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Methodological Review

Marginalization and health geomatics

Gregory L. Alexander,[a,b,*] Edward L. Kinman,[c] Louise C. Miller,[b] and Timothy B. Patrick[a]

[a] *Department of Health Management and Informatics, University of Missouri, Columbia, MO 65211, USA*
[b] *Sinclair School of Nursing, University of Missouri, Columbia, MO, USA*
[c] *Department of Natural Sciences, Longwood University, Farmville, VA, USA*

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Abstract

Marginalized groups have been defined as groups that have been peripheralized from the center of society. Increasing nursing knowledge of marginalized groups and the dynamics of population diversity will enable nurses to better recognize shifting health patterns, plan for utilization of health services, and determine ethnic and cultural differences that exist in marginalized populations. The authors of this article review theoretical models responsible for defining the concept marginalization, describe geographical information systems as a recommended tool to evaluate marginalized groups, and provide a case study utilizing tools and maps as a means of assessing marginal situations.

Keywords: Marginalization; Geography; Geographical information systems; Population; Diversity; Mobilization

1. Introduction

Recent statistics indicate 11.8% of the US population lives at or below the federal poverty threshold, a 30-year low [1]. Though this reduction is encouraging, aggregate figures can mask disturbing information. For example, the US Census Bureau estimated 12,109,000 children under 18 lived below the poverty level in 1999 [1]. Considerable differences exist by geographic location, ranging from 7.6% in Maryland to 20.8% in New Mexico [1]. Variation is further evident by race and ethnicity, with 22.8% of Hispanics and 23.6% of African Americans in poverty, compared with only 7.7% of non-Hispanic Whites. With a poverty rate of 50.3%, children of households headed by a female are particularly marginalized, more than five times the rate of 9.0% for married-couple households [1].

Identifying marginalized populations geographically can be problematic, regardless of geographic scale [2,3]. Aggregate statistics at the state, county, or municipal level tend to attenuate significant geographic variation. Differences may be hidden even within smaller units of analysis such as census tracts or block groups. There are also issues with the timeliness of data, which is typically based on the decennial census. Collecting and processing large amounts of geographically referenced data is a lengthy process, sometimes taking three years for socioeconomic statistics to be released. To further complicate analysis of decennial data, approximately 16% of the population aged 1 and older migrates in a given year [4].

Shifting dynamics in population diversity has important implications for nursing. First, visualizing changing health phenomena patterns provide a mechanism for nurses to understand environmental, cultural, and demographic patterns of disease. Second, as people move, the distance from and access to healthcare services may change, along with population density. Subsequently, these changing geographies impact decisions regarding where healthcare facilities should be located, appropriate levels of healthcare services for a community, and consumer health behaviors. Thus, better understanding of population diversity and changing demographies will enable nurses to plan for and provide improved service delivery. Furthermore, ethnic and cultural differences associated with perceptions of

* Corresponding author. Fax: 1-573-882-6158.
E-mail address: Greg_Alexander@missouri.edu (G.L. Alexander).

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healthcare, environment, and preventative health behaviors may impact the population. Increased awareness of ethnic and cultural differences will increase knowledge of diverse health practices in the community, which in turn will improve the individuality of nursing care planning in the community.

One approach to analyzing marginalized populations is the use of health geomatics techniques that link the integrative investigative approaches of medical geography with the technological advances associated with geographical information systems (GIS). GIS are computer-based technologies that allow for the integration and analysis of multiple layers of complex geographic data in ways not previously possible. Disparate databases such as census boundaries, streets, health resources, hospital records, and disease registries can be imported and their positions referenced for subsequent analysis and visualization with stratification. Coupled with advanced statistical analytical techniques such as time-series analyses, spatial statistics, or multivariate statistical analysis, GIS becomes a powerful analytical tool. These technologies form the newest base for defining hospital service areas, examining the effect of distance on health service access, and disease patterns. Despite these health geomatics innovations, GIS has remained underutilized [5]. The purpose of this paper is to review theoretical models associated with marginalized populations and to identify and describe tools from health geomatics that can be used to support health care planning decisions for marginalized populations using a case study from Boone County, Missouri.

2. Background

2.1. Marginalization: a theoretical construct for health geomatics

Marginalization has been defined as the existence of a population, group, or individual: (a) on the periphery or boundary of mainstream society; or (b) between two different cultures, being part of neither [6,7]. These exposed positions create environments that potentially threaten the well-being of individuals or communities who are marginalized. Research has shown that populations living in marginalized environments may experience poorer health outcomes, inequalities in health care access, and deficiencies in available health care resources [8,9].

Proponents of socio-spatial marginality, a concept derived from the uneven development of society and space, seek to develop a better understanding of the dynamics of marginality [10]. Two types of marginality may exist due to inequitable conditions. First, contingent marginality may occur as a result of competitive forces in the free market. For example, because of where they live, individuals in rural communities may have decreased access to hospitals, clinics, or healthcare workers with advanced technology or knowledge of how to use advanced technology. Limited access to these resources may place individuals or communities in rural areas at a disadvantage, impacting health outcomes associated with these populations. Other forms of contingent marginality may be related to cultural restrictions, inadequate labor skills, and lack of information sharing.

The second form of marginality results from a socially constructed hegemonic system that exerts power and control over marginalized populations [10]. This type of marginality, called systemic marginality, may result from stereotypes inflicted on the marginalized. For example, in a study of nurse perceptions toward homeless people, the authors found that homeless people were objectified, viewed as different, and were the recipients of judgmental behavior when rules were violated [11]. The same research also indicated that nurse perceptions of humanity and caring for the homeless were positively impacted as a result of deeper understanding of marginalized conditions.

2.2. Defining marginalization as a variable of space

GIS applications have been difficult to implement as a result of a lack of GIS knowledge, the lack of integration of GIS applications, and computing resources on the side of the client [12]. Popovich contends that incorporation of these applications into management of public health concerns, such as acts of bioterrorism or immunization registries, will improve methods of surveillance, detection, and communication among public health responders. Evaluation methods used in GIS, including mapping, spatial analysis, and data mining, will advance understanding of populations possibly marginalized by immunization status or environmental exposure.

2.3. Mapping

Health geomatics science plays a role in defining the spaces marginalized populations inhabit. Understanding the structure of marginalized environments including their proximity to health care resources can be visually represented using geographical mapping techniques. Maps are a depiction of reality, demonstrating relationships among variables that often are not apparent in traditional text-based data displays, such as tables or graphs. Maps represent geographical cognitive thought, which are abstracted into a cartographic format [13]. Spatial analysis, accomplished by thinking geographically and plotting environmentally referenced variables, adds a valuable descriptive dimension to explaining marginalization.

2.4. Spatial analysis and data mining

Spatial analysis describes 'where' things are in relationship to other environmental factors that may influence or control the distribution pattern of a phenomenon of interest [13]. To do so, health data and related factors must possess geographic location information such as longitude and latitude coordinates, a valid street address, census tract locator, or ZIP code. During data mining, variables that have geographical potential include those that describe magnitude, frequency, and distribution of diseases [14]. Health resources and population characteristics are also of great importance. These variables are particularly useful in epidemiological studies of disease occurrence and spread, such as AIDS, tuberculosis, various types of cancer, or even more common illnesses as with yearly flu outbreaks. By comparing variables over sequential time intervals, temporal aspects of duration and time-related cycles of the variables of interest can be tracked. The movement of AIDS has been followed by spatial analysis using GIS, which has offered a greater understanding of the disease in a given locale, but also contributed to forecasting its spread beyond boundaries of affected cases only.

GIS technology has also shown promise in public health and environmental health. It has contributed, for example, to our knowledge about the risk factors for childhood lead exposure [15]. Miranda applied GIS technology to estimate "...exposure risk across a variety of risk factors at a very fine geographic resolution." In related work, GIS have been used to investigate instances of environmental and health-related injustices [16]. Furthermore, nurses used GIS methods to explore relationships between unmarried teen births, ethnicity, socioeconomic level, and family composition [17,18]. Blake and Bentov found a higher percentage of unmarried teen birth rates in Black and Hispanic populations who also experienced lower socioeconomic levels and higher percentages of single parent households.

3. Method

3.1. A case study: using GIS to guide service planning

3.1.1. Merging data sets

We used GIS to mine useful characteristics of populations from three data sets that would guide further needs assessment with follow up service planning. In doing so, we hoped to show the utility of combining and analyzing data from multiple sources and display it as maps so that nurses could target identified populations with specific services.

This case study used three data sets. The first consists of Boone County birth certificates for children born between 1 January 1995 and 31 December 1998. Variables extracted include the birth mother's address, month and year of birth, and whether or not the birth mother was receiving public assistance in the form of Medicaid, WIC, or food stamps. The second data set contained 1998 patient records from a community health center (CHC) for all children under age 5. Each record contained information on the patients' age, number of consultations, household income, method of payment, and home address. The third consists of geographic information, obtained from the Missouri Spatial Data Information Service [19], including coverage for incorporated areas, roads, and census enumeration areas.

Before maps and spatial analysis could occur, residences from birth certificate and patient records had to be located. This process, known as "geocoding," successfully located 94% of the CHC patient and 98% of birth mother residences, high by GIS standards (typically 70–80%) [20]. The geocoded clinic and birth certificate coverages with the census enumeration areas allowed us to analyze results at various geographic areas. Boone County's 29 census tracts were the unit of analysis for defining the child service area, a resolution adequate to display spatial variation within the county. Census block groups are smaller subunits nested within census blocks and provided a finer spatial resolution for analyzing variation within Columbia.

ArcView 3.2, a leading GIS desktop software package from Environmental Systems Research Institute, was used to produce the maps that illustrate phenomena by geographic location. Dot maps were employed as they best communicate spatial density of discrete geographic phenomena. When aggregating data at the census block group or tract level, choropleth maps were used to show spatial variation with distinctive graytone values. While choropleth maps help identify geographic patterns, boundaries are imposed, irregularly shaped, arbitrary, and do not necessarily reflect the natural distribution of a phenomenon. Census block groups, for example, vary considerably in area and population and may mask variation within their boundaries. Further, boundaries between enumeration areas do not necessarily represent sharp discontinuities in the data. Density surface maps provide a way of overcoming these limitations by weighting point data to create a continuous surface to illustrate high and low concentration across an area based on the actual distribution of the phenomenon.

3.2. Defining child service area

Sixteen of Boone County's 29 census tracts were classified as having medically underserved populations when the CHC was approved as a federally qualified health center (Fig. 1). This designation, however, does not mean residents from these areas will utilize the facility as use can vary considerably within its identified

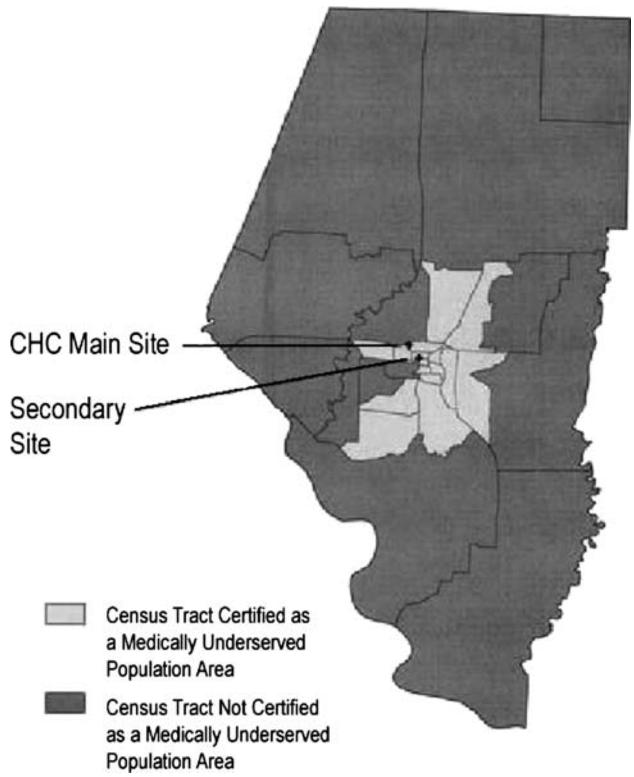

Fig. 1. Designated target service area of medically underserved populations.

service area [5]. To define the child service area we used the clinic database to first map patients by census tract. Next, we employed the Griffith commitment index to identify the core service area based on utilization [21]. It was calculated by dividing the number of clinic visits per census tract by the total number of visits for the county. Tracts were then ranked in descending order based on these commitment indices and classified as part of the medical service area until it accounted for 67% of clinic visits [22].

3.3. Location quotient

The location quotient (LQ) measures distributions of populations in need or compares relative use [23]. It is a useful technique when geographic patterns are a variable of interest. The first LQ (Fig. 2A) was based on birth certificate data. It reflects the proportion of total at-risk children under age 5 (born to households receiving public assistance at birth) in a census block group divided by the proportion of total Boone County children under age 5 population in that census block group. The second LQ (Fig. 2B) used CHC patient records. It shows the proportion of total clinic visits made by children under 5 and reside in households with incomes below 200% of the federal poverty level in a census block group divided by the proportion of total clinic visits by Boone County children under age 5 in that census block group.

3.4. Density utilization surface

Density utilization surface is a useful measure to examine spatial patterns of CHC use by at-risk children weighted by total number of consultations. This was done by dividing Boone County into uniform cells measuring 75 meters by 75 meters. Cells were assigned a density value based on the number of clinic visits within a defined search radius of half a mile divided by the area of the neighborhood created by that search radius. This process essentially assigns an average value to each cell, resulting in a smoothed surface [24].

Omitting names from both data sets before we obtained them protected confidentiality of both patients and children under age 5. Further, we deliberately and randomly offset points a distance of 0.1 mile in the geocoding process from their actual location to prevent the identification of individual homes.

4. Results

Based on socioeconomic census data, 16 of Boone County's census tracts were certified as a medically underserved population area in 1994 (Fig. 1). To examine the extent the CHC's service region coincided with the geographic distribution of potentially at-risk children, dots representing babies born to households receiving public assistance were placed over the target service area (Fig. 3A). This reveals many children under age 5 reside outside the designated medically underserved area. While the largest concentration is proximate to the CHC service sites, several large clusters are located away. The tract in the northeast corner of Boone County, for example, contains 86 children under age 5 born to a household receiving public assistance at birth. GIS can provide similar counts within any enumeration area.

GIS allow for the comparison of target and actual child service areas based on CHC utilization (Fig. 3B). Five census tracts coincide with both the original medically underserved and the actual child service areas. Eleven certified underserved tracts were not included in the core child service area, while 3 census tracts not included in the 1994 certification were part of the 1998 core child service area.

While dot density and core service area maps provide useful insights, standardized measures are necessary to more precisely identify geographic areas with clusters of at-risk children relative to their base population. This relationship is displayed as a LQ choropleth map in which darker grays represent areas with higher than expected concentrations of children born to households receiving public assistance (Fig. 2A). If the potentially at-risk children were equally distributed throughout the county in relation to the total children of the same age cohort, a LQ value of 1.0 would be found in that area. A

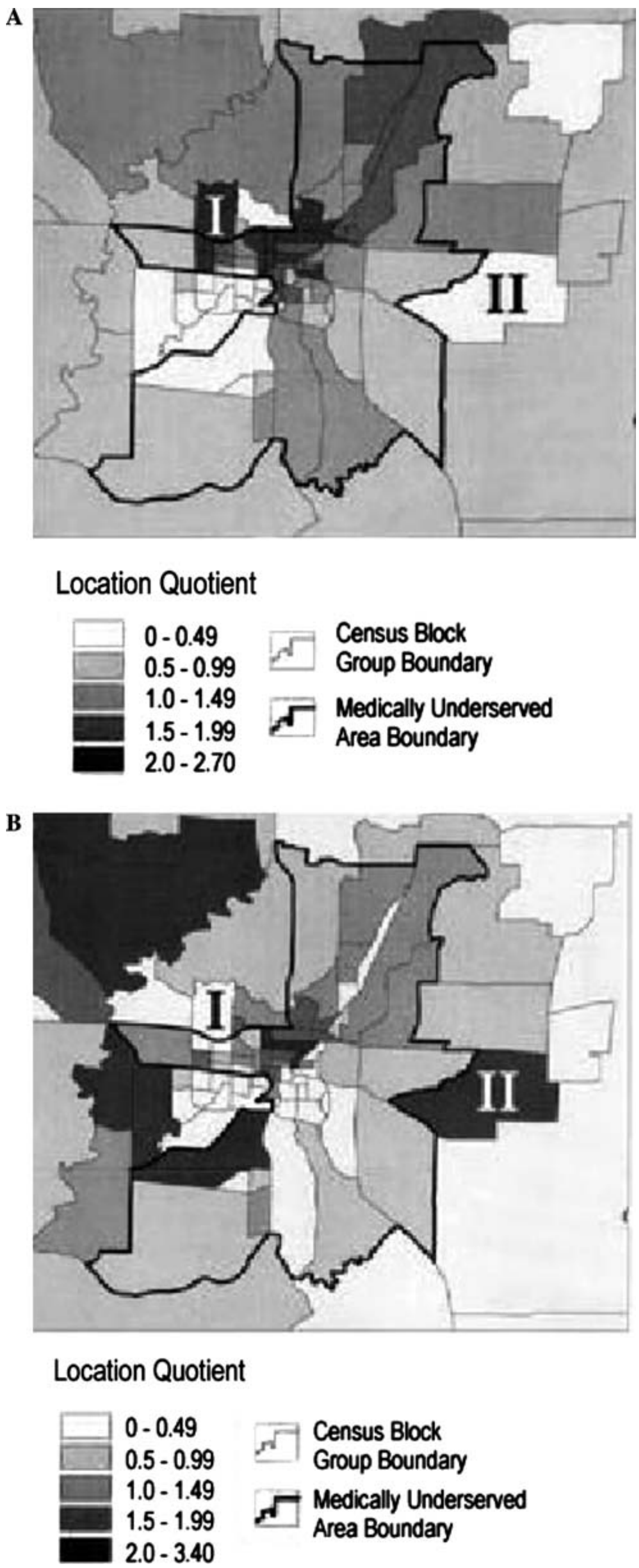

Fig. 2. (A) Location quotient of children born to households receiving public assistance by census block group. (B) Location quotient of CHC use by children under 5 and in households with incomes below 200% of the federal poverty level by census block group.

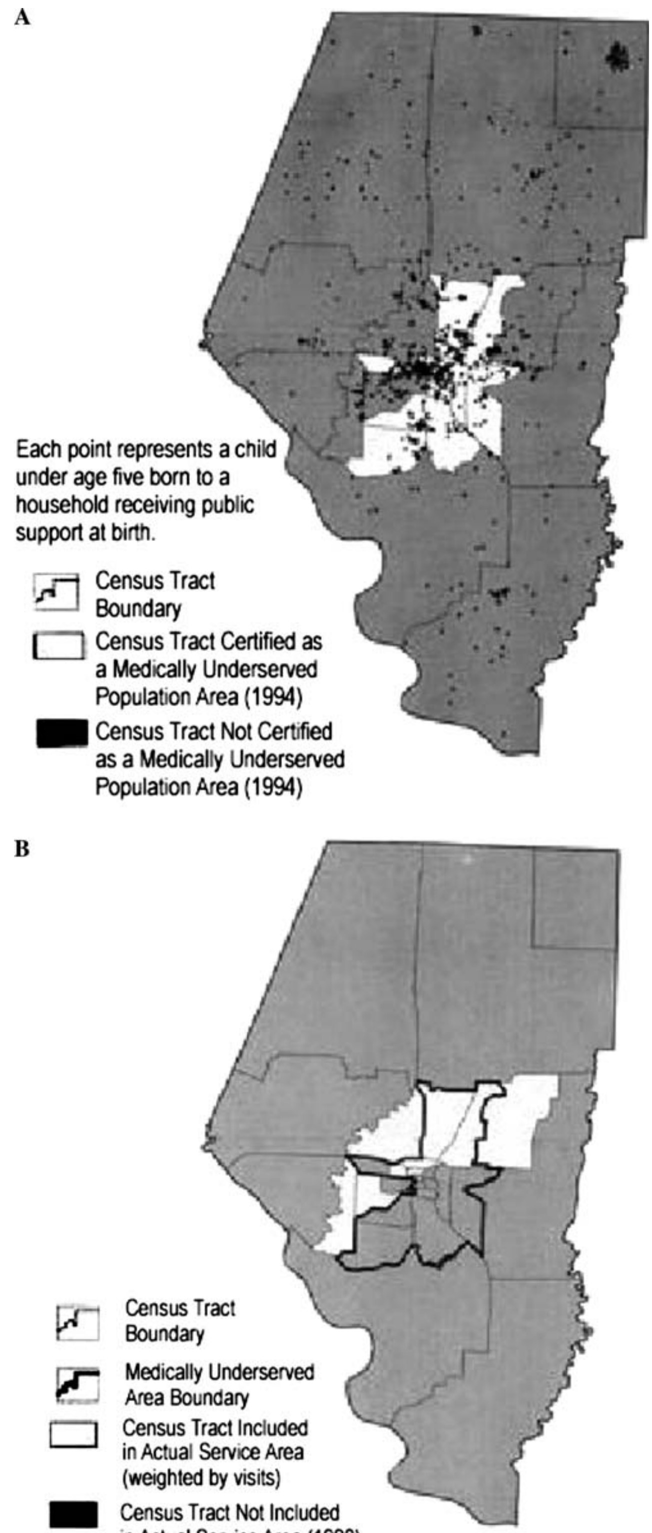

Fig. 3. (A) Target service area. (B) Actual child service area.

LQ greater than 1.0 suggests a greater number of at-risk children reside there than would be expected given the total children within that block group, while a location quotient of less than 1.0 suggests the opposite. Using a smaller unit of analysis such as block groups allows spatial variation to emerge. In west Columbia, for example, block groups of high concentration are contiguous to block groups of low. Overall, the highest location quotients were found in and around central Columbia in areas with close proximity to the CHC service sites, while the block groups with the lowest location quotients were mainly in southwest Columbia. The designated medically underserved area boundary shows that variation occurs within and outside of this area.

LQs were also used to demonstrate utilization rates of children living in households below 200% of the poverty level (Fig. 2B). Areas of high utilization, represented by darker shades, are block groups where the number of CHC visits made by at-risk children is high in relation to the number of at-risk children living there. Several areas within the target medically underserved area, as well as a number of rural block groups, emerge as areas of low utilization. Areas of high use are located mainly in urban areas, including block groups both within and outside of the target medically underserved area.

Comparing Fig. 2A and B illustrates that areas with high concentrations of at-risk child poverty do not necessarily have relatively high levels of CHC utilization. The census block group labeled I, in northwest Columbia, shows a high concentration of potentially at-risk children (Fig. 2A). Despite this, Fig. 2B shows that this same block group underutilizes the CHC given its base population. Similarly, block group II, located to the immediate east of the designated medically underserved area, reveals a low number of at-risk children but a relatively high number of CHC use. This type of analysis offers an example of the ways in which GIS can be used to identify variation among specific populations.

Dot density and density surface techniques were combined to create a hybrid map (Fig. 4). The CHC density utilization surface by children residing in households below 200% of the federal poverty level reveals the highest concentration of clinic visits occurs in central Columbia adjacent to the CHC sites. There are, however, several areas of relatively high density outside the original target service region like the cluster to the immediate west of the northernmost tip of the target area. Dots depicting potentially at-risk children reveal a similar distribution, with several clusters found outside of the target area. Comparing the locations of potentially at-risk children (dots) and CHC utilization (surface) reveals that several clusters of potentially at-risk children are not using the CHC. The region east and southeast of the high central density area was of particular concern to CHC staff.

5. Discussion

Marginalized populations, which are located on the periphery or at the edge of society, are in vulnerable positions. These vulnerabilities make these populations more susceptible to inequalities in health care and poorer health outcomes. The ability of nurses to define spaces inhabited by marginalized populations has been limited by our methods of displaying and organizing data in a geographically cognitive way. Nursing would benefit by incorporating knowledge and methods used by geographers in the science of health geomatics. These techniques would enable nurses to forecast spread of disease beyond just the affected cases and provide

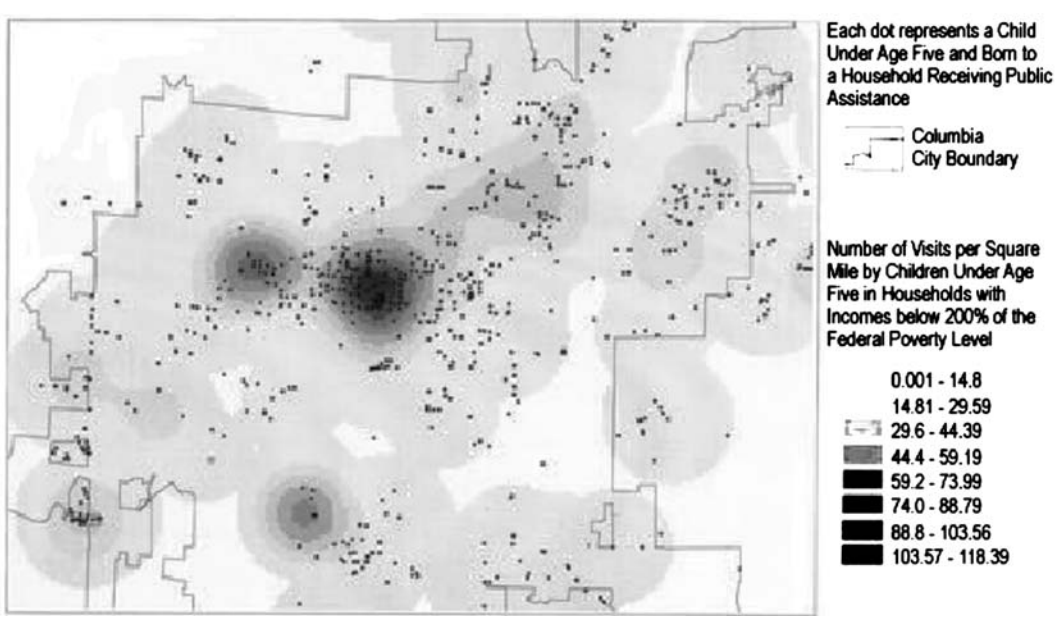

Fig. 4. Child density utilization surface of CHC.

methods of visualizing spatial patterns and relationships that exist in marginalized environments.

Case studies of marginalized populations, such as the medically underserved populations identified in the Boone County's 29 census tracts, provide valuable examples of how geographic methodologies can provide new means to visualize data. The aesthetic value of these methods is displayed in the construction of elaborate maps that use shading to illustrate spatial variation, dots to communicate spatial density, and a regional display to emphasize boundaries, movements, and shifts in marginalized populations. CHC administrators have found these maps important for raising community awareness of their services by placing CHC literature in those areas with high concentrations of at-risk child poverty and low CHC utilization. In addition, maps depicting the overall CHC utilization and at-risk populations were employed to evaluate potential sites for the relocation of the CHC main site.

As potential users of GIS software, nurse researchers need to be aware of limitations in gathering data and populating a GIS. To do this work, nurses must identify data containing geocoded information to link health variables of interest to the location variable. Individual health data with a street address provides the most reliable information for geocoding but create confidentiality issues surrounding individual privacy. In this case study, a distance of 0.1 mile offset actual locations of individual homes. Ideally, health data with census enumeration areas are preferred to assist analysis with census data. However, census tract information is often not available. Commonly, ZIP codes are likely to be the finest spatial resolution available. Unlike census information, ZIP codes can be problematic since they represent an imposed, arbitrary unit of analysis that does not necessarily reflect the natural distribution of the data collected. Further, ZIP codes are not stable temporally; the US Post Office modifies their spatial extent to facilitate mail delivery. Other locators beyond ZIP codes may be useless for geocoding, as with post office box addresses, which are of no value as geographical markers. It is important to recognize that GIS software continues to evolve and, in some situations, may not be comprehensive enough to visualize the data. For nursing and health researchers, geographic information in combination with other health, economic, and social-cultural variables provide supporting data to pinpoint critical population issues and areas of need that, in turn, guide decision making and policy development.

Another limitation relates to scale. Focusing on too small an area can obscure important spatial patterns if patients are drawn from a relatively large geographic area. Maps in this article, for example, only focus on patients and potential patients from one county. While this area accounts for most patients (88%), a sizable number came from surrounding counties. For services designated for a specific geographic region, exclusion of areas adjacent to the targeted service area can hide cases of "border jumping." This may be particularly problematic in those incidences when a service is located near city, county, or state borders.

It is expected that population diversity, migration, and mobility will continue to increase during the next century. Nursing will need to have tools to evaluate changing cultures, changing demography, and changing health patterns. Through partnership with geographers, nurses have the opportunity to use health geomatics to make strategic contributions in service planning, program implementation, and policy development that directly impact the health and welfare of marginalized populations.

References

[1] Dalakar J, Proctor BD. Current population reports, poverty in the United States: 1999. Washington DC: US Census Bureau; 2000. Report No.: Series P60-210.
[2] Knickman J. A foundation executive on access measures. Health Aff 1998;17(1):187–8.
[3] Wright RA, Andres TL, Davidson AJ. Finding the medically underserved: a need to revise the federal definition. J Health Care Poor Underserved 1996;7(4):296–307.
[4] US Census Bureau. People on the move: geographic mobility, 1999–2000. 2000.
[5] Phillips RL, Kinman EL, Schnitzer PG, Lindbloom EJ, Ewigman B. Using geographic information systems to understand health care access. Arch Fam Med 2000;9:971–8.
[6] Hall JM, Stevens PE, Meleis AI. Marginalization: a guiding concept for valuing diversity in nursing knowledge development. ANS Adv Nurs Sci 1994;16(4):23–41.
[7] Choi H. Cultural marginality: a concept analysis with implications for immigrant adolescents. Issues Compr Pediatr Nurs 2001;24:193–206.
[8] Stevens P. Marginalized women's access to health care: a feminist narrative analysis. ANS Adv Nurs Sci 1993;16(2):39–56.
[9] Esposito NW. Marginalized women's comparisons of their hospital and freestanding birth center experiences: a contrast of inner-city birthing systems. Health Care Women Int 1999;20:111–26.
[10] Mehretu A, Pigozzi B, Sommers L. Concepts in social and spatial marginality. Geogr Ann 2000;82(B):89–101.
[11] Minick P, Kee CC, Borkat L, Cain T, Oparah-Iwobi T. Nurses' perceptions of people who are homeless. West J Nurs Res 1998;20(3):359–69.
[12] Popovich M, Fiedler R, Fiedler S, Massee J. Bioterrorism GIS can help fight a new threat. Available from: http://www.geoplace.com/gw/2002/0207/0207bio.asp; June 2, 2002.
[13] Meuhrcke PC. From reality to map. In: Earle C, Mathewson K, Kenzer M, editors. Concepts in human geography. Lanham, MD: Rowman and Littlefield; 1996. p. 273–92.
[14] Lewis ND, Mayer JD. Disease as a natural hazard. Prog Hum Geog 1988;12:15–33.
[15] Miranda ML, Dolinoy DC, Overstreet MA. Mapping for prevention: GIS models for directing childhood lead poisoning prevention programs. Environ Health Persp 2002;110(9):947–53.
[16] Maantay J. Mapping environmental injustices: pitfalls and potential of geographic information systems in assessing environ-

mental health equity. Environ Health Persp 2002;110(Suppl 2):161–71.
[17] Blake BJ, Bentov L. Geographical mapping of unmarried teen births and selected sociodemographic variables. Public Health Nurs 2001;18(1):33–9.
[18] Whitener (Miller) LC. Using Hongvivatana's model to evaluate health care access: a field study of adolescent women's access to reproductive health care services in rural Missouri counties. [Unpublished doctoral dissertation]. Columbia, MO: University of Missouri-Columbia; 2000.
[19] Missouri Spatial Data Information Service; 2003.
[20] Clark KC, McLafferty SL, Tempalski BJ. On epidemiology and geographic information systems: a review and discussion of future directions [review]. Emerg Infect Dis 1996;2:85–92.
[21] Griffith JR. Quantitative techniques for hospital planning and control. Lexington, MA: Lexington Books; 1972.
[22] Simpson K, DesHarnais S, Jacobs A, Menapace A. Methods for defining medical service areas. In: Ricketts TC, Savita LA, Gelser WM, Osborne DN, editors. Geographic methods for health services research. Lanham, MD: University Press of America; 1994. p. 207–32.
[23] Meade MS. Changes and measures in the crucial dimension of population. In: Ricketts TC, Savita LA, Gelser WM, Osborne DN, editors. Geographic methods for health services research. Lanham, MD: University Press of America; 1994. p. 49–80.
[24] Mitchell A. The ESRI guide to GIS analysis vol I: geograhical patterns and relationships. Redlands, CA: Environmental Systems Research Institute (ESRI); 1999.