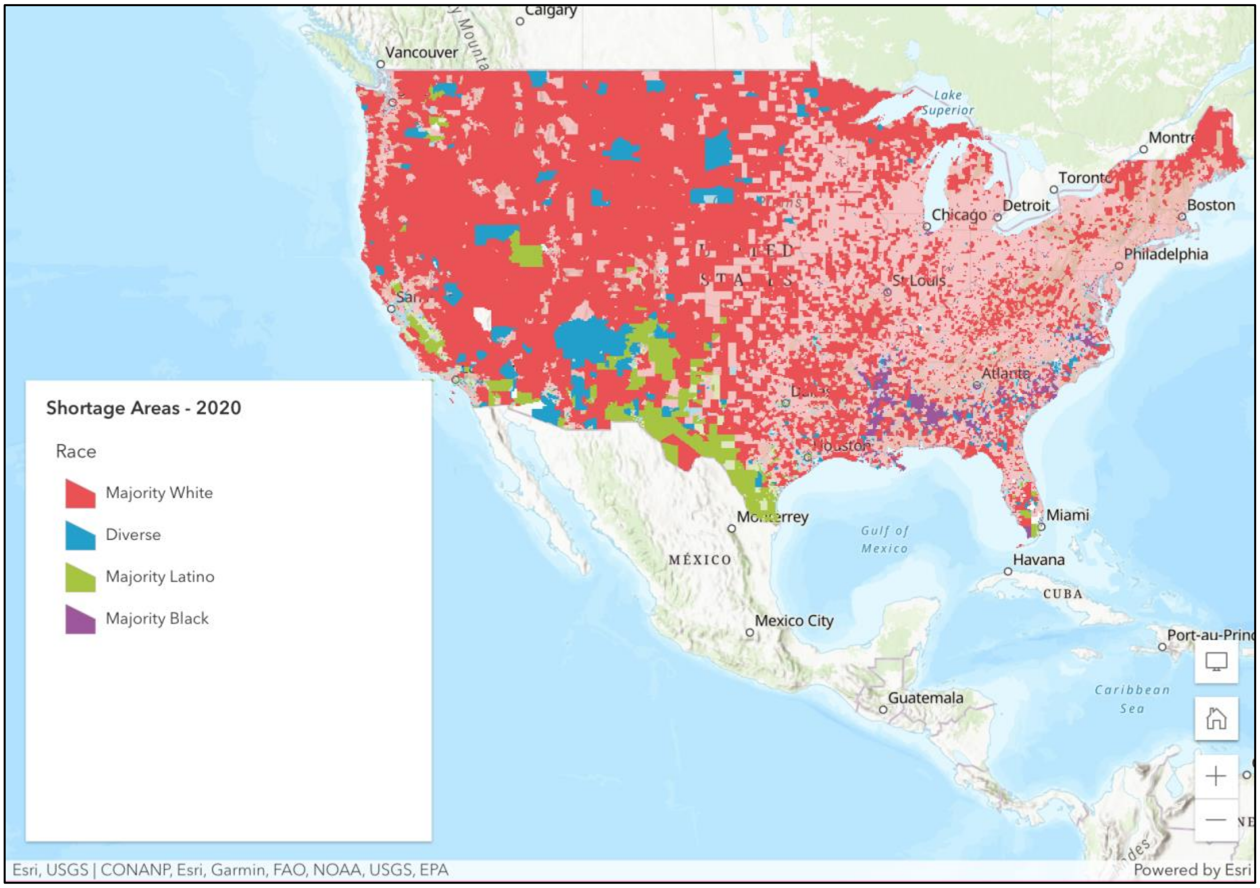

Figure 6: Distribution of shortage areas by majority race

The pharmacy locations as shown by status, opened by 2020, closed by 2020, and active both years are distributed in Figure 7. The layer below the pharmacy points show the shortage areas by urbanicity, as in Figure 4. The closed pharmacy locations are not all surrounded by newy opened locations and vice versa. This proves that some pharmacy shortage areas were due to having lost a pharmacy, while others were due to the pharmacy locations staying the same but the area maintained a distance longer than the distance threshold for its urbanicity. The distribution of pharmacy locations are shown to be heavily prominent in more populted areas causing the rural areas in the western areas of the United States to be considered shortage areas even with the creation of new pharmacies. The large city areas (Houston, Dallas, Chicago, Los Angeles, etc.) are the areas with the most closed and opened pharmacies. Plenty of the pharmacy locations which stayed active both 2018 nd 2020 were located in the areas that were considered non-shortage areas.

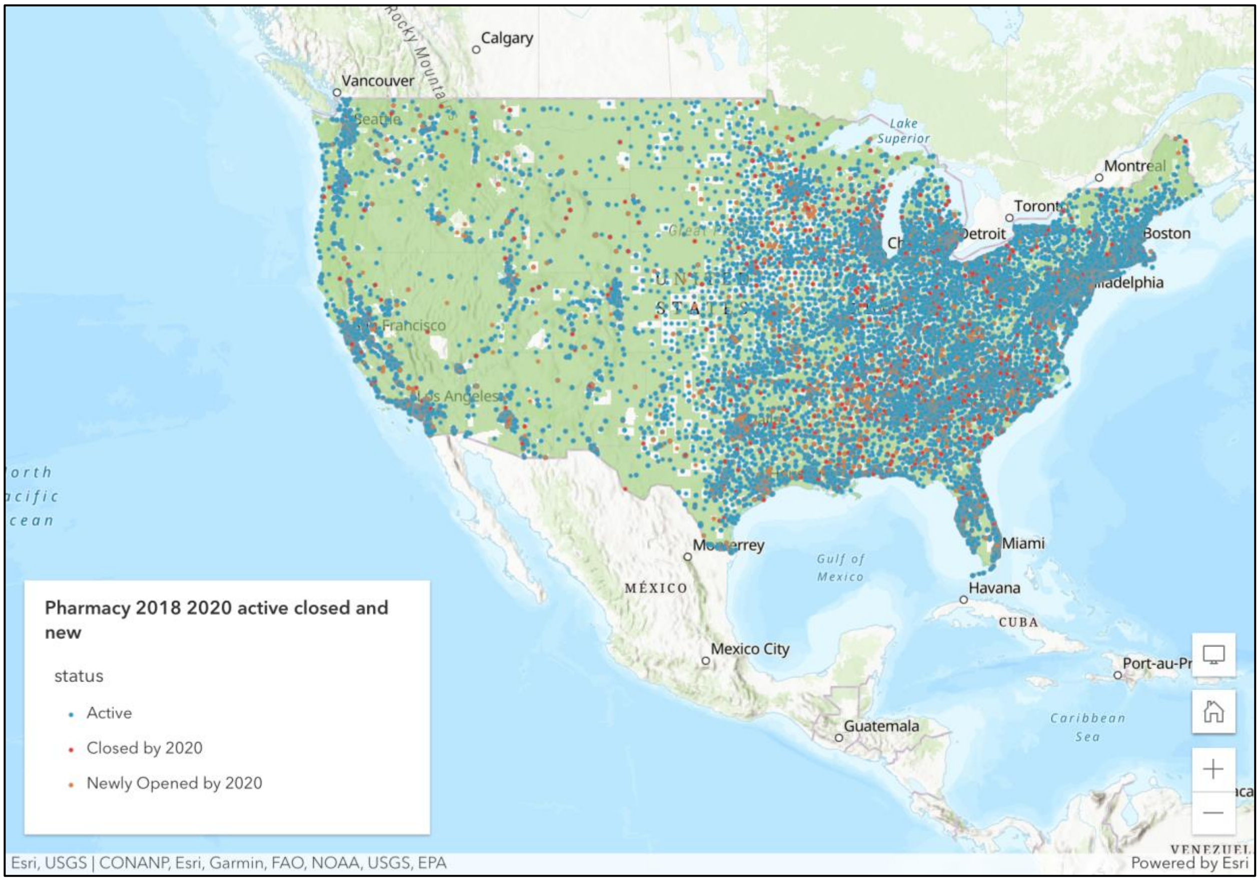

Figure 7: Pharmacy distribution by status

The pharmacy distribution by type, chain or independent, show the chain pharmacies heavily placed in the more urban areas, as shown in Figure 8. Throughout the rural areas in the western section of the United States contain more independent pharmacies than chain. When looking at the non shortage areas, the majority shown are independent pharmacies. Comparing the independent pharmacies most prevalent in the non-shortage areas, and the active pharmacies from figure 10being active, the assumption can be made that when an independent pharmacy is in a location where its residents can reach their locations reasonably, the pharmacy remains able to serve its customers for longer. This visualization means that a main factor of pharmacy longevity depends on its customer access.

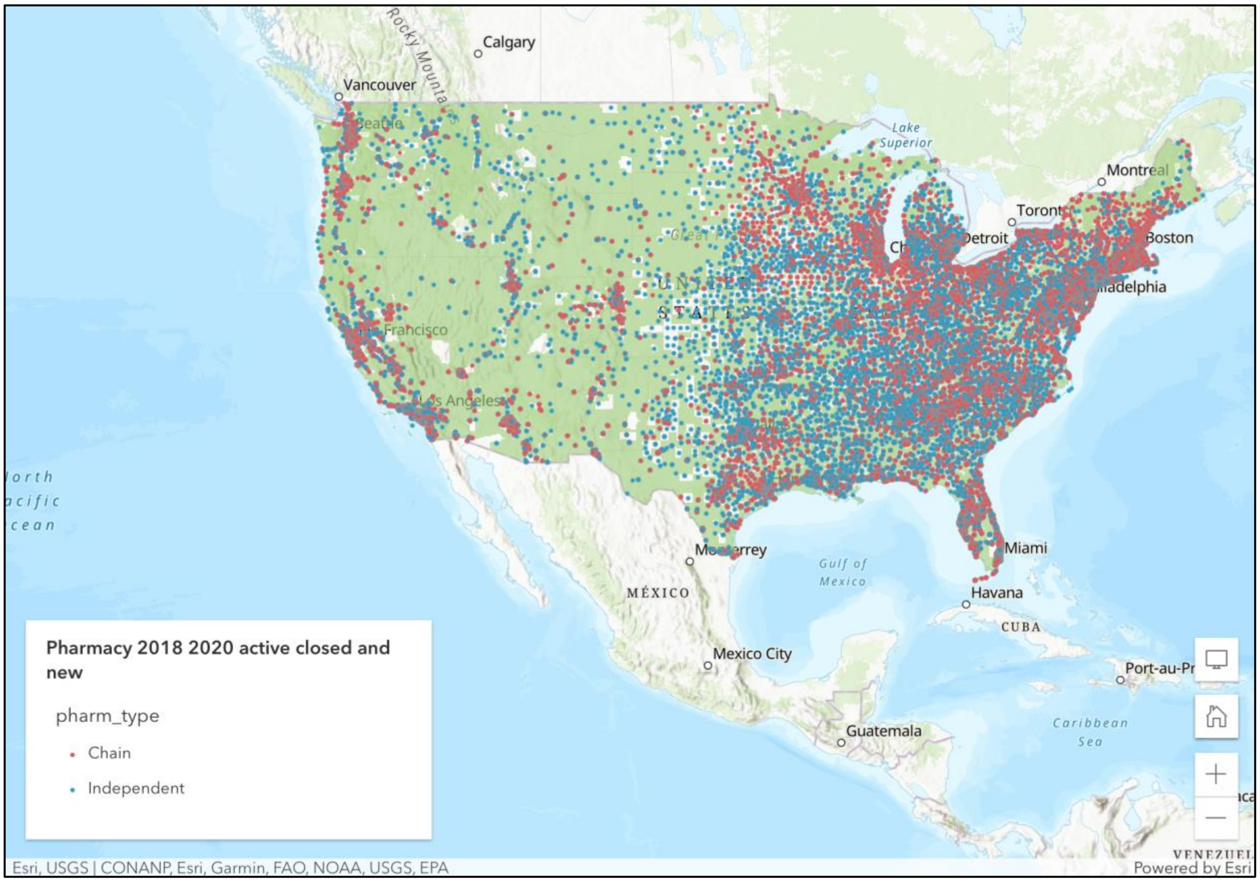

Figure 8: Distribution of pharmacy locations by type

4.2. Web Mapping Application

The web mapping application was created in ArcGIS online using data manipulated in ArcGIS Pro. This section provides an explanation of how the application works, the benefits of the tool and the data that is provided.

4.2.1. Web Map Dynamics

Opening the web mapping application, the user is able to visualize the study area. This web mapping application allows for the user to manipulate what layers are visible within the map, as shown in Figure 9 below, by checking and unchecking the different data layers. The layer that is the highest in the list is what is shown above all other layers when clicked on. If all layers are turned on at the same time, there may be only one or two layers visible to the layers because of a hierarchy within the layers. With the top layer being placed on top of the others and the lowest layer in the list underneath those before it.

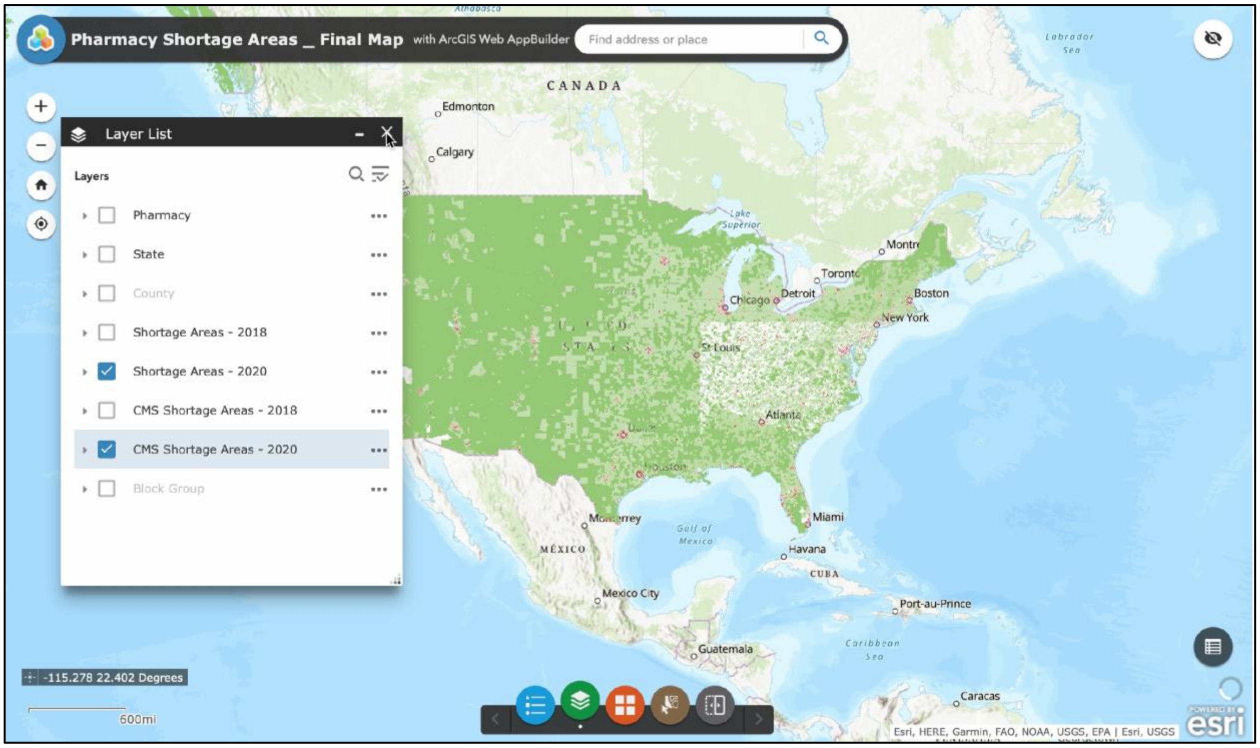

Figure 9: Web mapping application showing the layer list

By having the ability to turn on and off the data layers, the map can show exactly what the user wants to see and alter the goal of the map for each user. The widgets on the bottom of the map allow for the user to show the legend, change the base map, select a location to focus on, or use the swipe tool. The legend shows the different colors or shaped of each of the layers in order to differentiate what is being shown on the map. As seen in Figure 10, the legend shows the difference in colors between the shortage and non-shortage areas for each urbanicity type. With the pharmacy data layer, the legend will show the three different classes for a pharmacy and the assigned colors: active both 2018 and 2020 (blue), closed by 2020 (red), and newly opened by 2020 (orange).

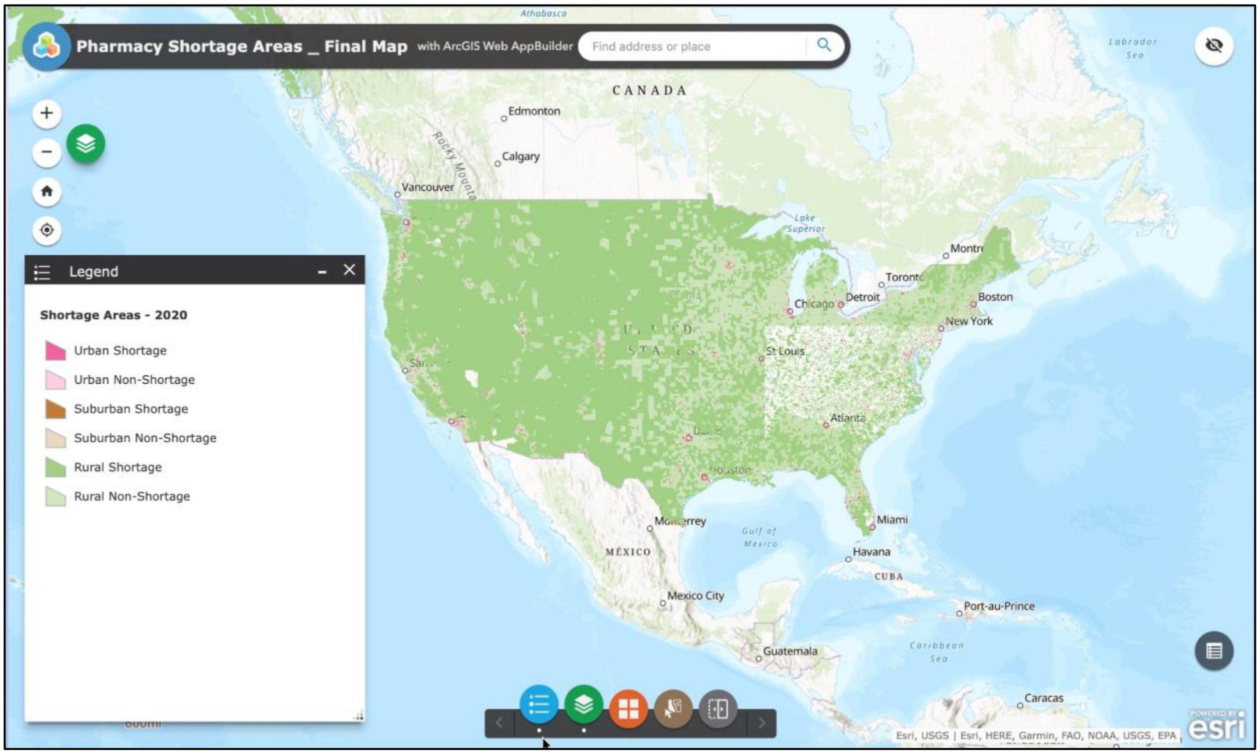

Figure 10: Web mapping application showing the legend and the home view of the study area

The zoom buttons on the top left of the map along with the home button allow the user to zoom to the specified level. The home button will allow the user to see the original view of the study area which is seen in Figure 11. At the home view the layers that would be viewable include the shortage area layers for 2018 and 2020, the CMS shortage area layers for 2018 and 2020, and the state layer.

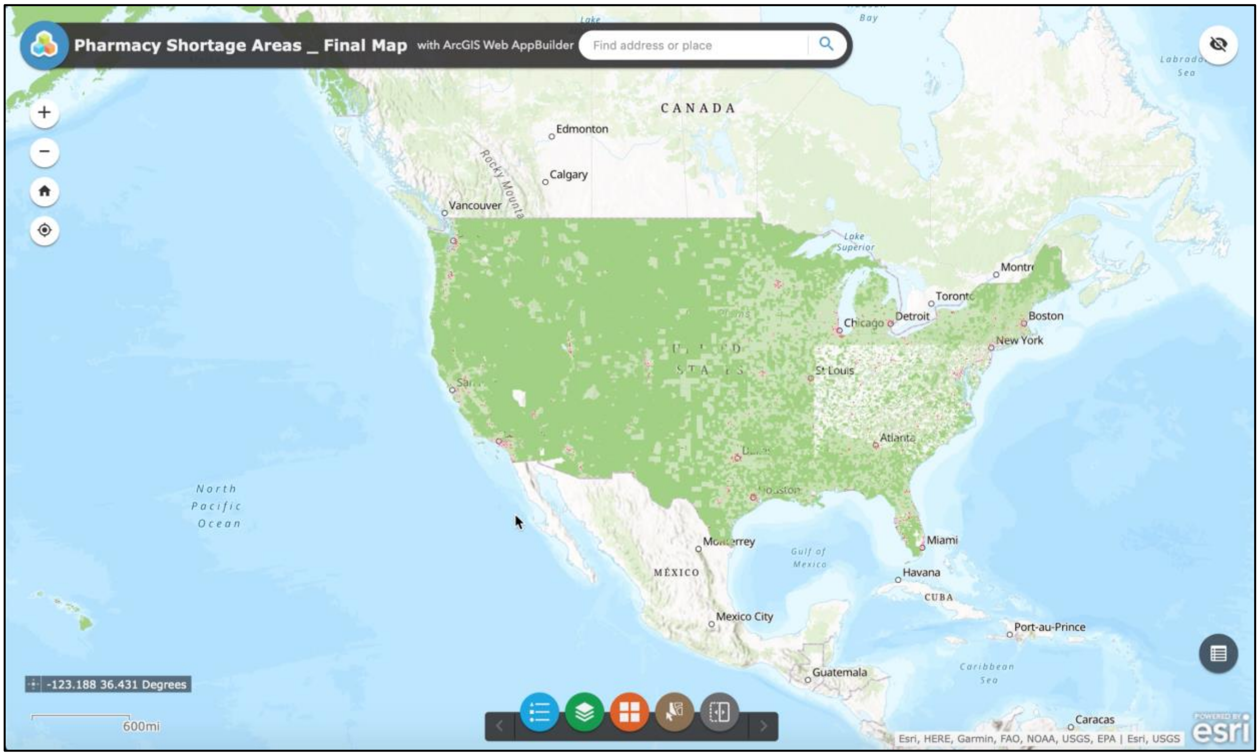

Figure 11: View after clicking the home button

4.2.1.1. State Level

At the state level, once a state is clicked, a pop up appears providing statistical information for that specific state. Some analyses shown include number of tracts, state population, number of shortage tracts for both 2018 and 2020, and other Medicare, Medicaid, and demographic statistics. A way of finding or zooming into a state could be done by typing in the state in the search bar at the top of the mapping application. This will allow you to click on the state, county, city, or even an address and zoom into the specific location. The chosen location will be outlined in a thin blue line to show the location chosen. Once clicking on the location, if there are layers turned on, the pop up will show an arrow in the top right corner to toggle between the different pop-up information for each layer at that location. Figure 12 below shows an example of the pop-up that would be shown at the state level in Illinois.

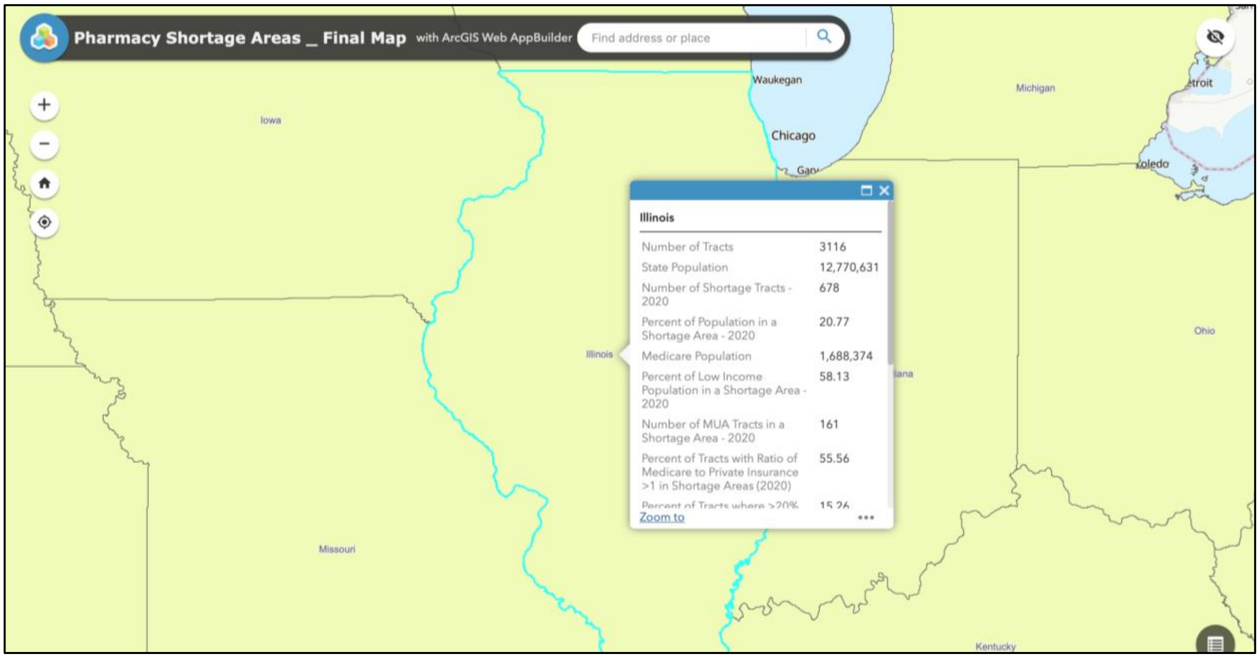

Figure 12: Web mapping application showing the pop up on a state.

4.2.1.2. County Level

At the county level, once zoomed in the state layer turns off and the county layer turns on, as shown in Figure 13. This is due to the visible range which was applied to these layers to provide a visual hierarchy within the map and to prevent over crowdedness within the map. The county layer pop-up provides a similar structure to the state pop-up. Once zoomed into the county layer, clicking on a county allows for the pop up to show. The statistical analysis provided in the county pop-ups include the name of the county, population, number of tracts, percentage of tracts in a shortage area for 2018 and 2020, the distribution of shortage areas by urbanicity, and pharmacy closing and opening percentages for the county.

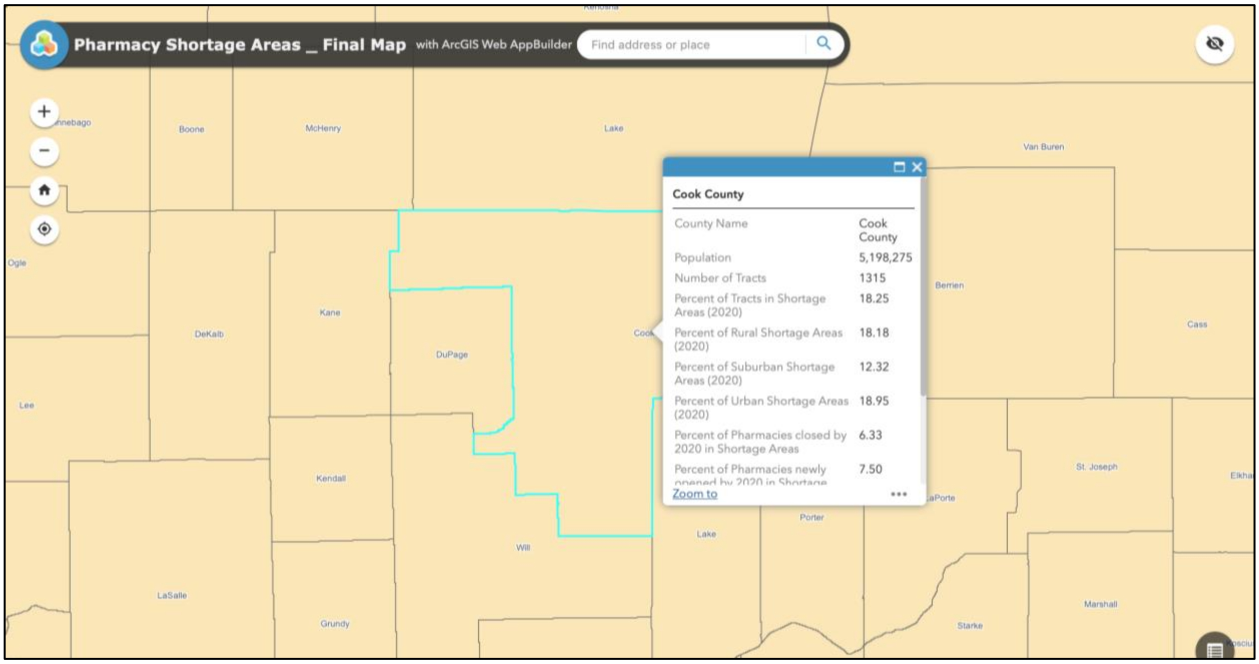

Figure 13: Web mapping application showing the county level and pop-up

4.2.1.3. Tract Level

When zoomed in to the tract level, the county layer is no longer visible. The tract layer is able to be seen for a wider visible range because some tracts are very small and require additional zooming. As shown in Figures 14 and 15, the pop-ups for the tract layers include the type of tract it is, whether or not it is a shortage area and its urbanicity, the majority race of the tract, Medicaid and Medicare percentages, percent with no insurance, population living in a shortage area and percent over the age of 65. The pop up also shows what the shortage status is for CMS thresholds for the selected tract. The tract level differentiates its urbanicity and shortage area status by color and transparency respectively. The darker or more vibrant the color shows a shortage area, the lighter and more transparent tracts are non-shortage areas with the pink color representing urban tracts, brown representing suburban tracts and green representing rural tracts. The difference in transparency is done to be able to see where the urban, suburban, and rural tracts are whether they are considered shortage areas or not. The thin blue line shows what tract is selected and what tract the pop-up is shown for.

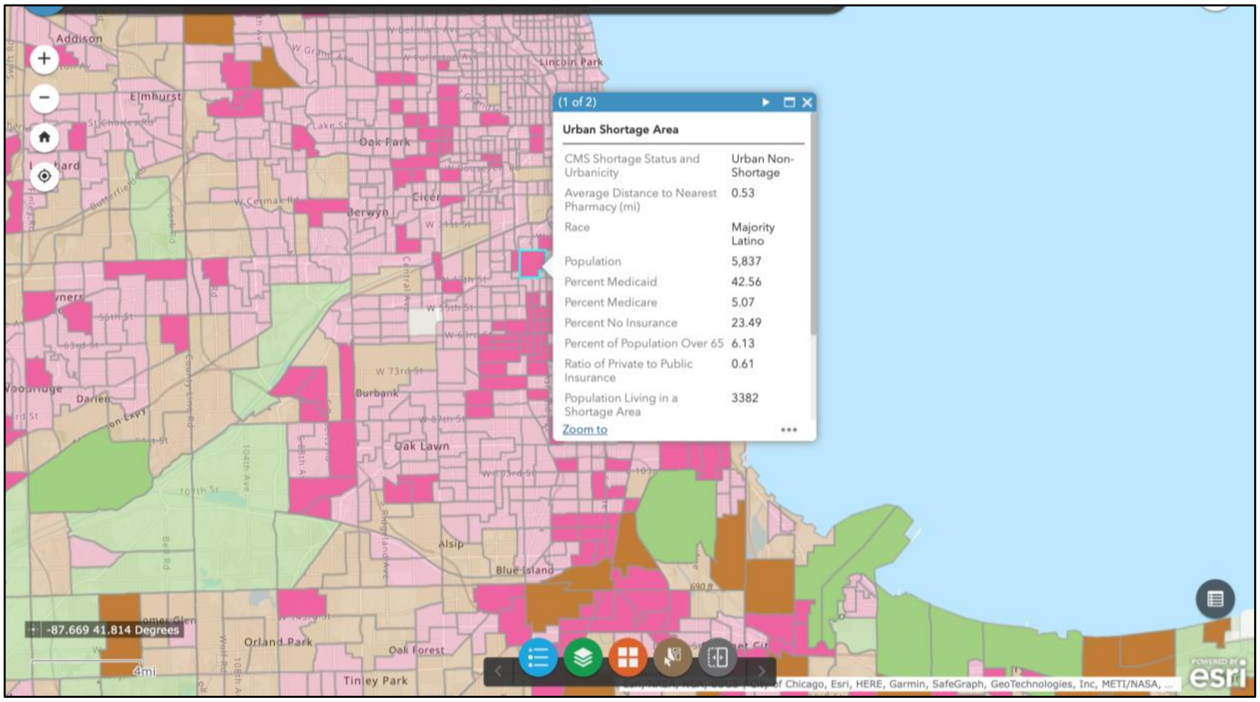

Figure 14: Web mapping tool showing tract layer and an urban shortage area pop-up.

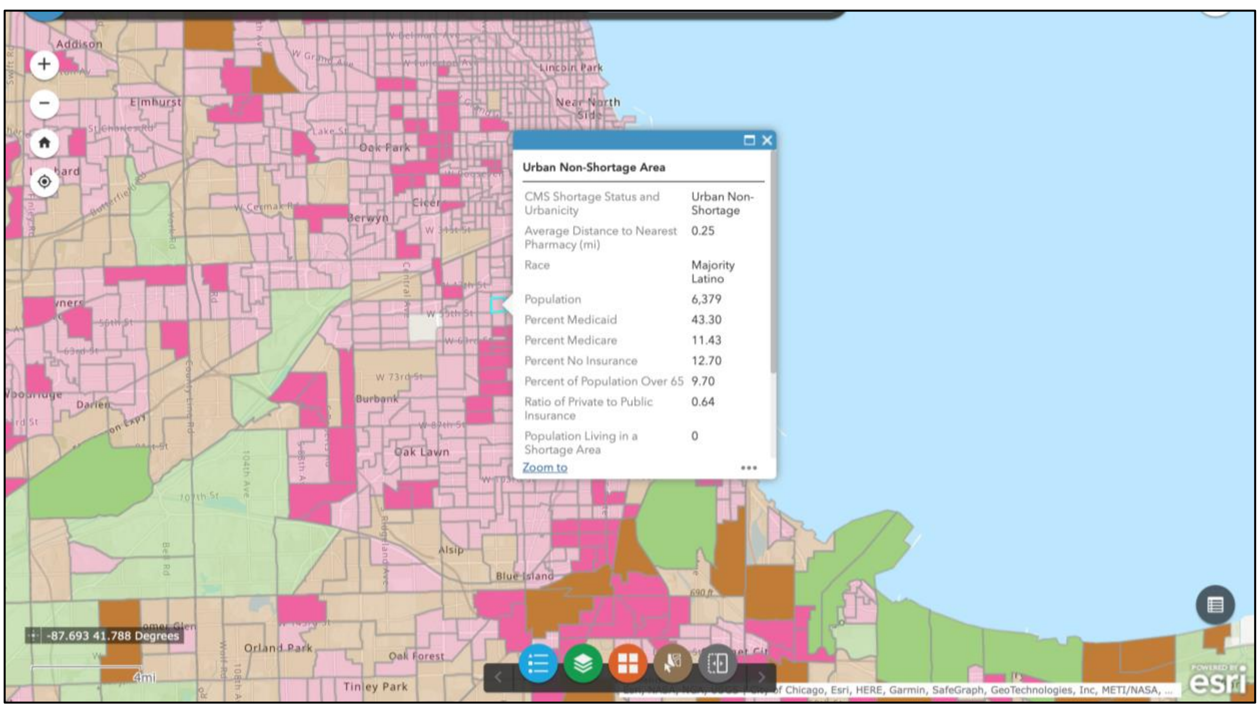

Figure 15: Web mapping tool showing tract layer and an urban non-shortage area pop-up.

4.2.1.4. Block Group Level

The block group level is visible once zoomed in past the tract level, shown in Figure 16. The block groups are smaller census designated sections within a census tract. Each of these block groups provides a pop-up as well when clicked on. These pop-ups provide the population, majority race, distance to nearest pharmacy for 2018 and 2020, and the type of pharmacy that is the nearest for each block group. The block group layer is not labeled but visualized by a solid color with a black outline.

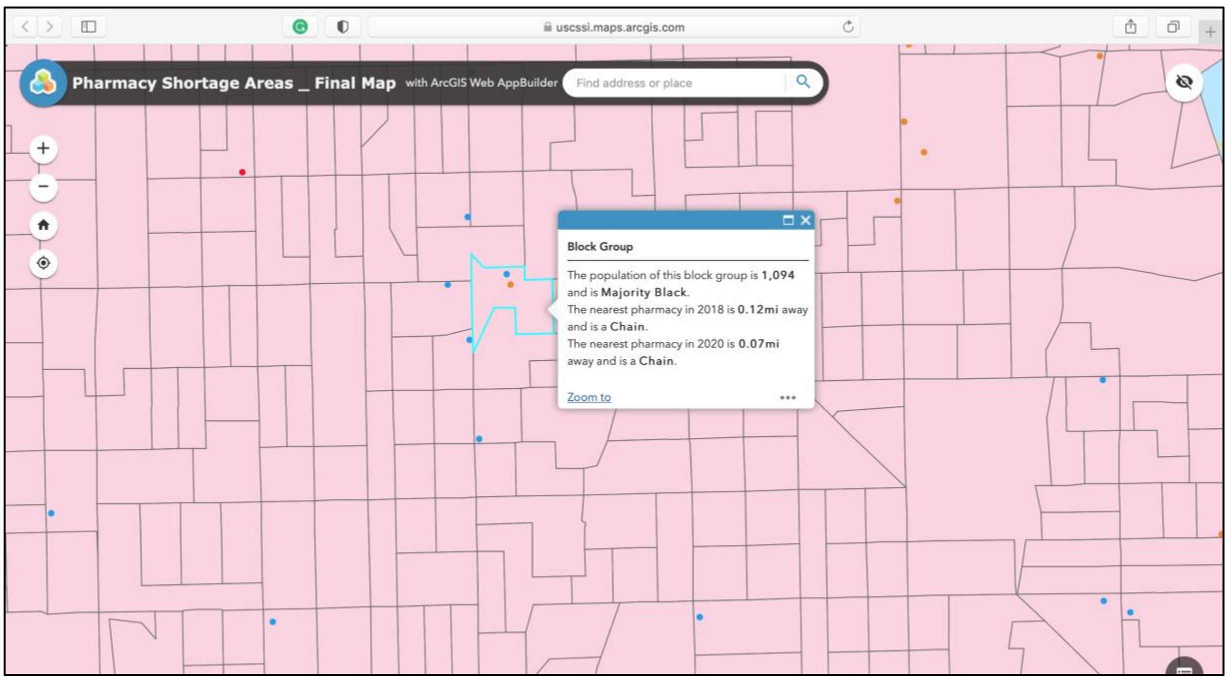

Figure 16: Web mapping application showing the block group pop-up

4.2.1.5. Pharmacy Layer

The pharmacy layer provides point data of the pharmacy locations across the United States. Each pharmacy location or point provides its own pop up as well as shown in Figures 17, 18, and 29. The pop-ups for the pharmacy layer include the type of pharmacy, its status, the county it is in, and the amenities of the pharmacy. The amenities included in each pop up for the pharmacies are drive up access, vaccine access, and if a walk-in clinic is available. The pharmacy points are color coded by its status, closed by 2020, newly opened by 2020, or active for both 2018 and 2020. The pop-ups for this level are activated when clicking on the individual points for each pharmacy. There is the ability to toggle between the pharmacy point layer pop-ups and other data layers if there are multiple layers turned on at once. If a block group boundary, for example, is clicked with the pharmacy layer on, the pop-up will provide the option to toggle between the block group's pop-up and the different pharmacy pop-ups which reside within the chosen block group.

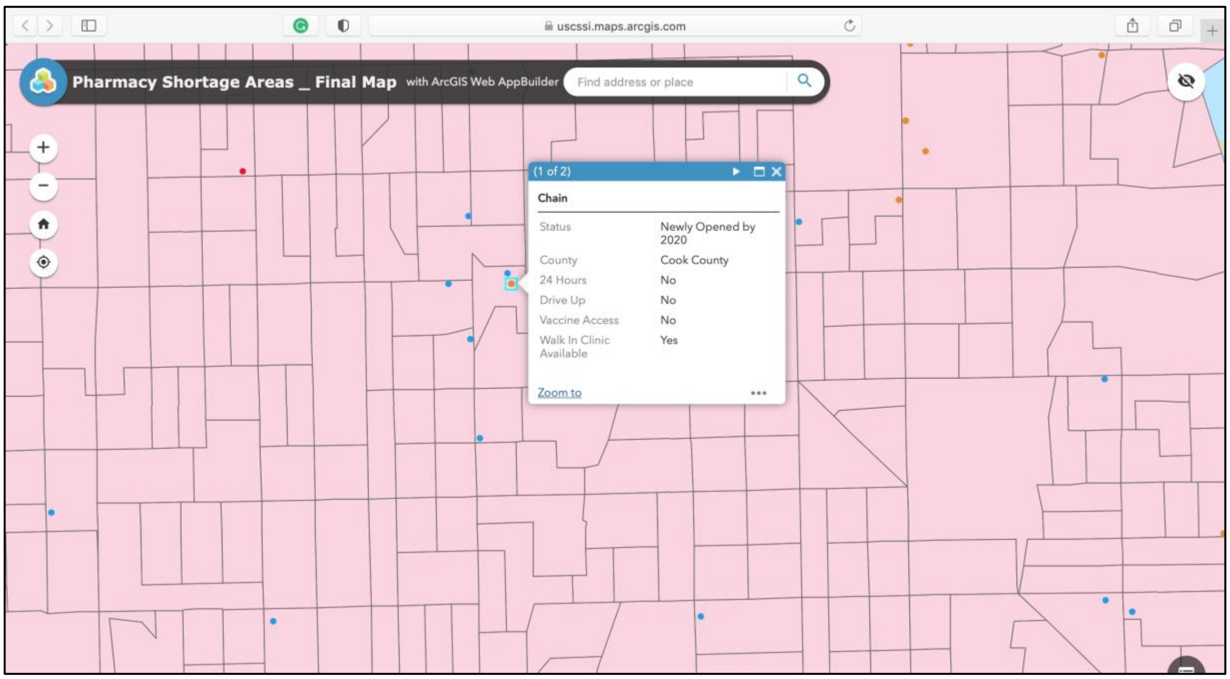

Figure 17: Web mapping application showing a newly opened pharmacy pop-up

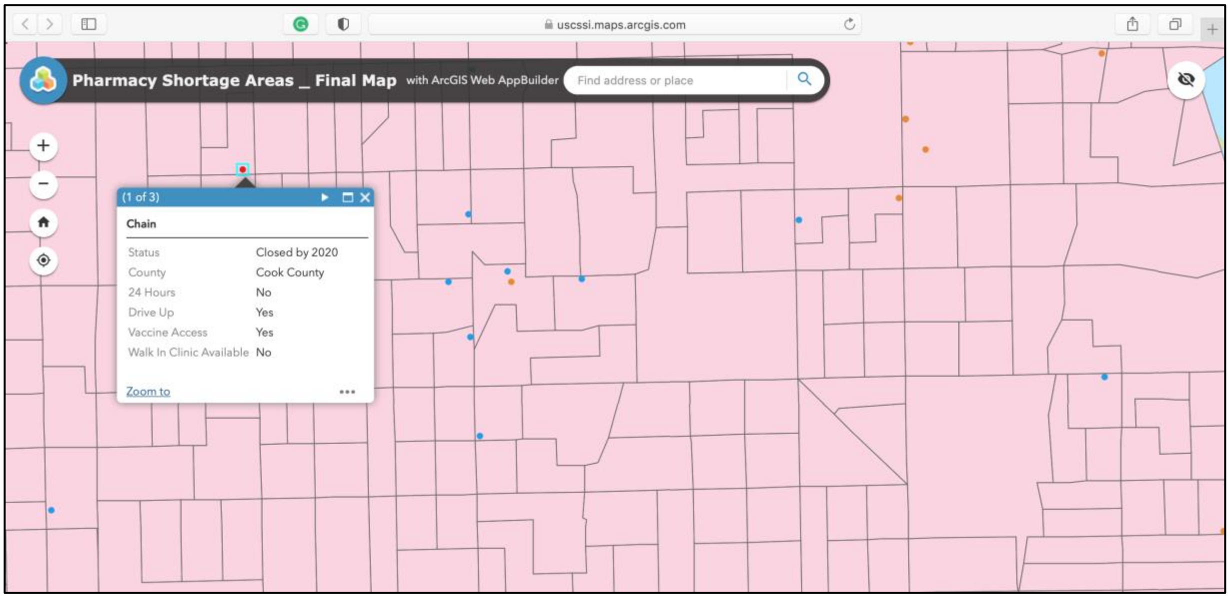

Figure 18: Web mapping application showing a closed pharmacy location

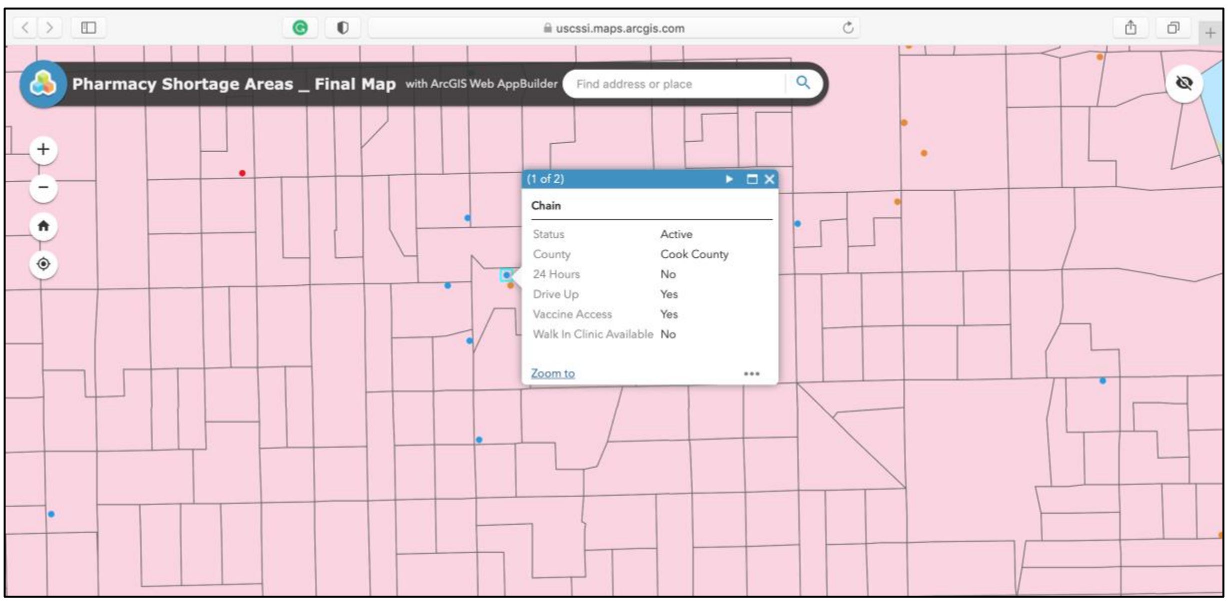

Figure 19: Web mapping application showing an active pharmacy location.

4.2.1.6. Swipe Tool

The swipe tool within the mapping application is used to show differences between two data layers. When the tool is clicked on, you can choose between any data layers that are turned on to swipe between. The tool allows a straight line with a left and right arrow showing it can be swiped in either direction. This is useful for showing comparisons between the 2018 and 2020 shortage area data layers. It can also be useful to show the difference in how this project defines a shortage area compared to the CMS thresholds.

Throughout Figures 20, 21 and 22, there is a visual representation of how the swipe tool works. Starting with Figure 20, the mapping application can be seen showing the swipe tool clicked on, the swiping line in the middle of the screen along with the option to choose which layer to swipe. When first clicking on the swipe tool, Figure 20 is what is shown. The selected layer is the forward most layer that has been clicked on. The tool can be used at any zoom level to see the changes at even the block group level.

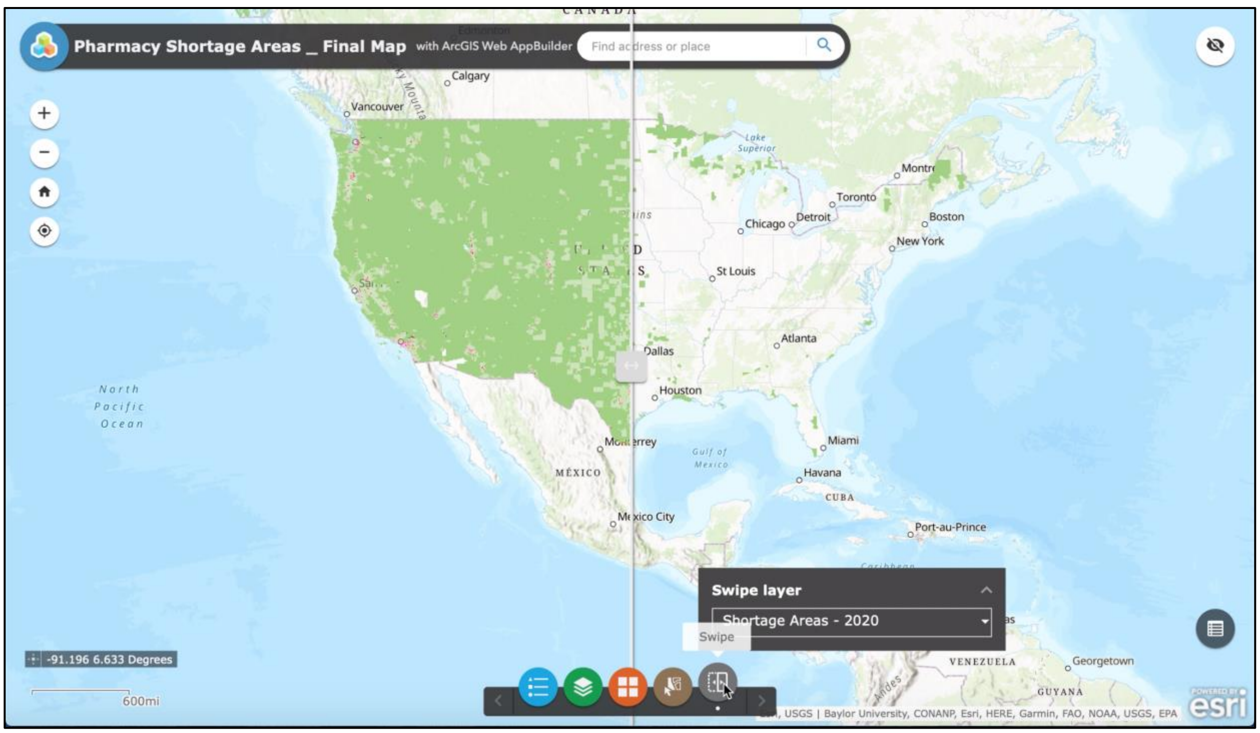

Figure 20: Swipe tool showing comparison of two layers.

In Figure 21, the swipe tool was swiped to the left side of the screen to show the CMS shortage areas for 2020. The swiping layer, shortage areas by this projects definition for 2020 is swiped away in this image. This tool allows for the base map to stay the same while adjusting the data layers. The only layer that is affected by the swipe tool is the layer most forward on the map, which is selected in the black outlined bot on the right side of the screen. This layer can be changed by clicking the drop-down button to select which layer will be used to compare to the layer below it.

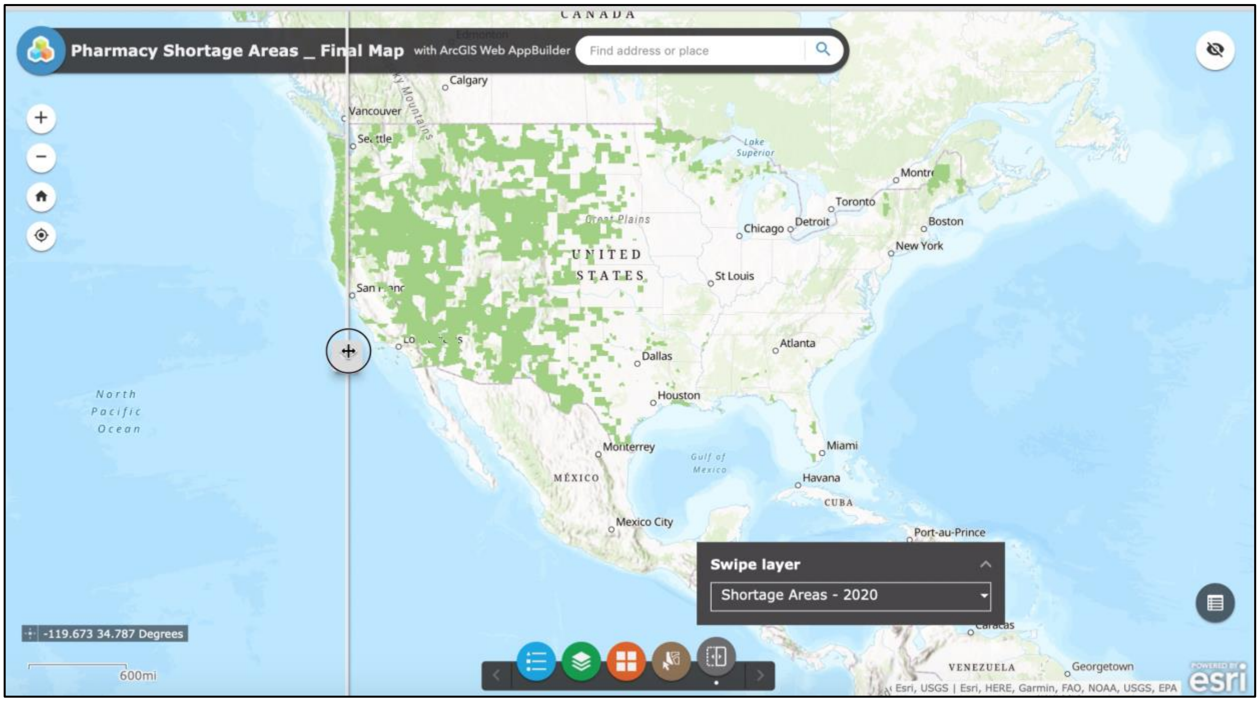

Figure 21: Showing how swipe tool works and can be used.

In Figure 22, the swiping tool is swiped to the right to show the shortage areas for 2020 by this project's definition, completely covering the CMS shortage areas layer. The layer being swiped is the one chosen in the black "Swipe Layer" box at the bottom right of the image. While using the swipe tool, to tell what is being shown, the legend tool can be turned on as well to prevent any confusion between the layers. The search bar at the top of the screen is disabled while using the swipe tool and in order to use the search tool again, clicking the swipe tool a second time will stop the swipe tool and enable the search tool to be used again.

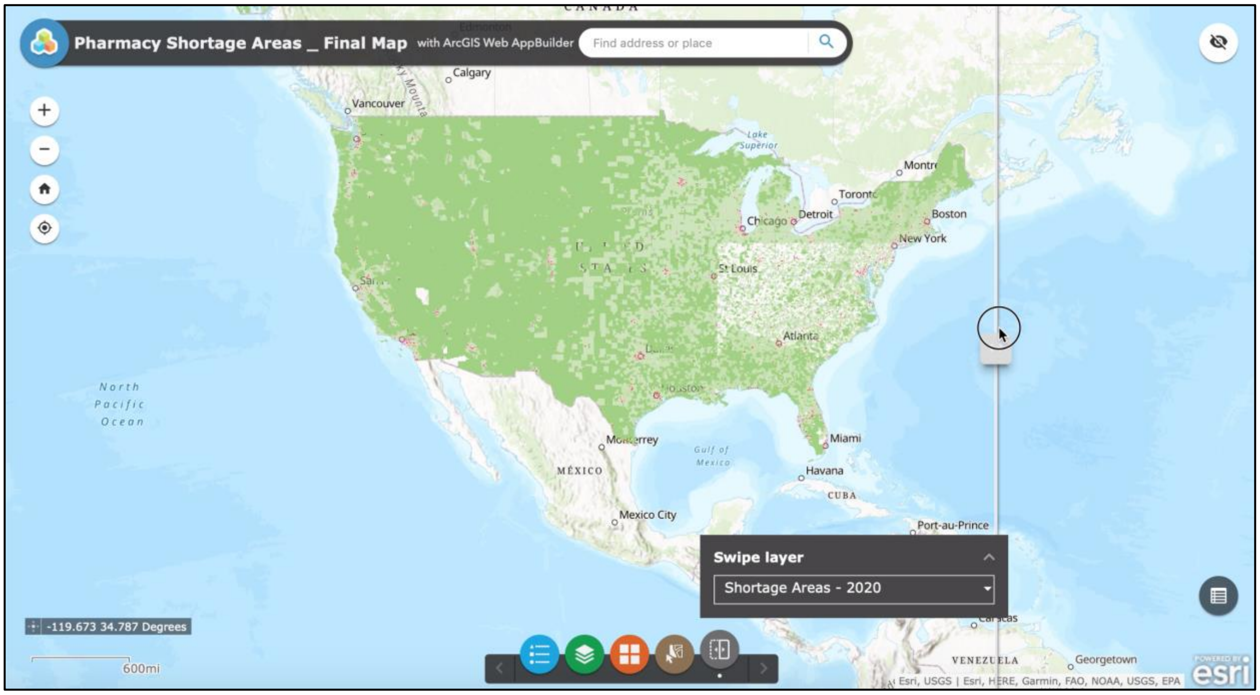

Figure 22: Showing how swipe tool can be used to compare layers.

Chapter 5 Conclusions

This chapter discusses the real-world meaning of the statistical results described in the prior chapter and the utility of the web mapping application which displays these results in an interactive and intuitive format. The chapter next describes some limitations of the project and then describes possibilities for future extensions of this project.

5.1. Discussion

The visual analysis supported by the web mapping application leads the viewer to understand that that Black and Latinx communities are most affected most by farther distances to pharmacies. Across the US, Black populations appear to have more areas of population living in a shortage area. This general visual finding holds true in urban, suburban, or rural census tract. The visual analysis also supports the finding that Latinx populations living in urban, rural, and suburban tracts have more areas of populations living in shortage areas as compared to the White populations . Nationally, Black and low-income communities have the most shortage areas, according to the visual results of the web mapping application.

The thresholds of one mile for urban tracts, two miles for suburban tracts, and ten miles for rural tracts caught significantly more shortage areas than those of the CMS thresholds. This shows how the CMS thresholds should be redefined knowing that populations that live in a shortage area show significantly less areas with inadequate pharmacy access by applying what is a reasonable distance for their Medicare Part D beneficiaries to travel to their nearest pharmacy. The distances chosen for this project were chosen as reasonable distances to travel for each type of tract based on urbanicity. For urban tracts, the thought process for choosing one mile came from the ability to access a pharmacy within a city area where many people walk or take public transportation for their main forms of transportation. For suburban areas, being that the houses are usually in deeper neighborhoods, the distance is somewhat further with also being reasonable for those traveling out of their neighborhoods to their nearest pharmacy. For the rural areas, ten miles was considered to be a reasonable distance being that most rural populations have to travel far distances to reach many amenities of their communities or nearby cities. The ten-mile distance by car is a distance that would be sound for the rural populations. For low income and low vehicle tracts, applying a half mile distance was considered reasonable being that if no vehicle is able to be used by the population, the primary form of transportation would be walking or public transportation without the option to drive. With the results showing that low-income areas are one of the groups of populations most affected by farther distances to pharmacies, this provides insights to CMS to reconsider their "reasonable" distance measures for their Medicare Part D beneficiaries but also provides a blueprint of where there should be more pharmacy access for these communities. With the CMS thresholds being applied as distances for determining a shortage area, there seems to be a disregard for reasonable access for those who are minorities or those who live in low-income neighborhoods.

Alaska contains the most tracts considered shortage areas because of the large amounts of uninhabited open space. Many tracts in Alaska are used for science research or extraction of natural resources and do not actually have a population. This causes the number of pharmacies in these areas to be scares or nonexistent which raises the distance to the nearest pharmacy and increasing the number of tracts considered a shortage area.

Populations living in shortage areas alters by state as does the number of tracts. The states with the most population living in a shortage area are Texas and California. These two states have the highest populations in general, therefore having the highest number of people living in a shortage area is understandable. However, the areas of tracts considered pharmacy shortage areas in Texas and California cover less than half of their states . This means the tracts that are considered shortage areas for these states have high populations. Alaska contains the highest areas of tracts considered a shortage area and a very low population living in a shortage area. This confirms that the tracts that are considered shortage areas have very small populations or none at all.

There were significantly more independent pharmacies that opened by 2020 that were not open in 2018. This result shows that there could have been a push in the creation of independent pharmacies. Another way this result could be interpreted is that some independent pharmacies closed and moved locations from 2019 to 2020. More independent pharmacies closed by 2020, however more independent pharmacies were created by 2020 also. This fluctuation in the creation and closing of independent pharmacies shows that chain pharmacies have what could be better resources to stay active for longer than independent pharmacies can.

This tool was shown to the members of NCPA and AMPAC during an August 2022 meeting of the USC-NCPA Pharmacy Access Initiative group. The National Community Pharmacist Association is a national association that represents independent community pharmacies. The goal of the NCPA is to promote and protect the independent pharmacists and their patients and communities. The Access to Medicines and Pharmacies Advisory and Advocacy Committee is a committee including state representatives, government employees and educators. This committee is dedicated to finding ways to create better pharmacy access to patients across the United States.

The dynamics of this web mapping application and the amenities, widgets, and tools within this map were presented. A general consensus of this tool was found to be useful. Members of both the NCPA and AMPAC groups found the tool to provide information in a way that is easy to understand and knowledgeable. The visual representation of the view of the United States and the shortage areas across the nation was found to be the best view of the tool. It was said to really show the impact of how pharmacy locations can affect its neighboring populations. Another consensus of this web mapping application was that it could be used for many other uses with pharmacy locations in the future. The members of both groups also agreed this web mapping application would be beneficial when providing statistics to state and federal government representatives. This web map seems to be a useful tool in many different pathways in the field of pharmacy.

5.2. Limitations and Improvements

A limitation of the web mapping application is the speed in which it takes to load the data layers. Having multiple data layers on at one time reduces the loading speed of the application. This could provide some issues for the user depending on their needs. Another limitation which occurred during the data management portion of this project was keeping adequate storage. Because the license of ArcGIS Pro is through USC, each student is given a certain amount of storage. Multiple times throughout this project there was a need for more storage. This did not affect the end product of this project, however, running out of storage at certain times reduced the efficiency of the data management timeline.

Due to the contract written between the Programs on Medicine and Public Health USC group and NCPA, the data is not yet public. this limits the reach this data could go to for the time being, however, the goal is to present this to policy holders and representatives to make changes related to pharmacy access.

When presenting the shortage areas by race and ethnicity, only White non-Hispanic, Black non-Hispanic and Latinx communities were provided. This study did not consider majority Asian populations when depicting shortage areas by race/ethnicity.

Lasty, margins of error when presenting majority Black, White, or Latinx populations within census tracts were not incorporated. The margins of error when being applied to the statistical analysis used when presenting the web application to the NCPA and AMPAC groups were not included here either.

5.3. Future research

Building upon this research, this web mapping application can be used to provide an in depth understanding of what exactly a resident can expect from their nearest pharmacy. Providing the types of services offered at each pharmacy, such as what medications are available, hours, and other lifesaving services, can be critical to a patient. With drug overdose being prevalent and rates rising in most states, knowing that naloxone (buprenorphine) or Narcan is available at your nearest pharmacy or what pharmacy carries them is very important. Also, knowing if a pharmacist can prescribe Narcan to you without a prescription and actively keeps it in stock is useful information. Along with naloxone and Narcan, availability of emergency contraceptives is another resource that patients should know their nearest pharmacy does or does not have. Another drug which can be prescribed by pharmacists, depending on the location, is an EpiPen which is another lifesaving drug which its availability could be presented in the web map as well.

A second addition which could be applied in future works is the distribution of insurance networks. Having each pharmacy be able to provide the insurance plans they accept would be monumentally helpful to the determination of pharmacy shortage areas. Being able to know that you have multiple pharmacies within a mile of you is good to know, however, if your insurance is not accepted at these locations, this should be another factor which would consider your neighborhood or census tract a shortage area. Also, being able to provide information on what the preferred pharmacies are within each network (i.e., each pharm could say "Aetna preferred pharm" etc.) would be beneficial to the resident or patient as well.

Expanding this project to include years of pharmacy data before 2018 and after 2020 would be a great continuation of this mapping application. With the web application being able to show changes over time, having multiple years of data would be interesting to show where pharmacy locations have closed or opened throughout the years and what tracts have become shortage areas or not because of the pharmacies.

The current study area of this project only includes the contiguous United States, Alaska, Hawaii and the District of Columbia. In future works, expanding the study area to include the united stated territories could be the next step in order to provide a complete US analysis. Expanding to other countries would also be a great next step to show pharmacy shortage areas in other nations.

The data used within this project are not public information at this time and are only to be seen by the members of the AMPAC and NCPA groups. With the data not being public, this requires the web mapping application to not be public as well. Having this shown to the public eventually is the goal of this project to ensure government and state representatives have an accurate visualization and understanding of the problem of pharmacy shortage areas.

Lastly, expanding this study to include not only all pharmacies, including non-retail pharmacies, but also primary healthcare facilities, hospitals and emergency care and shortage areas of these facilities would also be useful to show in the web map. Including more than just pharmacies into the web map along with multiple years of data could present a time lapse of how healthcare changes over the years and who is affected by these changes. It could also show if we are moving in the correct direction or if we are staying stagnant with the healthcare coverage currently being provided.

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