

Informing Planning to Address Health Care Disparities: Assessing Spatial Accessibility to Health Care Using GIS Analysis

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Abstract

Ability to physically get to a primary healthcare provider has been one of the issues that has led to healthcare disparities in the US. As the number of people that can get insurance grows, spatial/transportation accessibility to primary healthcare becomes an even bigger issue and a growing concern for the overall population. The aim of this study is to examine spatial patterns of primary-care health professionals' availability and spatial accessibility travel time using Geographic Information Systems (GIS) analysis techniques. Generalized travel time to locations of NPs and PCPs were developed using network analysis and primary health care service areas were delineated. Additionally, global correlation statistical methods and network analysis were conducted to analyze populations to be considered as medically underserved due to limited spatial accessibility to the primary health professionals. Urban areas show higher clusters of spatial availability and less travel time. However, although urban areas have a large number of healthcare providers, some areas are more likely to have a lower clustering pattern that reflects limited spatial accessibility. Compared to physicians, accessibility to NPs has a tendency to take much longer travel time and is mostly concentrated in rural areas.

The understanding of health care spatial accessibility gaps at a much more granular level can inform planners and health policy maker to coordinate efforts in order to address this problem in a much more targeted fashion. The understanding of health care spatial accessibility gaps at a much more granular level can inform planners and health policy maker to coordinate efforts in order to address this problem in a much more targeted fashion.

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Introduction

Primary healthcare plays a fundamental role in US medical facilities because it is the first defense for the population and a critical part of preventive care (Luo & Qi, 2009). Limited access to primary healthcare is a growing concern for the overall population (Guagliardo, 2004). In 2014, there are approximately 46 million people underserved by primary care (DHHS, 2014) and who experience limited access to services due to physical distance, or other barriers related to finance, culture, or language (Wang & Luo, 2005). These are some barriers that can impede progression from potential access to realized access. According to Penshansky and Thomas (1981), access can be grouped in five dimensions including accessibility, availability, affordability, acceptability, and accommodation. The last three essentially elaborate non-spatial perspectives that vary by population groups depending on their socioeconomic status and demographic background; whereas the first two dimensions speak to a spatial element. Accessibility refers to travel impedance between origin and destination, and is measured in travel time or distance (Wang and Luo, 2005). Availability refers to the total number of facilities within certain boundaries where users have options to choose (Langford & Higgs, 2012). Although it is useful to distinguish between availability and accessibility, these two dimensions merge into “spatial accessibility” in current healthcare planning, most noticeably for primary care providers (Guagliard, 2004; Luo & Qi, 2009; McGrail, 2012; McGrail & Humphreys, 2009; Nemet and Bailey, 2000).

Background of health professional shortage designation in US

There have been many attempts to measure spatial accessibility of healthcare, and to identify areas with shortage in healthcare providers (Wang & Lou, 2005). These areas have been termed *medically underserved* and the US Department of Health and Human Services (DHHS) has designated specific areas as Health Professional Shortage Areas (HPSA) and Medically Underserved Areas or Populations (MUA /P). These areas have at least 3500:1 ratio of population to full-time-equivalent healthcare providers (e.g. physicians, dentists, mental health workers, etc.) in common. In 2014, there are 4,960 designated HPSAs of primary medical care across the US and its territories. Approximately 46 million people reside in these areas and are considered an underserved population.

There are some problems recognized from DHHS designations. First, they cannot reveal the detailed spatial variations within those large designation types (such as whole counties, geographical area, or population groups). For example, entire counties are designated as a shortage area, although some neighborhoods are underserved and some may not. Second they carry the assumption that the boundaries are impermeable, that is, the actual interaction across boundaries is not adequately accounted for (Joseph and Phillips, 1984). Although recent revisions of HPSAs and MUAs/MUPs designations intend to address the problems by using geographic units smaller than counties as rational service areas (such as minor civil divisions or census tracts), existing methods can still easily lead to overestimate or underestimate in some areas. Also DHHS designations primarily quantify the distribution of provider versus users under an assumption that people within pre-defined areas have equal access to the providers within areas which are not always true in reality.

Research Question and Objective

The aim of this study is to examine spatial patterns of health professionals' availability and accessibility in the state of Florida and to analyze populations to be considered as medically underserved due to limited spatial accessibility to the primary health professionals. This study intended to develop a practical approach for defining health professional shortage area that may improve HPSA designation. The research questions are as follows:

- 1) What is the spatial extent of primary healthcare disparities in Florida?
- 2) Who is served by the primary care health professions in the state?

This paper aims to build upon prior research and seeks to make contributions as follows:

- 1) The methods are applied to measure healthcare accessibility in smaller geographic units- healthcare providers and population in census block group. Therefore it reveals more details of accessibility variations
- 2) It identifies spatial patterns of health professionals in need of populations. Output maps present areas of high and low clusters of healthcare professional density

- 3) Unlike most prior work using Euclidean distance, this research uses travel times to measure accessibility between residents and primary care physicians.

Study area and data source

It must be highlighted that not all primary care is delivered by physicians. According to Cooper & Dietrich (1998), Nurse Practitioners (NPs) contribute a great deal of quality of primary care. To illustrate the spatial accessibility for primary healthcare service, this study used number of population and number of primary healthcare providers including nurse practitioners (NPs) and primary care physicians (PCPs) data in the state of Florida.

Primary Healthcare Provider

Mailing addresses for NPs and PCPs were acquired from American Association of Nurse Practitioners and the American Medical Association (AMA) Masterfile respectively: NP data included 1,187 addresses records and the AMA Masterfile data had 13,432 addresses of PCPs in Florida. As an analysis preparation, this study successfully geocoded 99.76% of NP and 99.99% of PCP mailing addresses. For primary healthcare provider locations, we created density layers for each NP and PCP to represent availability across the state.

Cartographic Boundary and Population

2012 population data are used that were extracted from the 2010 Census. Population is used to normalize a variability associated with number of primary healthcare professionals, as a density. Block group was chosen as the analysis unit because it is the smallest scope of the unit used in the current practice. The 2010 census data show that there are 19,016,069 people living in the study area in year 2012.

Street Network

The street network data was acquired from Street Map USA provided by ESRI. This data provides information on driving restrictions and connectivity of all street segments in the United States. The data included a travel time for each street segments that is calculated from the length of the segments using speed limits.

Figure 1a and 1b shows the location of the study areas, the NPs and PCPs location and graduated colors of population. To compare the results with current health professional shortage areas (HPSAs), data are retrieved from Health Resources and Services Administration (HRSA) data warehouse. As of 2014 July, there are 2,443,483 population considered as under primary care shortage.

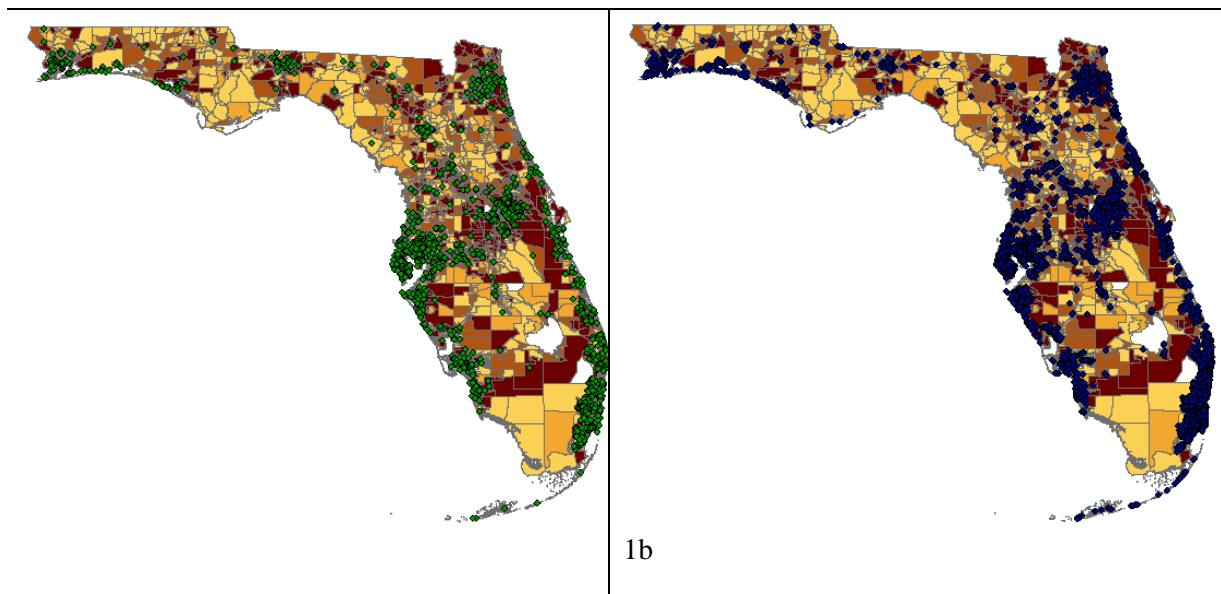


Figure 1a and 1b. Study Area with population. 1a and 1b represents location of NPs and PCPs respectively

Data analysis (Method)

This study has two methodological approaches. First is to examine availability of primary healthcare providers. It seeks to measure current distribution of primary healthcare provider density by population and analyze their cluster or randomization. The distribution is examined using Hot Spot Analysis to calculate the Getis-Ord G_i^* statistic, global and local statistic of spatial autocorrelation that identifies clusters of high/low values for each block. A high value for the G_i statistic indicates high values (i.e., higher than the mean) that tend to be close to one another, while a low value indi-

cates values lower than the mean and tend to be found together. A hot spot refers to an area with relatively higher primary healthcare density compared to surrounding areas, whereas a cold spot indicates the reverse. The outputs are the maps of census block group level z-scores symbolizing significant ($p < .05$) hot and cold spots (Aim1). In order to quantify accessibility of primary healthcare provider, second aim is to calculate travel time to NPs and PCPs separately and identify the number of people residing more than 30 minutes from the providers. 30-minute is considered as a threshold time of the areas with limited accessibility based on HPSA descriptions. Assuming people taking the shortest/fastest path, we used O-D cost matrix in network analysis tool in ArcMap (v.10.2), which assess the shortest travel time between any two locations, from residence of population (centroid point of census block group) to the nearest healthcare location (NPs and PCPs separately).

Result

Availability: Identifying significant primary healthcare density clusters

The results of the Global Moran's I tool was conducted in fixed-band distances. Although the overall result of Getis-Ord-Gi* analysis showed that NPs and PCPs density do not appear to be significantly different than random for both NPs density ($z\text{-score}=0.68$, $p\text{-value}=0.50$) and PCPs density ($z\text{-score}=-0.79$, $p\text{-value}=0.43$), there are specific hot spots (red/orange) and cold spots (blue) of primary healthcare service density in the study area (Figure 2a and 2b). Spatial cluster was most significant at block group (FIPS: 121150011021) in the city of Englewood, Sarasota County for NPs ($p \leq .01$, $z\text{-score}=7.12$), and at block group (FIPS: 120890501022) in the city of Jacksonville, Nassau County for PCPs ($p \leq .01$, $z\text{-score}=3.49$) respectively. 3,077 block groups (out of 11,405 total) were identified as NPs density hot spots ($p \leq .05$, $z\text{-score} \geq 1.96$) in the panhandle and the central-west of the state; whereas cold spots ($p \leq .05$, $z\text{-score} \leq 1.96$) were predominantly identified in the north and south-east of the states, including 4,186 block groups, which indicates statistically significant clusters of low density of NPs per population. Hot spots of PCPs density were predominantly found in northeast Florida. Smaller hot spots were seen in parts of Putnam, St. Johns, and Flagler counties that are with the boundaries of the Jacksonville metropolitan area. There were no consistent hotspots for both NPs and PCPs, however the northeast region surrounding Jacksonville metropolitan area was identified as NPs density hot spots and PCPs cold spots.

The global measure from this result suggests that availability of primary healthcare professionals by population has a positive auto-correlated pattern throughout at hot spots for NPs and PCPs. Furthermore, a number of population corresponding to hot spot areas were extracted to get an indication of population with primary healthcare availability. Populations residing in hot spots of NPs and PCPs are 1,575,644 (8.29%) and 4,490,274 (23.61%), respectively.

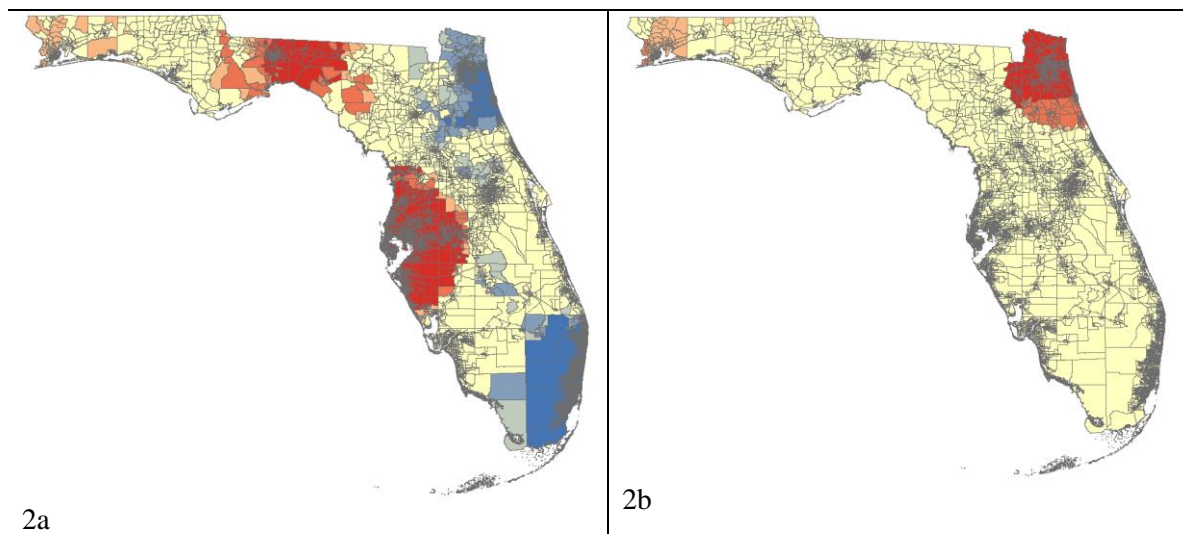


Figure 2a and 2b. Availability of census block groups estimated by Getis-Ord G_i^* analysis: density of NPs per population (2a) and density of PCPs per population

Accessibility: Travel time estimation

The result of network analysis shows individual census block groups serviced by each NPs or PCPs along with the total drive time for each routes (Figure 3a and 3b). Neighborhoods that were within 30 minutes travel time to a NP location includes 10,658 block groups and contained 93.25% of the study area population. About 5.7% of population could not reach the closest NP location within 30-60 minutes; whereas nearly 1.05% have accessibility over 60 minutes. Figure 3a shows that the areas with the longest travel time to NP location are close to small town/rural areas categorized

by RUCA code of census tract¹. Like the result of NP location, the majority of the study area population, 97.21%, was within 30 minute driving distance to a PCP with the following exemptions: some of the rural areas in the west of Florida near Georgia border and a few neighborhoods in the Gulf of Mexico region.

Discussion

Spatial Accessibility

Throughout the Gi* statistical analysis to identify availability, it has been observed that the density of NPs are more to be randomized all across the state except certain clusters. Clusters of NPs indicate some similarity with Metropolitan Statistical Areas (MSAs²) of Florida and their fringe areas. MSAs in Florida are the major business and commercial centers, with high concentration of residents and commuters. The MSA NPs density clustering patterns analyzed by Gi* statistics indicate that NPs are ideally located to provide primary healthcare availability. Like the NPs result, PCPs did not reject the null hypothesis that density of PCPs in Florida is random.

¹ We have reconciled to assist in the categorization of the geographic context of GIS data according to their degree of urban and rural. Rural-Urban Commuting Areas (RUCA), follow census tract geographic boundary, is used to integrate work commuting patterns into the census-based urban area data. We reclassified RUCA codes into urban (RUCA 1-6) and small town/rural (RUCA 7-10) to provide more detail on the characteristics of rural area and to show presence or absence of PCP shortage areas. RUCA data has been used in a variety of health-related research (Chan, Hart, and Goodman, 2006; Rosenblatt, et al., 2006; Skillman, et al., 2006)

² Office of Management and Budget (OMB) has delineated Metropolitan Statistical Area (MSA) where city, metropolitan area, and their adjectives are placed. MSAs are statistical constructs used to represent integrated labor market areas. They typically are geographic areas combining a large population nucleus with adjacent communities that have a high degree of economic integration with the nucleus.

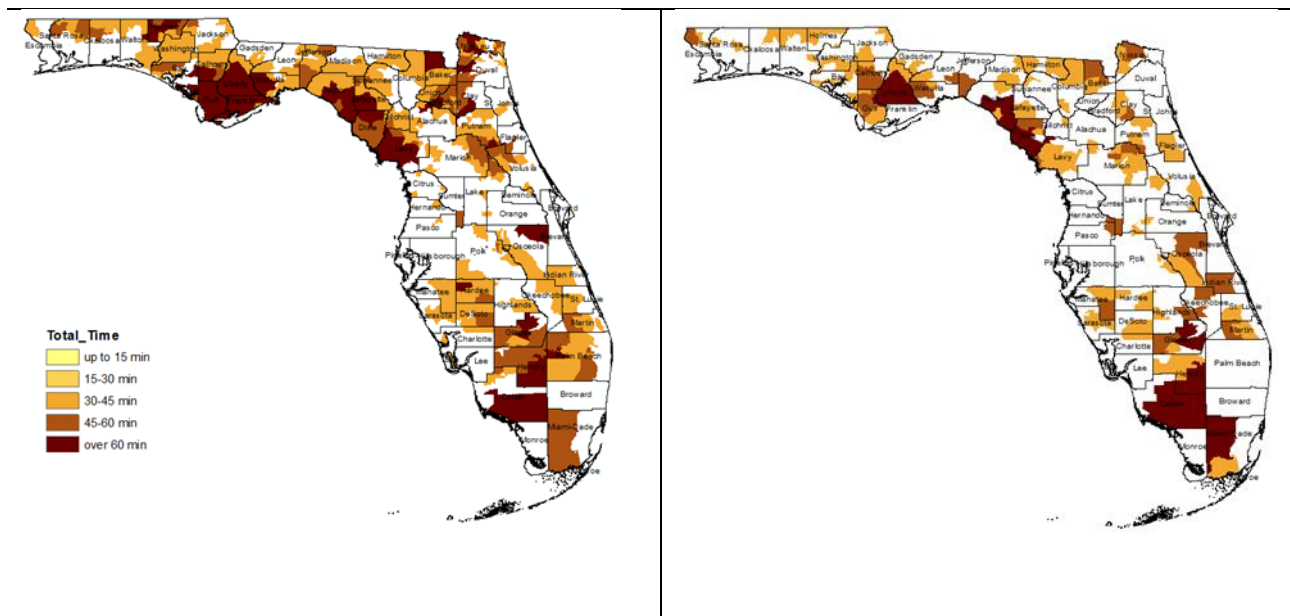


Figure 3a and 3b. Accessibility of census block groups estimated by: (3a) travel time to NPs and (3b) PCPs

However an intense clustering of high PCPs availability was found in Jacksonville MSA. This area had one PCP among 4 residents (average of 0.25:1 ratio of PCP to population), and the number of PCPs in the hot spot include 9.05% of all Florida PCPs. In terms of accessibility, approximately 95% of the study area population can travel to either NPs or PCPs location within 30 minutes, however, the result of this study indicates that populations in some neighborhoods in the border of the Gulf of Mexico are taking half or more than an hour within traveling to primary healthcare providers. Most of these neighborhoods are in the rural areas. Previous studies have stated similar disparities in rural areas with travel time comprising the greatest determinants of geographic accessibility health service (Baldwin et al, 2004; and Chan & Goodman. 2006). Moreover, the unequal geographic distribution of healthcare centers compose the disparities in access for rural populations (Arcury, et al., 2005; and Mao & Nekorchuk, 2013).

In this study area, the location of NPs and PCPs in probability of population are clustered in or near the urban areas. Thus, it is important for population health planners to be aware of neighborhoods that lack geographic accessibility in rural areas so as to better target health service and research programs. Although this paper did not relate any non-spatial factors, descriptive statistics potentially indicate there could be some correlation between income status of the population (Table 1).

	Travel time(min)	Census block group (n)	2010 total population (%)	2012 total population (%)	Mean of Median household income from 2012 American Community Survey
1	Up to 15	9,459	15,352,264 (80.73)	15,506,555 (81.54)	\$52562.34
	15-30	1,199	2,184,880 (11.49)	2,225,858 (11.71)	\$49965.15
	30-45	454	783,596 (4.12)	794,902 (4.18)	\$46702.61
	45-60	173	283,346 (1.50)	289,369 (1.52)	\$41625.47
	Over 60	120	197,224 (1.04)	199,385 (1.05)	\$43774.86
PCPs	Up to 15	10,380	16,963,718 (89.21)	17,149,224 (90.18)	\$52333.15
	15-30	733	1,314,634 (6.91)	1,335,396 (7.02)	\$47766.85
	30-45	201	367,238 (1.93)	373,700 (1.97)	\$43324.19
	45-60	63	110,209 (0.58)	111,566 (0.59)	\$43610.81
	Over 60	28	45,511 (0.24)	46,183 (0.24)	\$38062.82

Table1. Population distribution within specified travel times to NPs and PCPs

Comparison with HPSA

Aforementioned, HPSAs of Florida present lack of precision. Comparing to the commonly used 1:3,500 physician-to-population ratio as a standard, a method from this study identified 1,815,105 population without the appropriate access to primary health professional (travel time more than 30 min) in the study area, whereas 2,443,483 were identified by HPSA (Table2). HPSAs in the study area are mostly population groups and single/partial counties represented as census tracts. The HPSAs generally covered the shortage areas identified in this study, but there are many of the overestimated spatial extents. With consensus of both methods, counties near the border of the Gulf of Mexico (Calhoun, Gulf, Liberty, Franklin, Wakulla, Jefferson, Taylor, Lafayette, Dixie, Gilchrist, Levy county), east (Union, Bradford, Nassau County), and south-central (Hard-ee, Desoto, Glades, Hendry) have been highlighted as problematic. In addition HPSAs missed some other shortage areas identified by method from this study such as Baker county, and segments in Sarasota, Manatee and Palm Beach county.

Method	Measure	Area of shortage area	Population under primary healthcare provider shortage
HPSA (2014)	Primary Care	44390.40	2,443,483
Accessibility	NP	29458.12	531,449
	PCP	19742.97	1,283,656

Table 2. Primary care area shortage area statistics

Limitation and Future Direction

This study includes several limitations that need to be explored for future research. First, it did not include non-spatial factors. Access to healthcare includes both spatial and non-spatial frameworks; whereas non-spatial access represents nongeographic barriers such as age, race, educational attainment, income, and health insurance status. Many of the researchers have stated that access to healthcare varies by socioeconomic characteristics of the population (Acury, et al., 2005; Mahmoudi and Jensen, 2012; and Wang and Luo, 2005) despite the fact that they are residing

in areas that were identified with high spatial accessibility. Second, this study is limited in travel impedance data such as traffic congestion, weather condition and peak or off-peak time of the day to adjust travel time estimates. These factors were difficult to model due to their inherent variability and would require significant assumptions on the average or median values.

Conclusion

There is an unequal distribution of primary health care providers (NPs and PCPs) in Florida such that some geographic areas have few or no providers. The results highlight the imbalance between urban and rural areas of Florida. These suggest that the geographical distribution of PCPs is unbalanced, especially in Jacksonville MSA. There appeared higher concentration than average PCPs density of all examined. NP locations also appeared higher density in MSAs but it turned out to be more spread across the state. Network-based approaches used in this study could assess that it takes an average of 10.69 (min) and 5.86 (min) to NPs and PCPs by driving respectively. However it appears to have more tendency to take a longer travel time in rural Florida.

These results may improve the development of strategies to reduce spatial accessibility to primary healthcare providers. Furthermore, implementation of the Affordable Care Act this year will create millions of new consumers who will be able to afford care, but with the shortage of primary care providers in medically underserved areas, care may not be available to them. The understanding of health care availability gaps can inform planners and health policy maker to coordinate efforts in order to address this urgent problem.

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