Mapping Supply and Demand in Kentucky's Health Care System

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Introduction & Background Release of the most recent Kentucky health assessment paints a grim picture of the current health and well-being of Kentucky residents (Surveillance and Health Data Branch 2000). In 2000, Kentucky had the 10th highest death rate in the nation, the third highest rate of heart disease and cancer, and the 14th highest rate for unintentional injuries. Kentucky also has the highest percentage of smokers in the nation, the second highest prevalence of obesity, and the eighth highest rate of child poverty. These statistics, however, fail to convey variations in the spatial distribution of disease occurrence and corresponding distributions of hospitals and care facilities. Most previous research focuses on the geography of disease and health problems through the field of spatial epidemiology (Cromley 2003) using disease mapping, geographical correlation studies, risk assessment, and disease clustering (Elliot et al. 2000). Relatively little work has addressed the supply and demand issues related to health services.

This paper begins to fill this gap. We analyze the geographical distribution of supply and demand in Kentucky's health care system using maps of hospital usage by zip code zone to explore the distribution of demand for four categories of diagnosis-related groups (DRGs): circulatory, respiratory, neonatal and infant, and endocrine conditions. We also use maps of service locations and driving times to characterize the spatial nature of the supply of health care services and delineate potentially underserved areas. Finally, we create usage maps of particular hospitals by the four categories to characterize hospital service areas. This analysis is possible because of recent advances in spatial information technologies. GIS technology, in particular, is opening up new realms for

the study of how different types of service delivery systems interact with particular forms of spatial consumer demand (Yeates 2001).

GIS and Health Geographic Information Systems have revolutionized the way researchers explore numerous social and environmental issues (Hochberg *et al.* 2000; Longley *et al.* 1999; Lyon and McCarthy 1995), including the geography of health (de Lepper *et al.* 1995; de Savigny and Wijeyaratne 1995; Gatrell and Senior 1999; Ricketts 2003; Scholten and de Lepper 1990). One reason for the slower development of GIS-based investigations of health care services is the massive quantity of data required for such investigations at even moderate levels of spatial scale. Nonetheless, the need for such analyses has been documented in the context of debates over the importance of the national information infrastructure (U.S. Public Health Service 1995).

Research has begun to include attention to the geography of health care services (Bullen *et al.* 1996; McLafferty 2003). These studies analyze health care need, access, and utilization and are directed at supporting the planning and evaluation of service locations (Gatrell and Senior 1999:926). In other words, researchers are developing new techniques to support spatial decision-making for health care delivery systems. Some of these studies create models of customer flows (Birkin, Clarke, and Clarke 1999; Fischer 1999). Such flow mapping often utilizes Euclidean distance but travel expense or duration of travel along transportation networks can provide more realistic estimates of the effects of geographic distance on consumer behavior (Bullen *et al.* 1996; Gattrell 1983; Sen and Smith 1998; Wilson 1967, 1970). Utilization of travel cost might be essential in areas such as Appalachia where the terrain and status of roads, especially through seasonal changes in weather patterns, can constrain travel activities.

The interaction between the locations of demands for health services and the locations of health care centers necessitates the investigation of accessibility and utilization. Previous studies utilize GIS to define health service localities (Bullen et al. 1996), assess new locations for specific health services (Forbes and Todd 1995) and to calculate the potential accessibility of specialized services to populations with limited mobility (Love and Lindquist 1995). These comparisons of health center locations and consumer demand often entail the integration of point-referenced data, such as hospitals, with area-referenced socio-economic data (Brown *et al.* 1991; Carstairs and Morris 1991). In this context, GIS is used to identify service zones and describe associated patient profiles through comparison with social and economic data.

Study Area Kentucky encompasses 39,728 square miles and is divided into two zones by Appalachia, which occupies the southeastern third of the state (Figure 1). The population in 2000 was 4,041,769 and the population density was 101.7 persons per square mile (U.S. Census Bureau 2000). Kentucky is a relatively rural state with three primary metropolitan areas, all located in the northern and central regions of the state (Figure 2). Residents of counties distant from urban centers, particularly those in Appalachia, face significant barriers to acquiring health services (Stensland et al. 2002), including the lack of hospital-affiliated substance abuse treatment services in distressed counties, the lack of hospital-affiliated psychiatric services, and the lack of obstetric care. While several organizations have undertaken investigations of health care services in Kentucky, none have focused on geographical patterning below the county level. Most previous studies aggregated data into larger zones or ignored spatial patterning altogether. For instance,

the most recent Kentucky DPH report on Ambulatory Surgical Services aggregated data by Area Development Districts (ADDs) which lump Kentucky's counties into fifteen areas and did not use a GIS (Health Policy Development Branch 2003) to facilitate visualization and analysis. Other investigations have used detailed studies of a sample of health services in local areas, but without explicit attention to the effect of their relative locations (Kelly 2002; Schoenberg *et al.* 2001). The Kentucky Cancer Registry (KCR) Incidents web-GIS is the most sophisticated application of new spatial technologies to the study of health phenomena in Kentucky (2002). The KCR provides access to a spatial database of cancer incidents by type of cancer, but only at the county level and above.

Data and Methods We use hospital discharge records provided by the Kentucky Department of Public Health, which includes information about patients discharged from any Kentucky hospital during 2002. Discharge records contain demographic and health data for individuals by zip code. Included in the database are the primary treatment options, major disease categories (MDC), Diagnosis Related Groups (DRG) and ICD9 codes for diagnoses and procedures. By definition, individuals captured in the database spent at least one night in the hospital and therefore the records reflect relatively acute or severe cases. Since the purpose of this paper is to assess supply and demand for health services, four major categories of disease were selected for the initial analysis. These include circulatory, respiratory, neonatal and infant, and endocrine conditions. We use these conditions as indicators of overall demand.

Supply of health services is defined by the location of hospitals and health clinic in Kentucky (Figure 3). There are 132 inpatient health care clinics / hospitals in

Kentucky. These include large multiservice urban hospitals, rural regional medical centers, small local clinics, and behavioral health facilities. All of these health care centers report inpatient usage data to the Kentucky Department of Public Health and most of these submit service information to the American Hospital Association's Annual Survey (AHA 2004). Facility locations were determined by geocoding associated addresses. Data on service availability were tabulated and linked to the spatial database of facility locations.

Software and Methods We use ESRI's ArcGis 9.0 and ArcView 3.3 for processing, visualization, and accessibility analysis of the data, and GeoDa 0.9.5-i to apply a variety of exploratory spatial data analysis techniques. GeoDa is a free collection of software tools for a variety of spatial analysis techniques (Anselin, 2003 & 2004) and supports dynamic and interactive analysis of linked tables, charts, and maps. Preliminary data analysis revealed complex patterns and significant spatial autocorrelation. Spatially autocorrelated data contradict the statistical assumption of the independence of observations and underlying spatial effects can distort the results of statistical analyses (Messner and Anselin, 2002). To alleviate these problems, we selected several spatial statistical techniques that provide inferential tests of spatial patterns. These techniques reduce the subjectivity in the interpretation of complex patterns and minimize the impact of spatial effects, such as spatial dependence and heterogeneity.

The spatial distributions of hospital usage were assessed using a variety of thematic maps, charts, and spatial statistics, including univariate Moran's I, Moran Scatterplots, and univariate Local Moran LISA cluster maps (Anselin, 2003 & 2004).

GeoDa calculates significance values for Moran's I and Local Moran using a permutation approach that compares the data with spatially random distributions of the same data values. The spatial weights matrix used was based on rook's case contiguity.

Local Indicators of Spatial Association (LISA) compare values in specific locations with those in their neighbors and test the null hypothesis of spatial randomness in their associated distributions. LISA techniques applied to a single variable highlight statistically significant clusters of positive or negative spatial autocorrelation.

Results

Hospital Service Demand We examined the distribution of four prominent disease categories, based on discharge data for 2002. These categories include diseases and disorders of the respiratory and circulatory systems, diabetes related hospital discharges, and discharges related to newborns excluding births without complications. Figures 4, 5, 6, and 7 show the spatial distribution of patients by zipcode. These figures suggest that there is a strong spatial patterning of Diabetes and Respiratory related disorders. Appalachian Kentucky, and especially areas in the southeastern corner of the state, appear to have higher rates than other areas. Disorders related to the circulatory system also appear clustered in this area although the extent of clustering is not as broad. Very little clustering appears to occur for problems related to newborns, rather areas of higher incidence seem to be scattered across the state. We ran both global and local autocorrelation statistics using GEODA. Global Moran's I statistics range from 0.025 to 0.042 suggesting that there is little spatial autocorrelation. Although the global measures

suggest low overall spatial autocorrelation, local level statistics suggest that there are still several important and significant clusters.

Supply of Hospital Services To measure the supply of hospital services and their accessibility, we used drive time estimates at fifteen, thirty, and sixty minutes from hospital facilities. Figure 8 shows thirty minute drive times from all inpatient hospital services and reveals that the western area has almost full coverage, but significant gaps exist in the eastern Appalachian region. These gaps are even more evident when examining specific types of health services. For instance, figure 9 shows fifteen, thirty, and sixty minute drive times from all facilities with cardiac intensive care units. The pattern reinforces that presence of gaps in health care coverage in the eastern half of the state and is replicated by analyses of other health care services. These gaps in service availability and accessibility represent areas of particular need.

To understand the nature of the availability of hospital services in greater detail, we examine the usage of a single hospital, St. Claire Medical Center, by our four aggregated DRG categories. Figure 10 shows the total usage of St. Claire by frequency of inpatients by zip code and reveals the expected pattern of fall-off of usage with increasing distance from the center. Mapping the usage by particular services reveals a more complex pattern. Figures 11, 12, 13, and 14 depict usage of St. Claire services by our four aggregate DRG categories; cardiac, respiratory, endocrine, neonate and infant-related conditions. They generally show a consistant pattern of distance decay. The endocrine-related usage is striking in its extensive geographic distribution and because of the presence of inpatients who originate from areas within closer proximity to other large hospitals. For instance, the pattern extends to the zip code zones directly adjacent to

Lexington which contains many large and small hospitals. We look forward to examining the service areas of other hospitals in the area to better understand the nature of boundaries and overlaps between service areas. In addition, we will explore the nature of service areas for more specific categories of diagnoses and procedures.

Conclusions The application of a variety of univariate and bivariate techniques of exploratory spatial data analysis and thematic mapping reveal distinct patterns of supply and demand in Kentucky's health care system. Specifically, we find pockets of demand located in many rural areas, particularly in southeastern Kentucky. We also find corresponding gaps in the supply of related services. Closer examination of one health care facility reveals a complex set of patterns of usage by aggregated DRG's that suggests that other factors influence patient selection of particular health facilities. For instance, peoples' selection of facilities might be influenced by home county, insurance, particular doctors, proximity to friends and family, and transportation availability. Finally, these patterns reflect aggregated DRG's. Using more specific categories such as individual diagnoses and procedures are important in assessing the nature of boundaries and overlaps among health care service areas.

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List of Figures

Figure 1. Kentucky Population Distribution.

Figure 2. Base Map of Kentucky.

Figure 3. Total Inpatient Hospital Usage.

Figure 4. Hospital Usage Total Cardiac-Related DRG's by Zip Code Zone.

Figure 5. Hospital Usage Total Diabetes-Related DRG's by Zip Code Zone.

Figure 6. Hospital Usage Total Neonate-Related DRG's by Zip Code Zone.

Figure 7. Hospital Usage Total Respiratory-Related DRG's by Zip Code Zone

Figure 8. Total Area within 30 Minutes Driving Time of a Kentucky Hospital.

Figure 9. Total Area within 15, 30, & 60 Minutes Driving Time of Kentucky Hospitals with Cardiac Intensive Care Units.

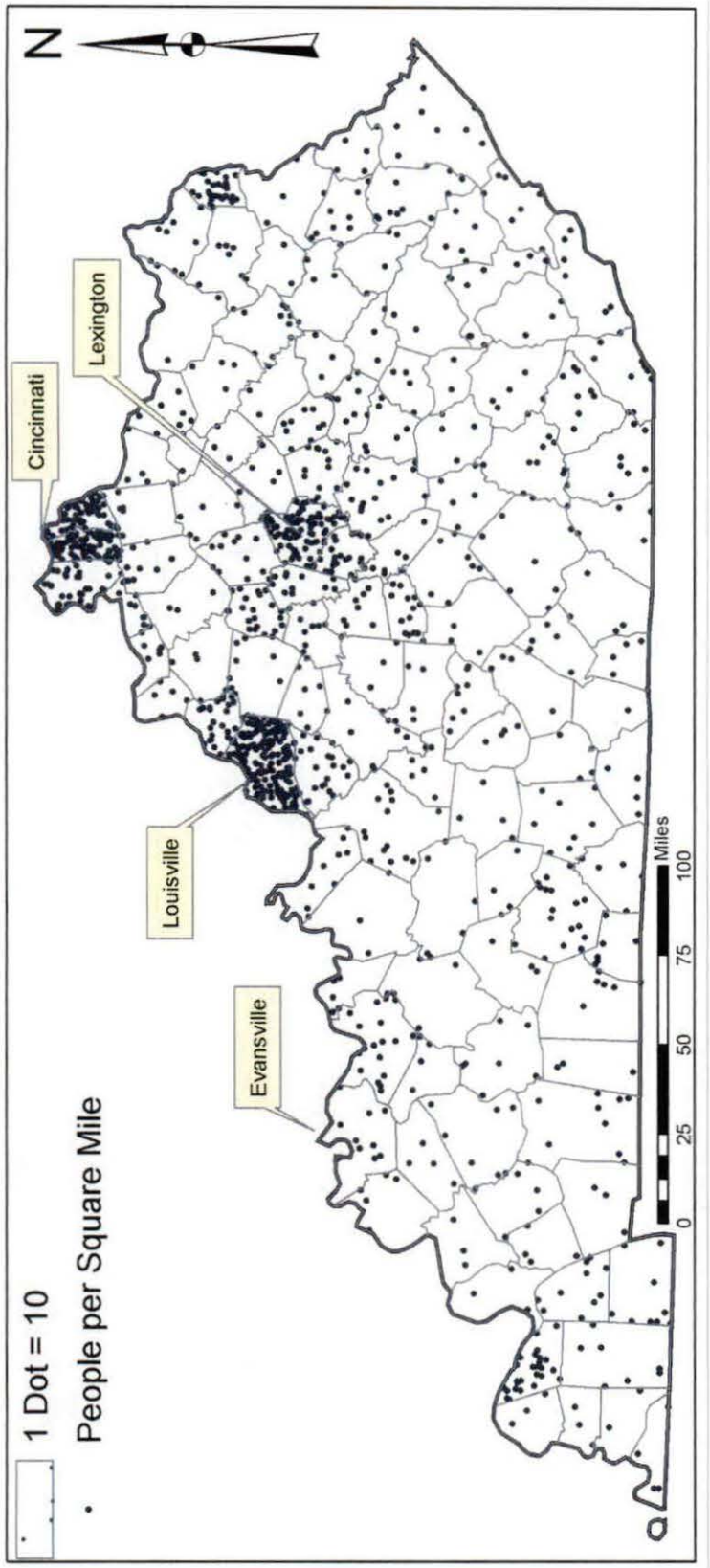
Figure 10. Total Usage of St. Claire Medical Center by Zip Code Zone.

Figure 11. Cardiac-Related Usage of St. Claire Medical Center.

Figure 12. Respiratory-Related Usage of St. Claire Medical Center.

Figure 13. Endocrine-Related Usage of St. Claire Medical Center.

Figure 14. Neonate-Related Usage of St. Claire Medical Center.



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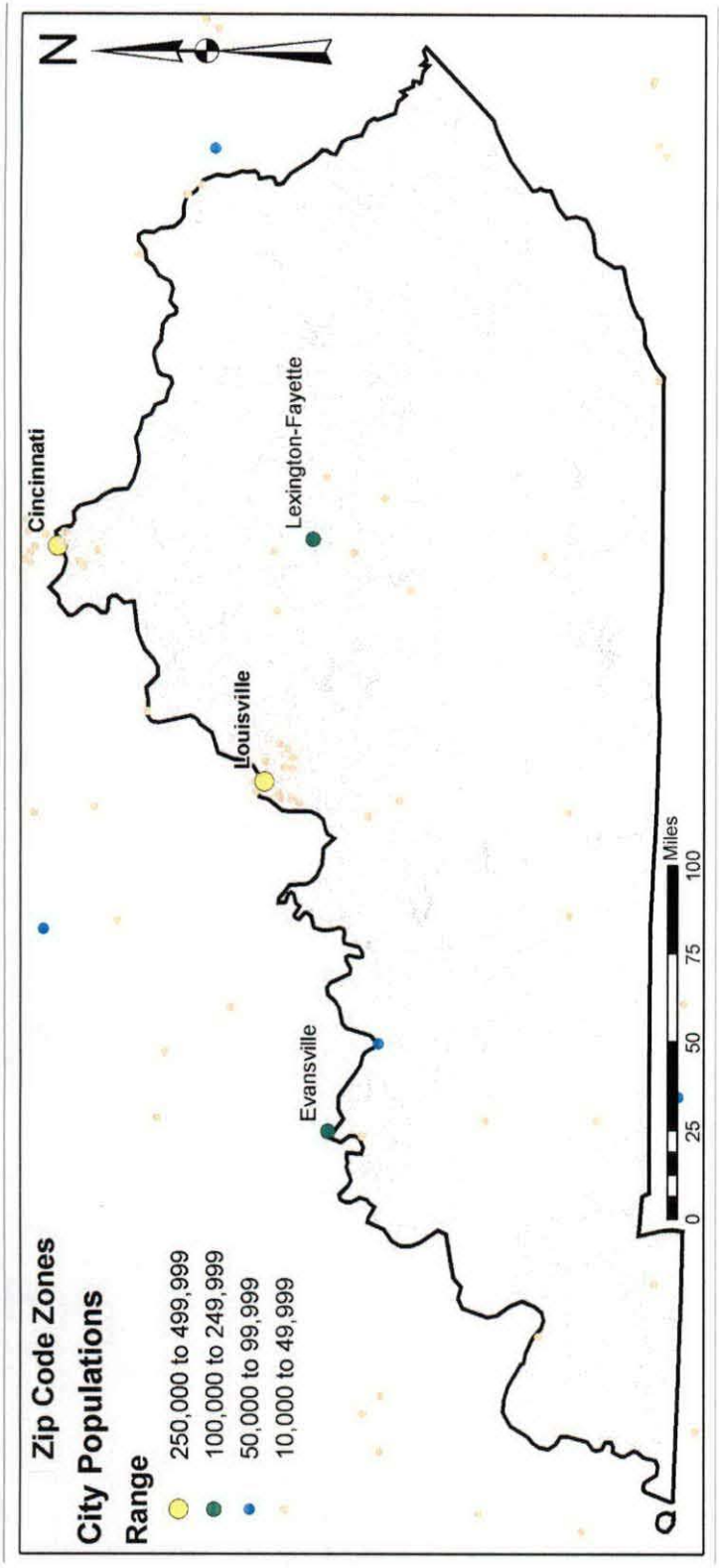


Figure 2. Base Map of Kentucky.

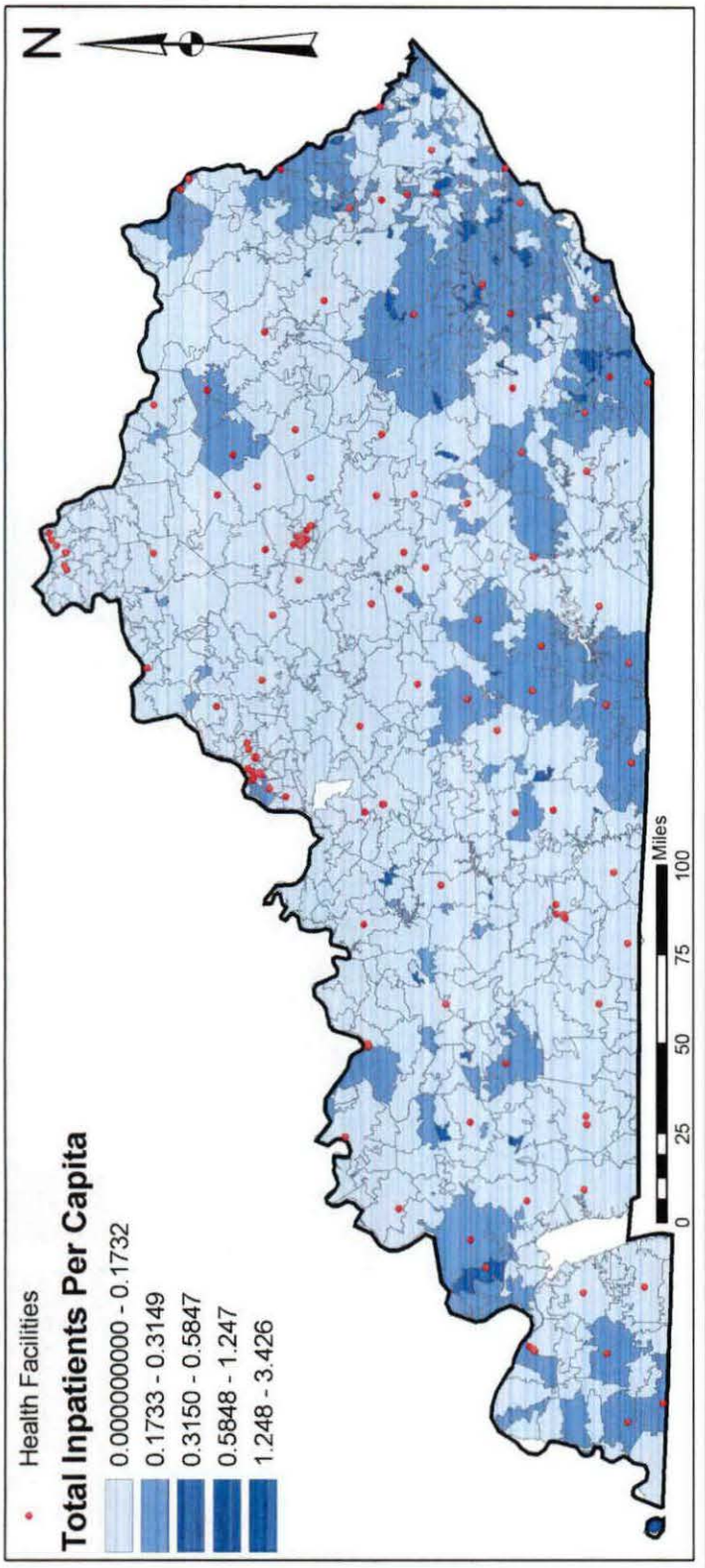


Figure 3. Total Inpatient Hospital Usage.

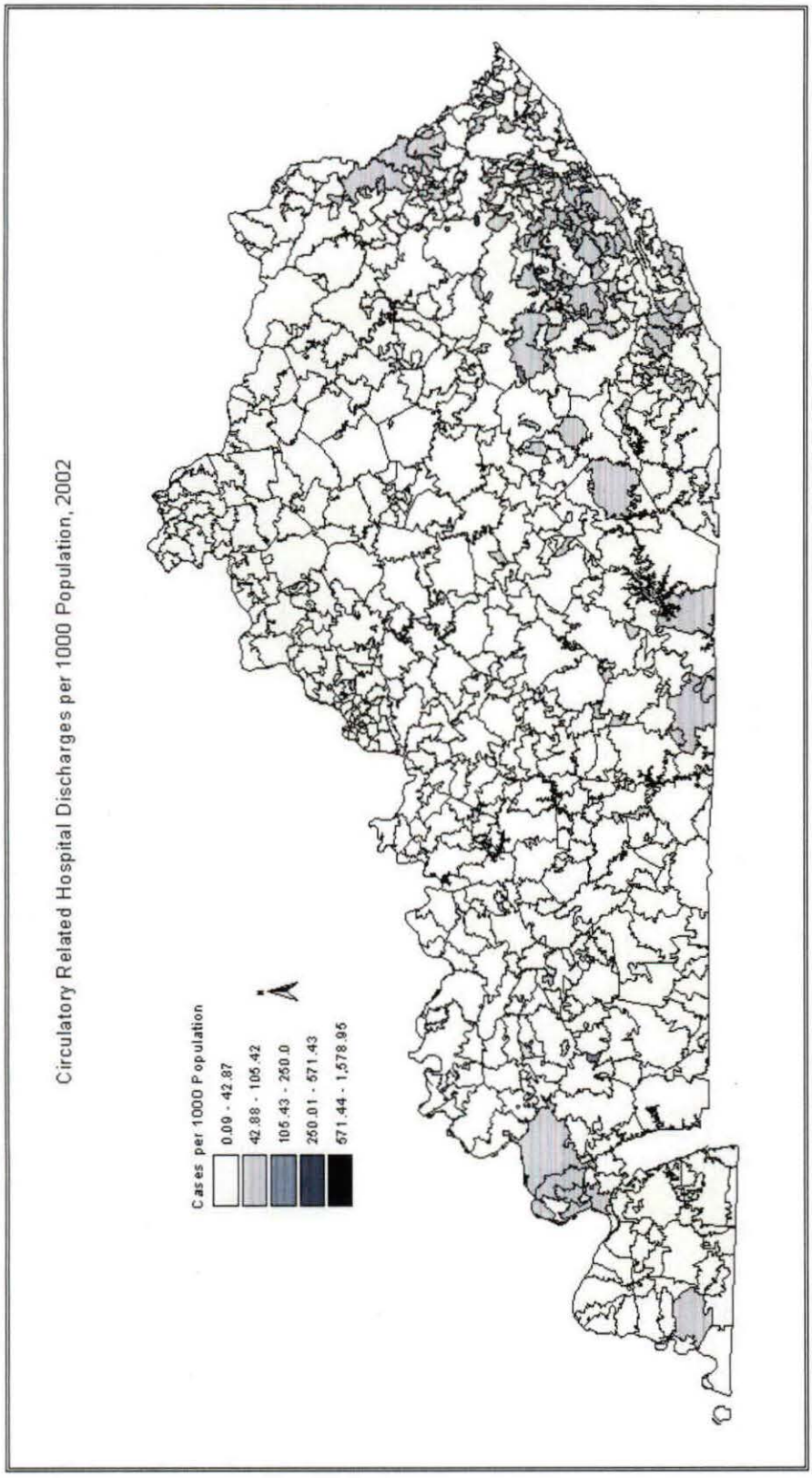


Figure 4. Hospital Usage Total Cardiac-Related DRG's by Zip Code Zone.

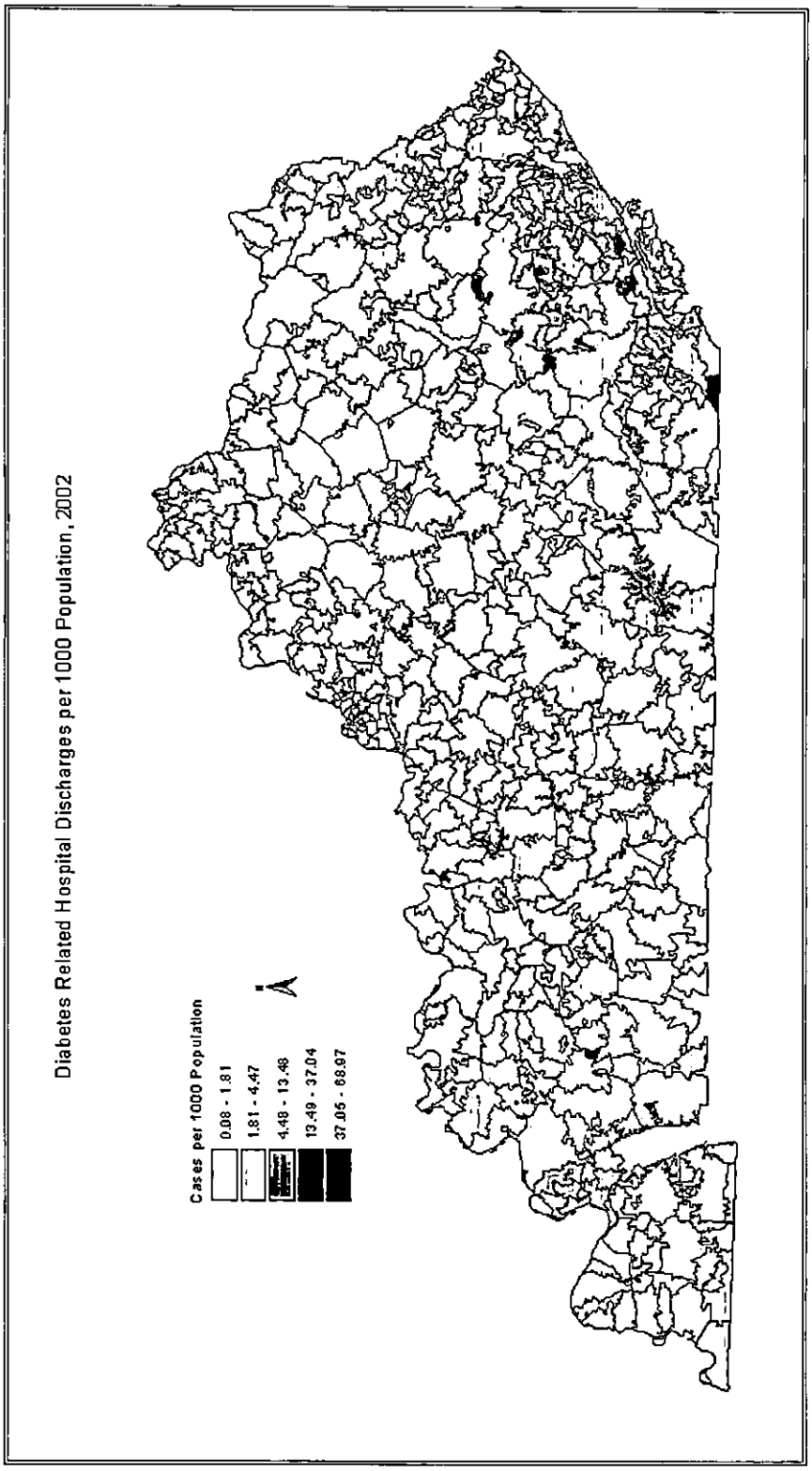


Figure 5. Hospital Usage Total Diabetes-Related DRG's by Zip Code Zone.

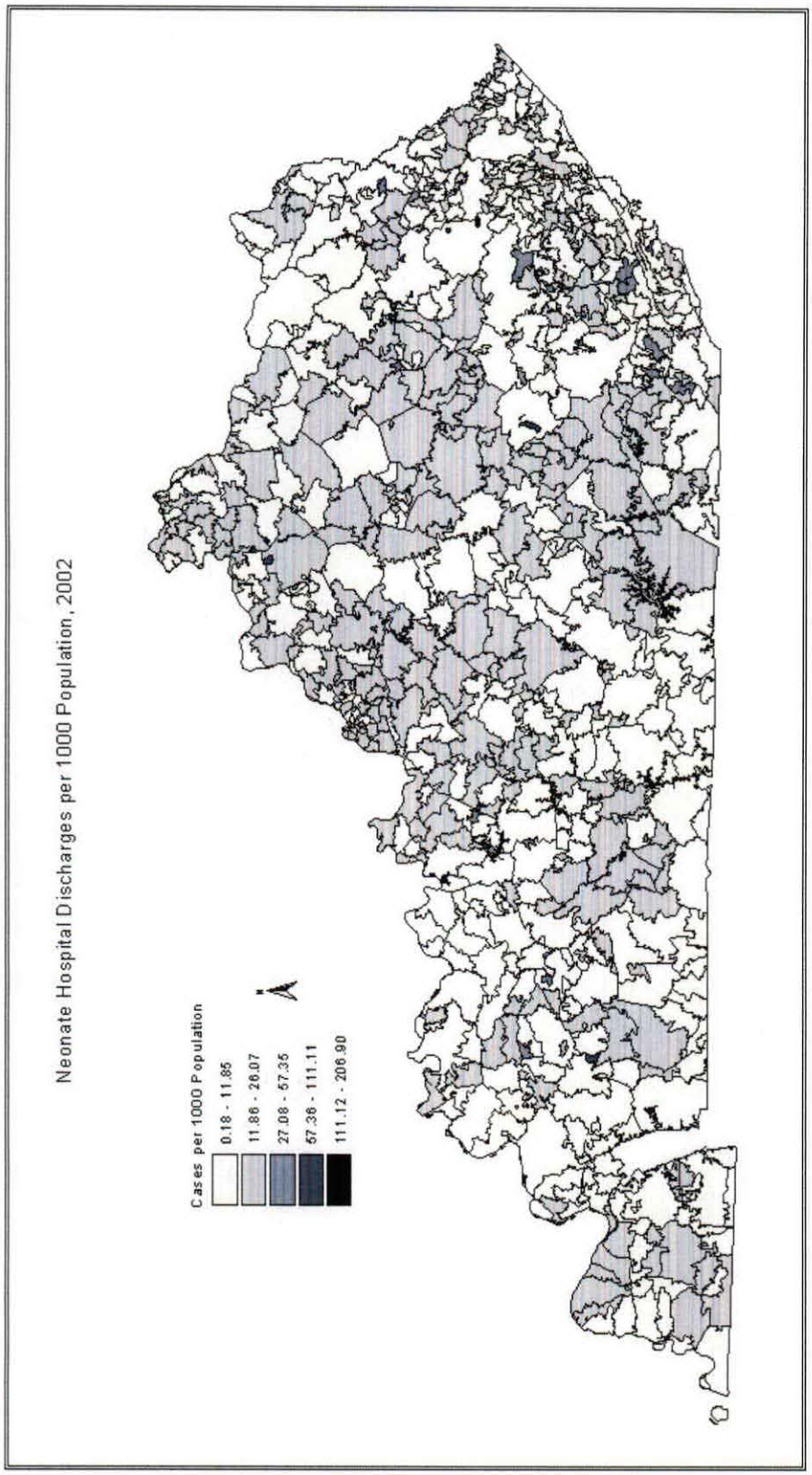


Figure 6. Hospital Usage Total Neonate-Related DRG's by Zip Code Zone.

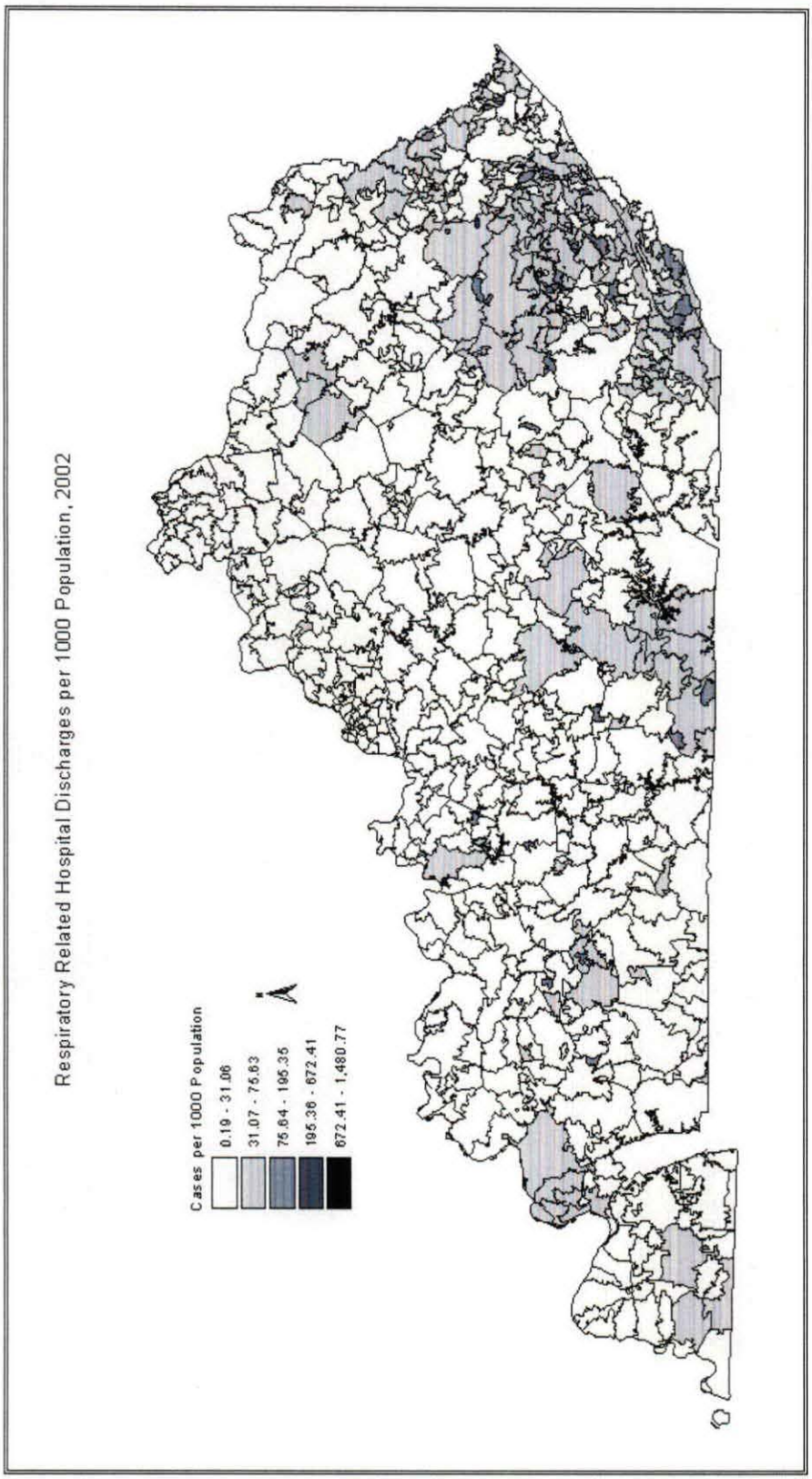
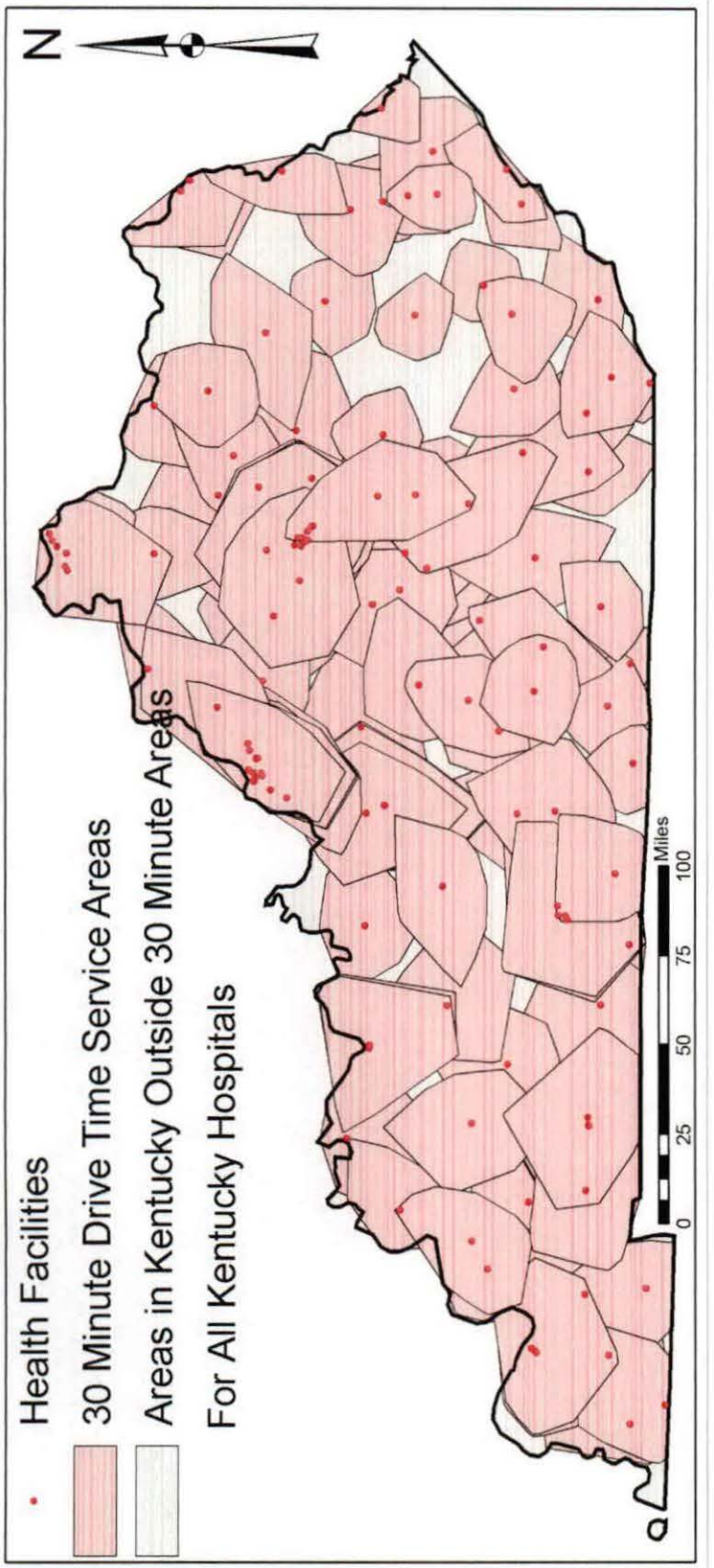


Figure 7. Hospital Usage Total Respiratory-Related DRG's by Zip Code Zone.



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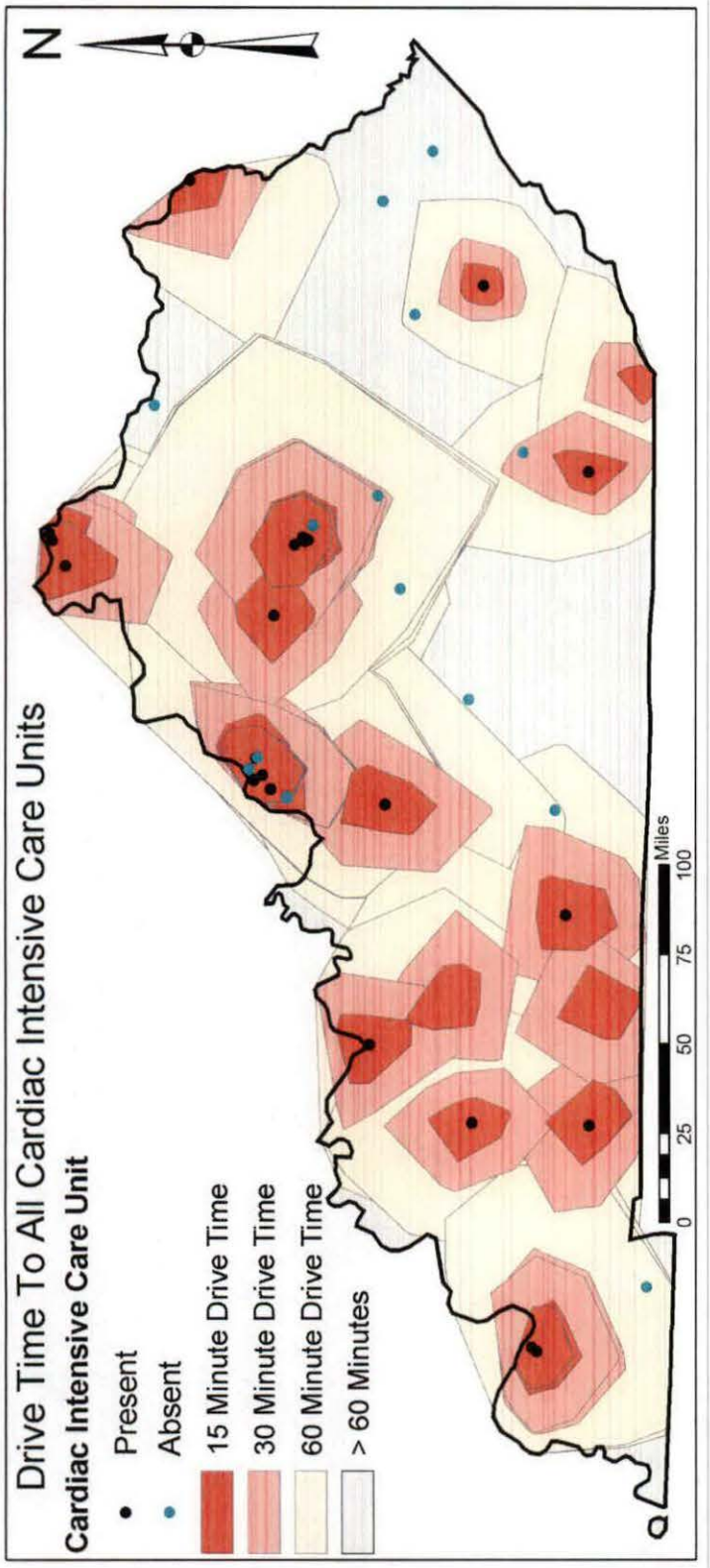

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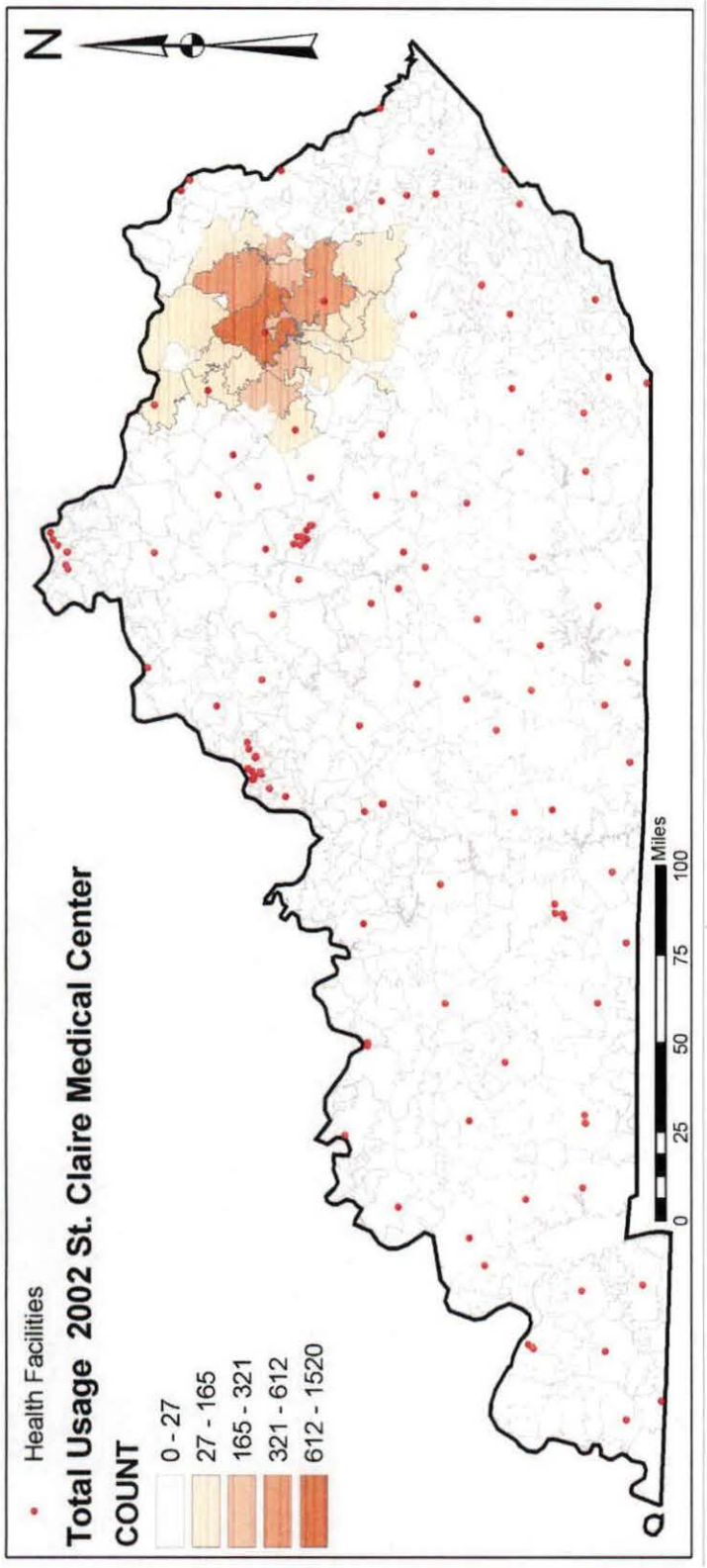

Figure 10. Total Usage of St. Claire Medical Center by Zip Code Zone.

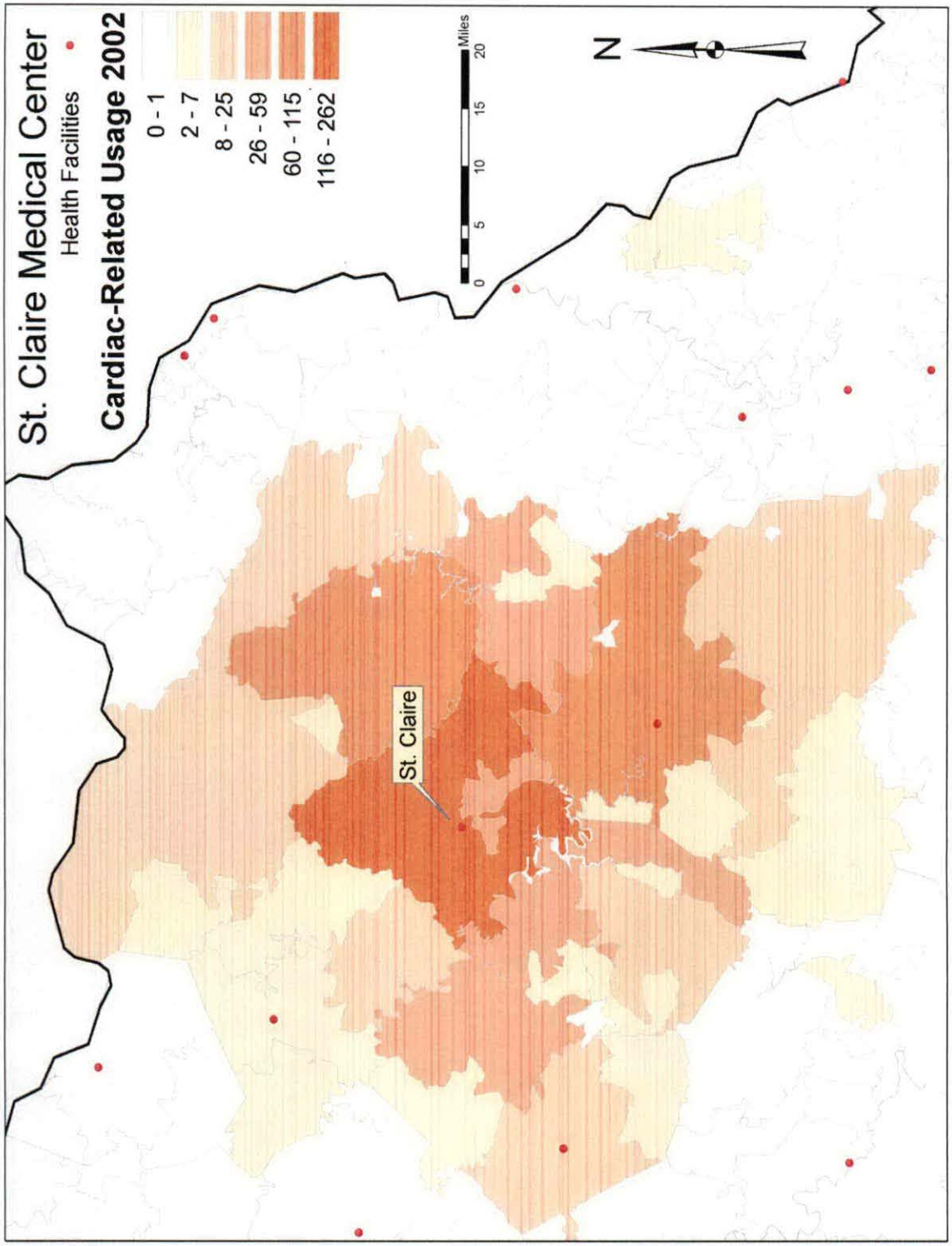

Figure 11. Cardiac-Related Usage of St. Claire Medical Center.

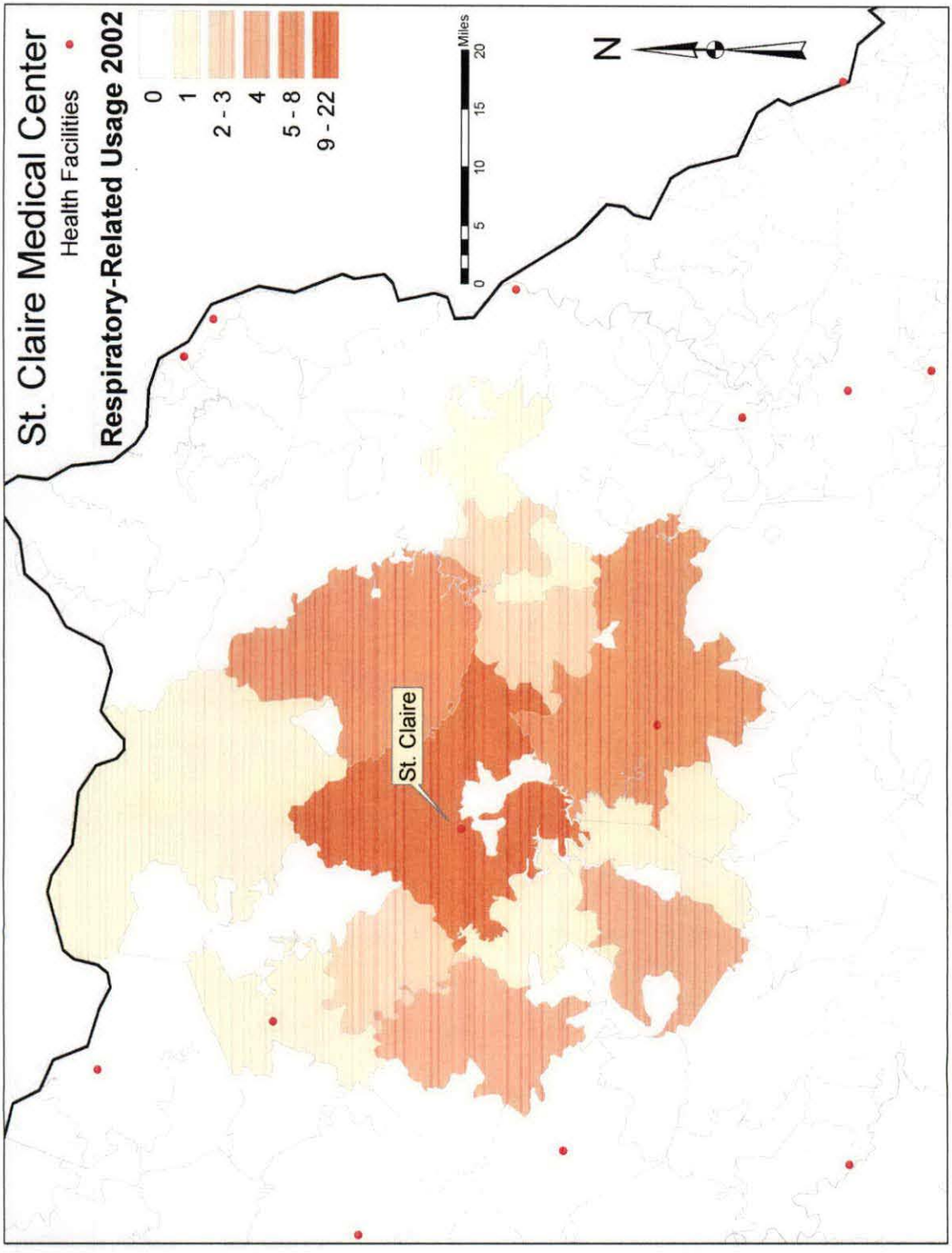

Figure 12. Respiratory-Related Usage of St. Claire Medical Center.

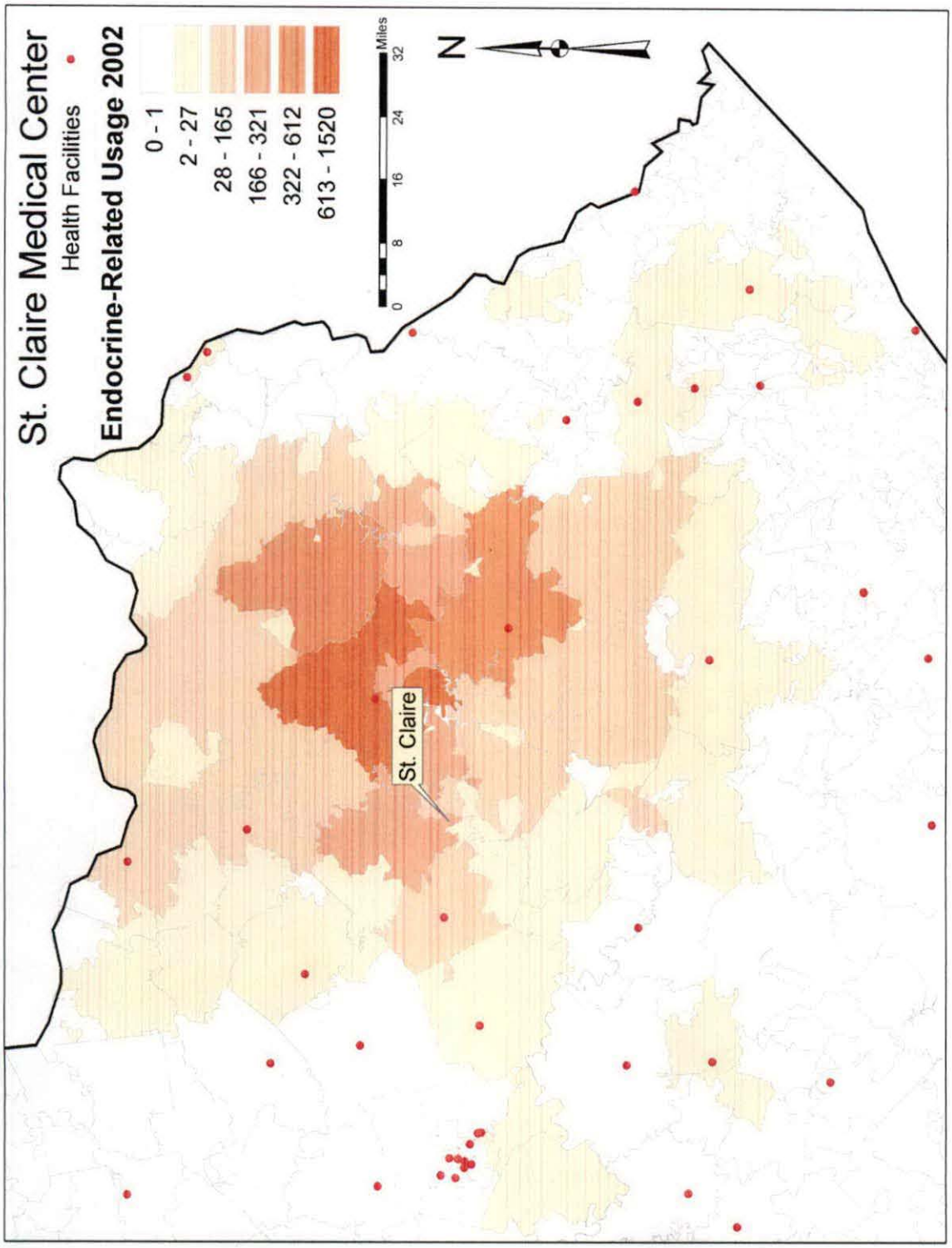

Figure 13. Endocrine-Related Usage of St. Claire Medical Center.

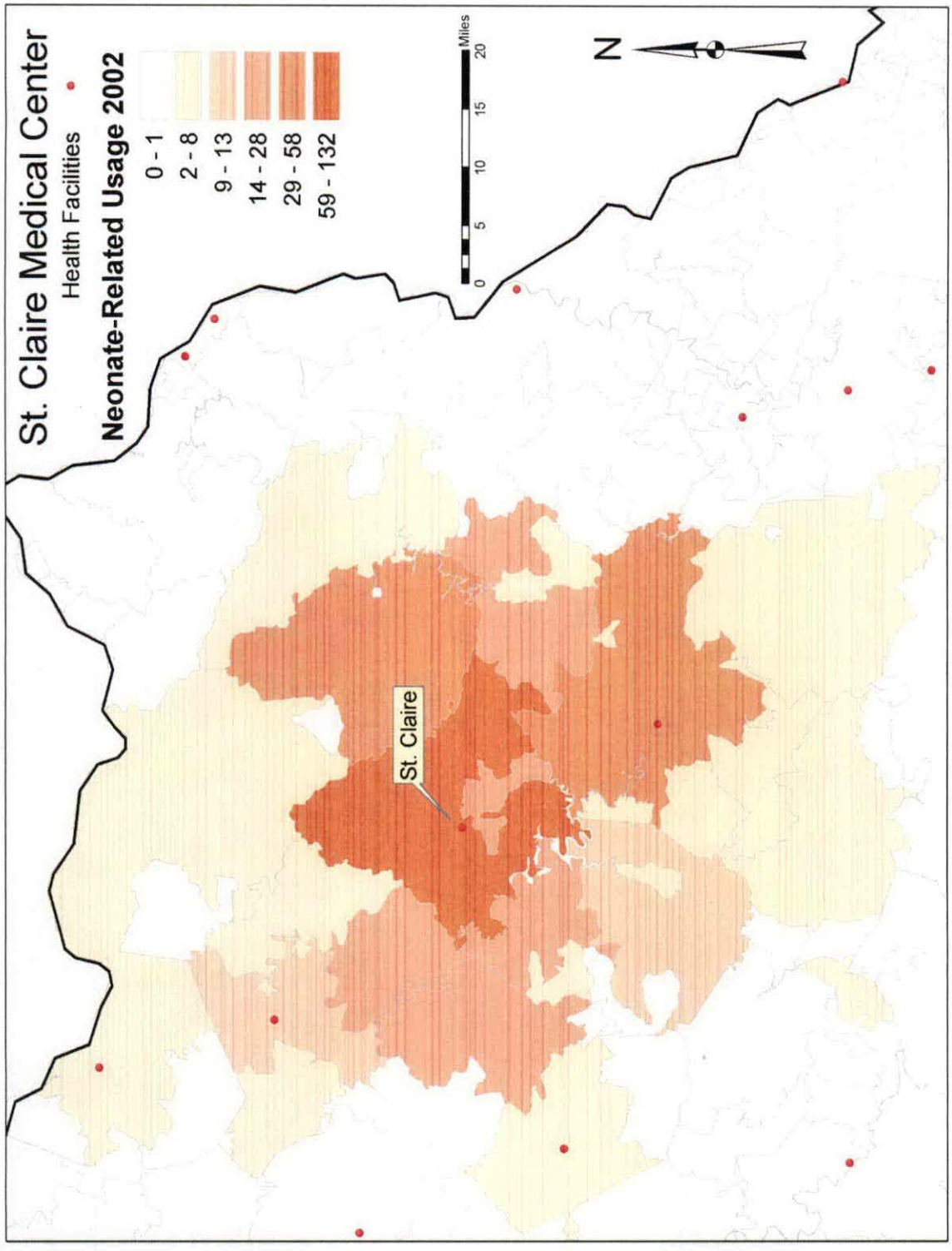

Figure 14. Neonate-Related Usage of St. Claire Medical Center.

Mapping the Use of Kentucky's Health Care Services with the AHA Survey & the 2002 Hospital Discharge Database

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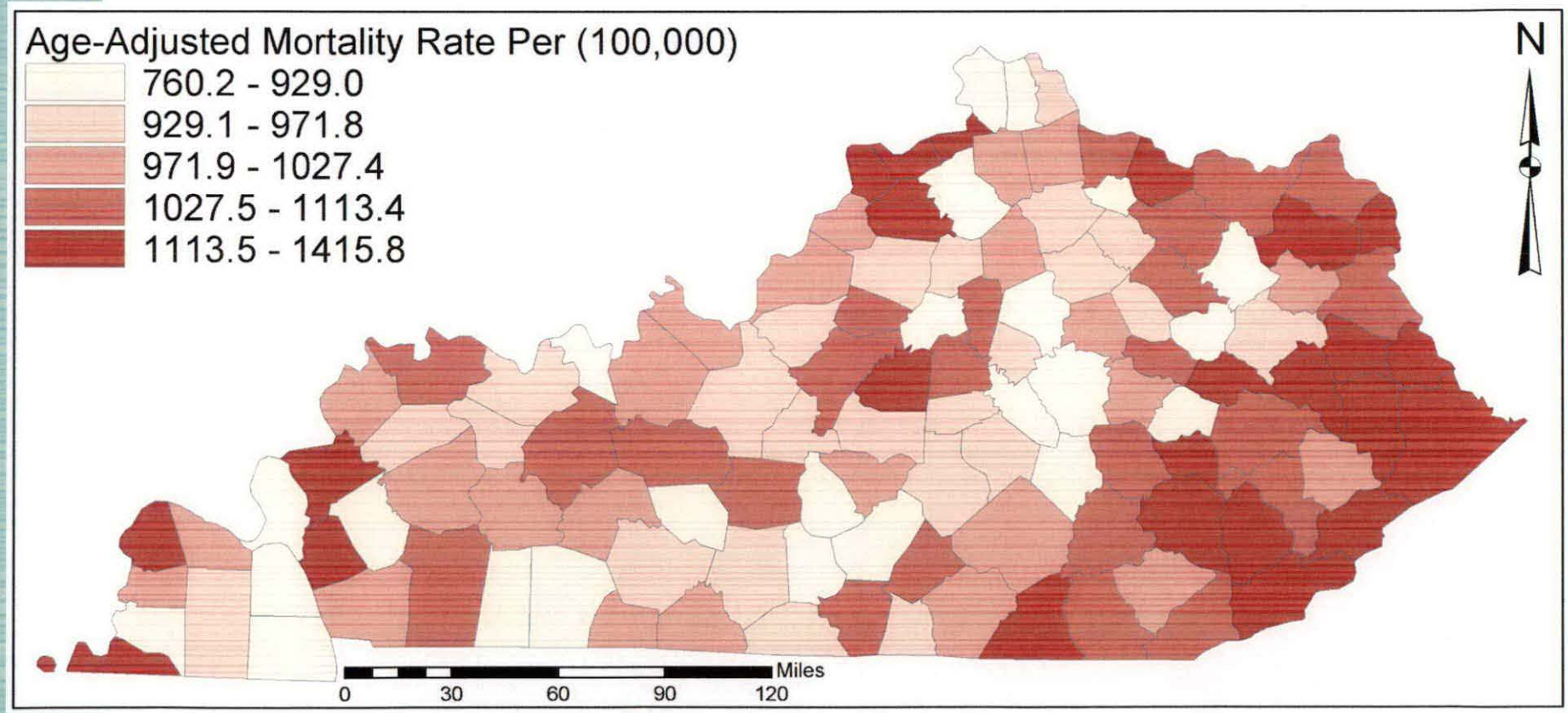
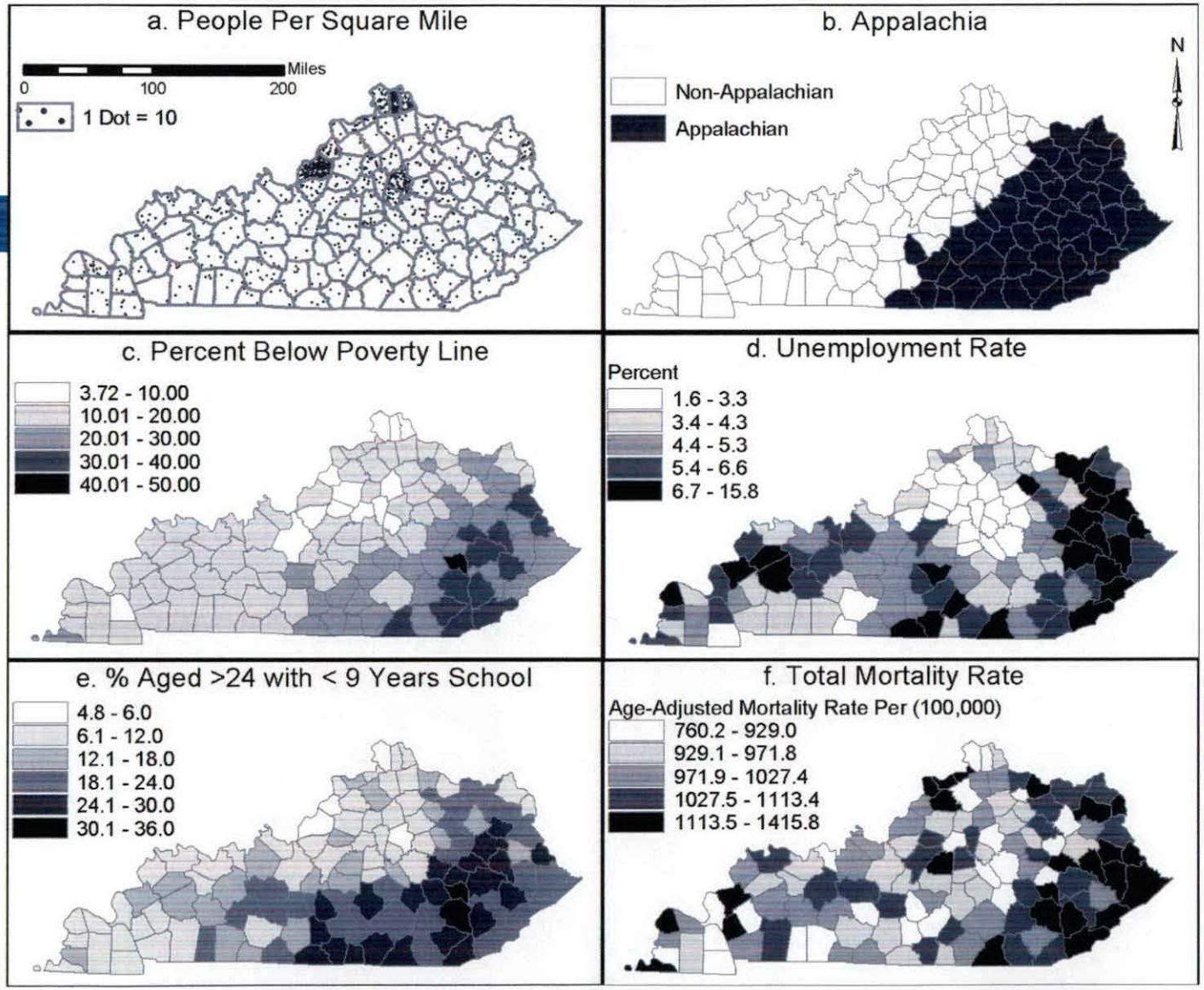
Total 2000 Mortality Rates



Background: Kentucky Stats



Goal: analyze the geographical distribution of supply and demand in Kentucky's health care system

- maps of hospital usage by zip code zone
  - For all hospitals
  - For individual hospitals
  - Total & by particular DRGs
- maps of service locations and driving times
  - Total & by particular services
- maps of the usage of particular hospitals by zip code zone
  - Total & by particular DRGs

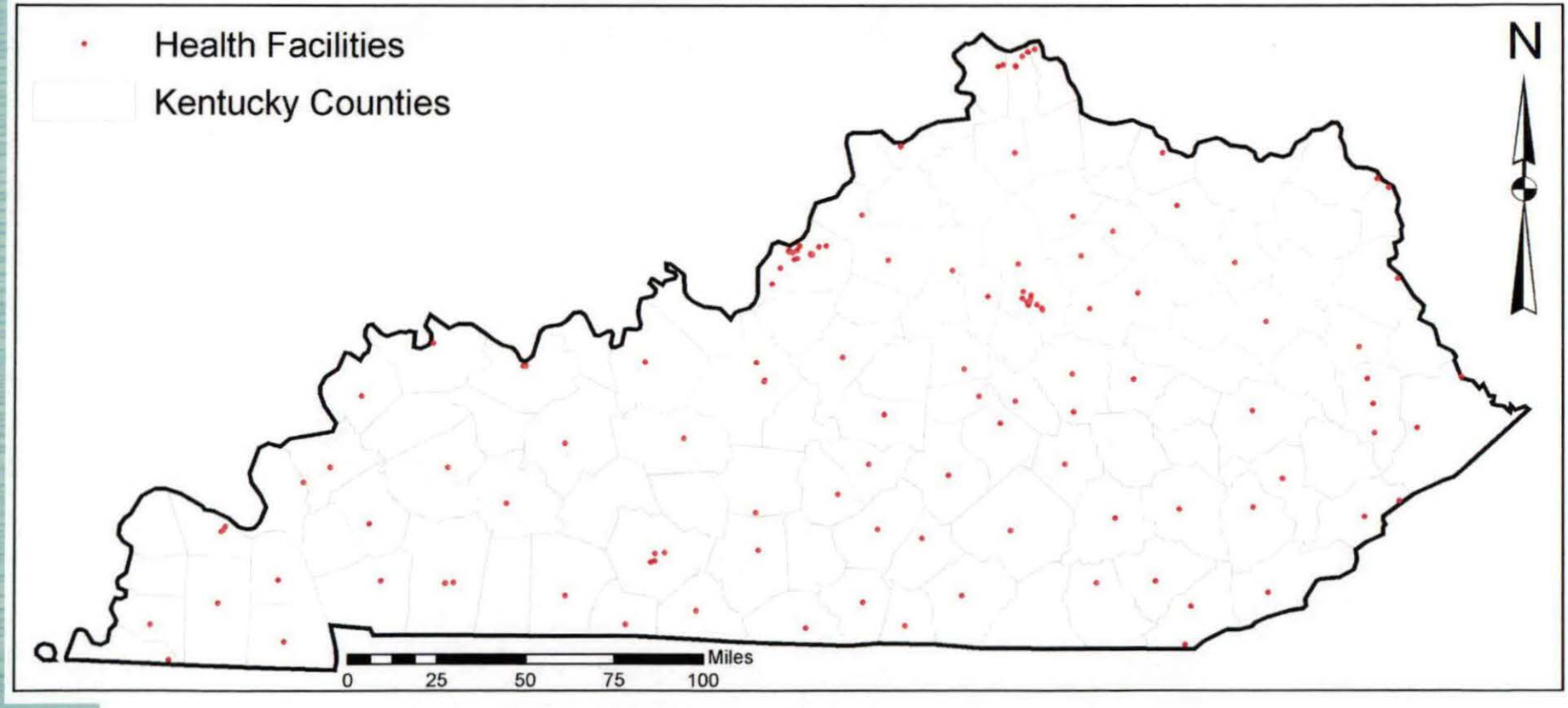
Data

- 2002 Kentucky Hospital Inpatient Use Database
- AHA Hospital Survey
- KY Transportation Cabinet's State maintained and local road centerlines

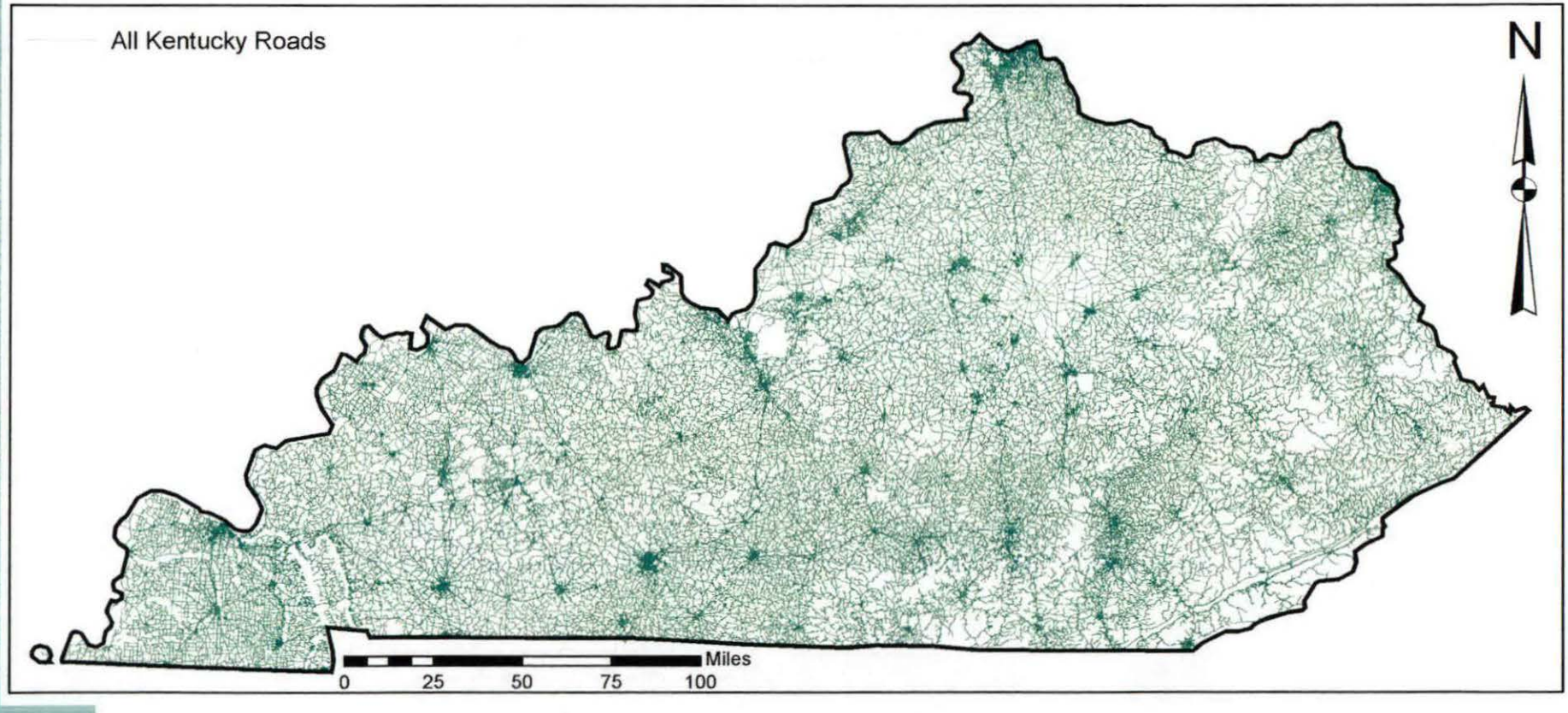
2002 Hospital Inpatient Use Database

- 622,498 events
- Mapped to zip code zones
- ICD9CM – diagnoses & procedures
- Major Diagnostic Group (MDG)
- Diagnosis Related Group (DRG)
- Miscellaneous Categories
  - Age groups, discharge status, pay source, & sex

The American Hospital Association Hospital Survey



KY Transportation Network



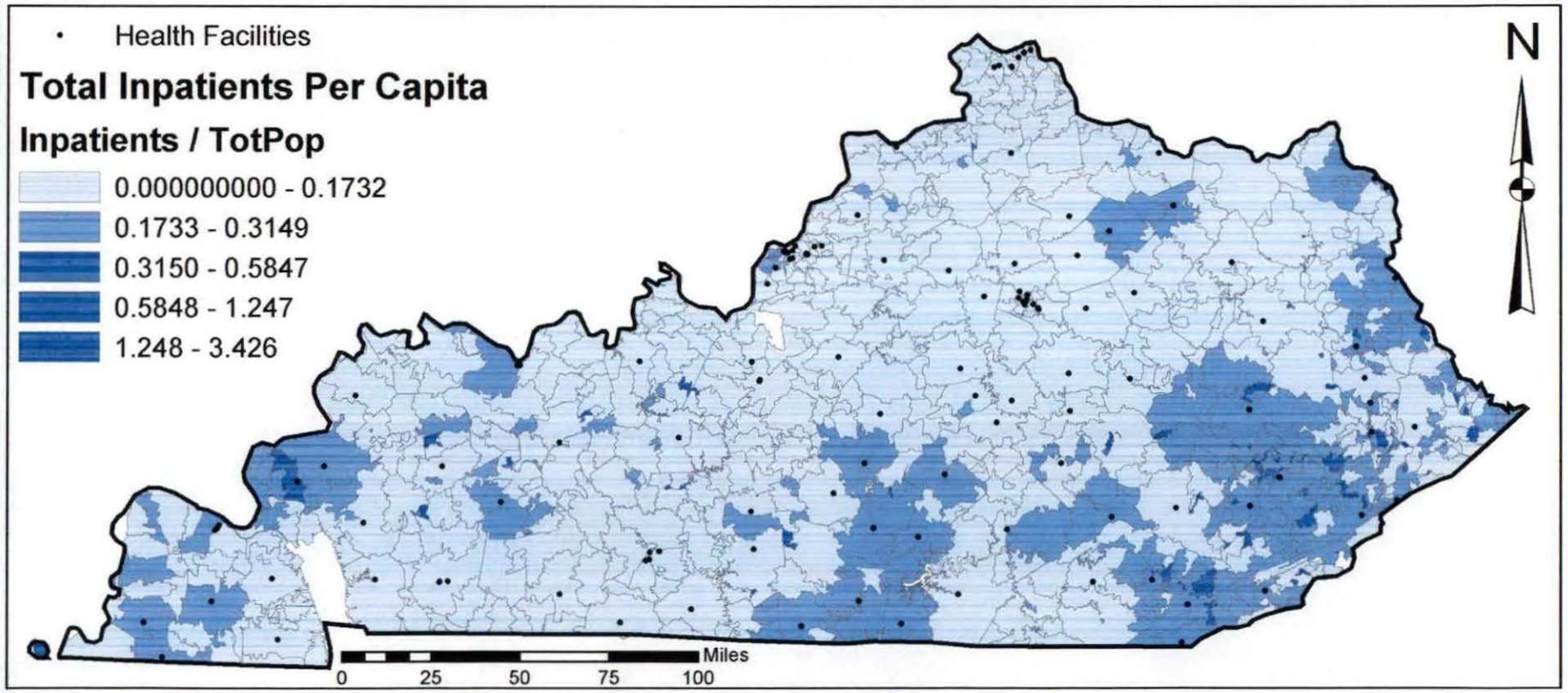
Research Questions

- What hospitals are people using?
  - for particular conditions
  - for particular procedures
- Where are particular services available?
- How far are people traveling?
  - Are facilities distributed optimally?
  - Are some areas underserved?
- Where are populations with particular needs located?

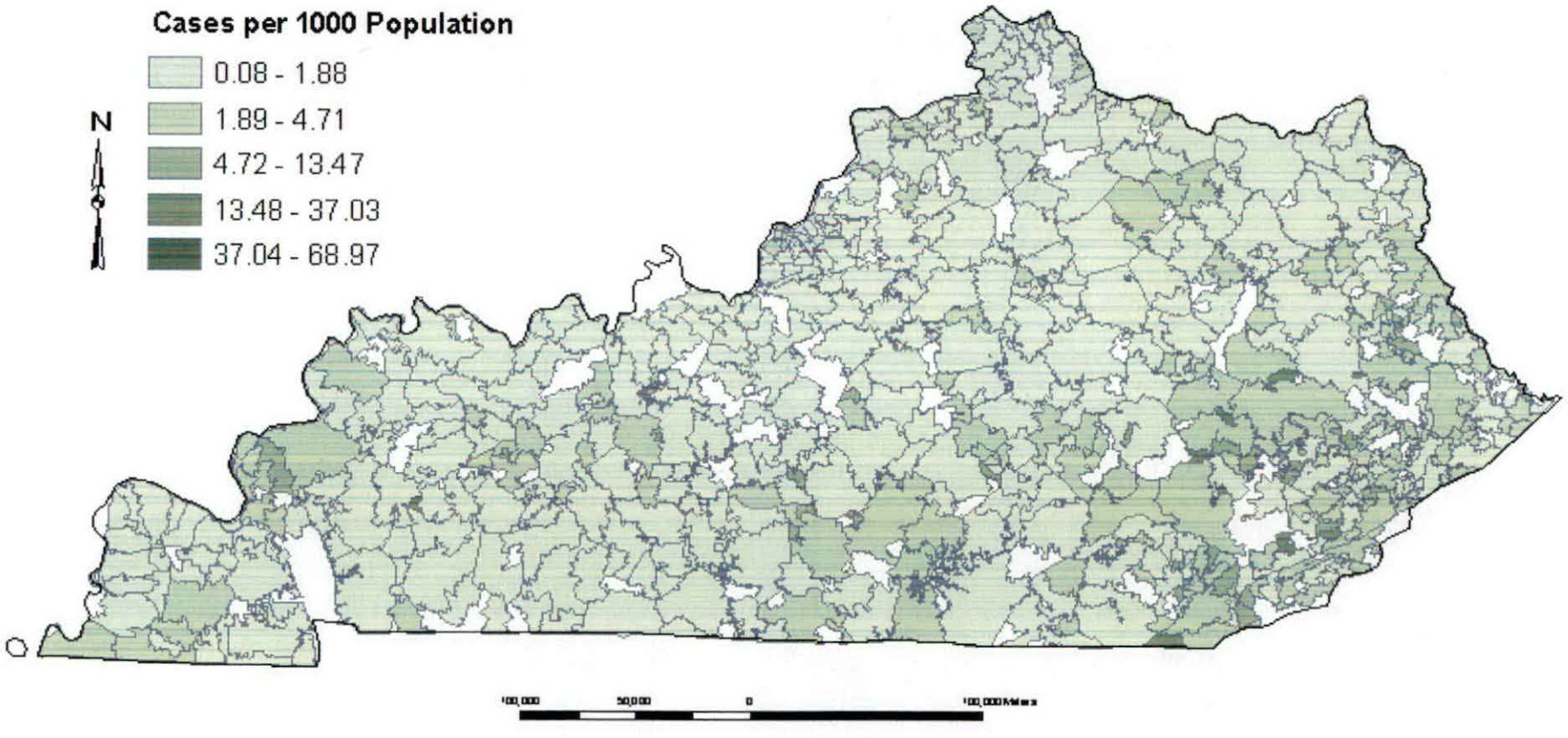
Four categories of diagnosis-related groups (DRGs):

- circulatory,
  - eg., heart conditions
- respiratory,
- neonatal and infant, and
- endocrine conditions
  - eg., diabetes

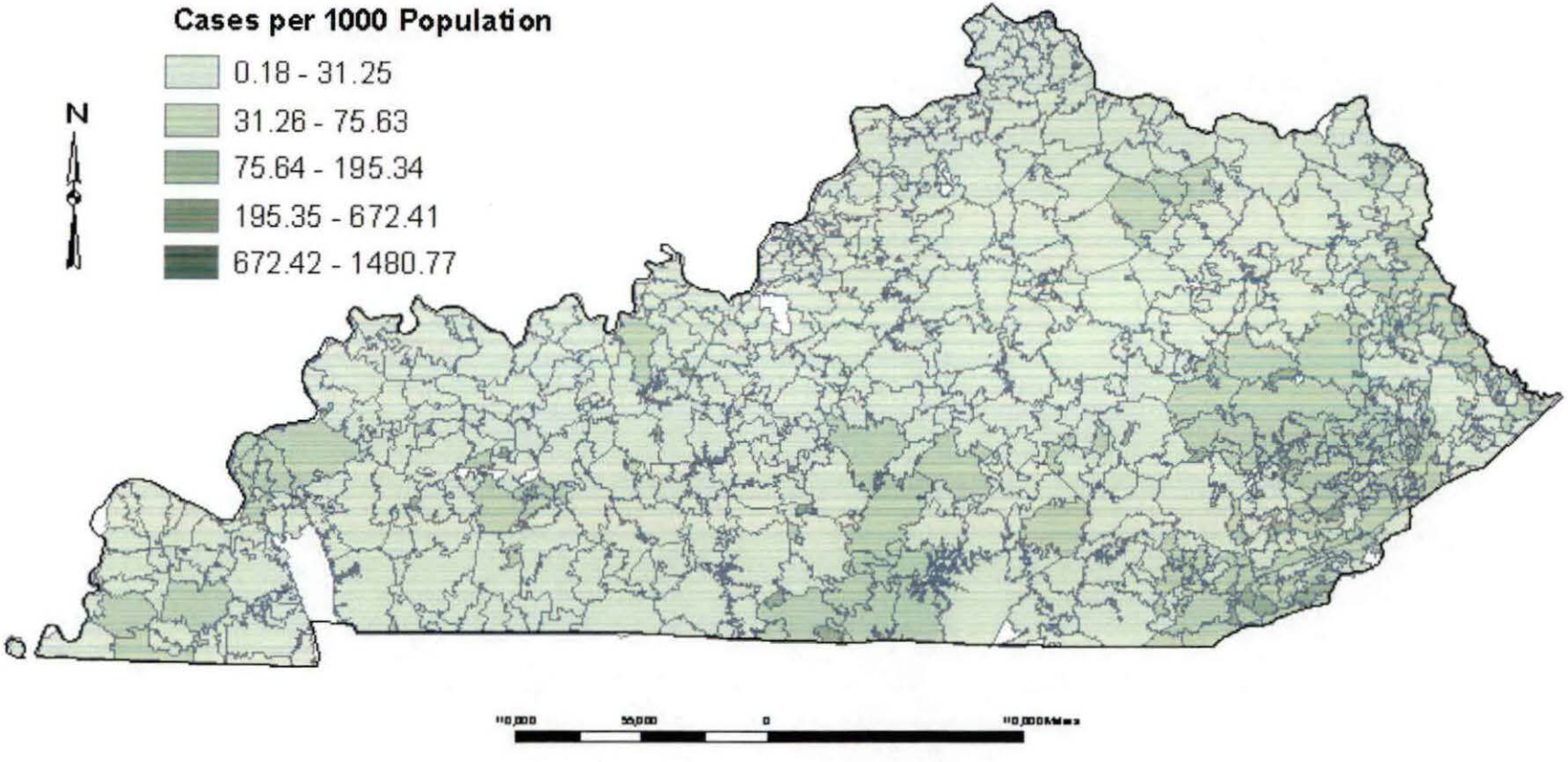
Total 2002 Inpatients Per Capita



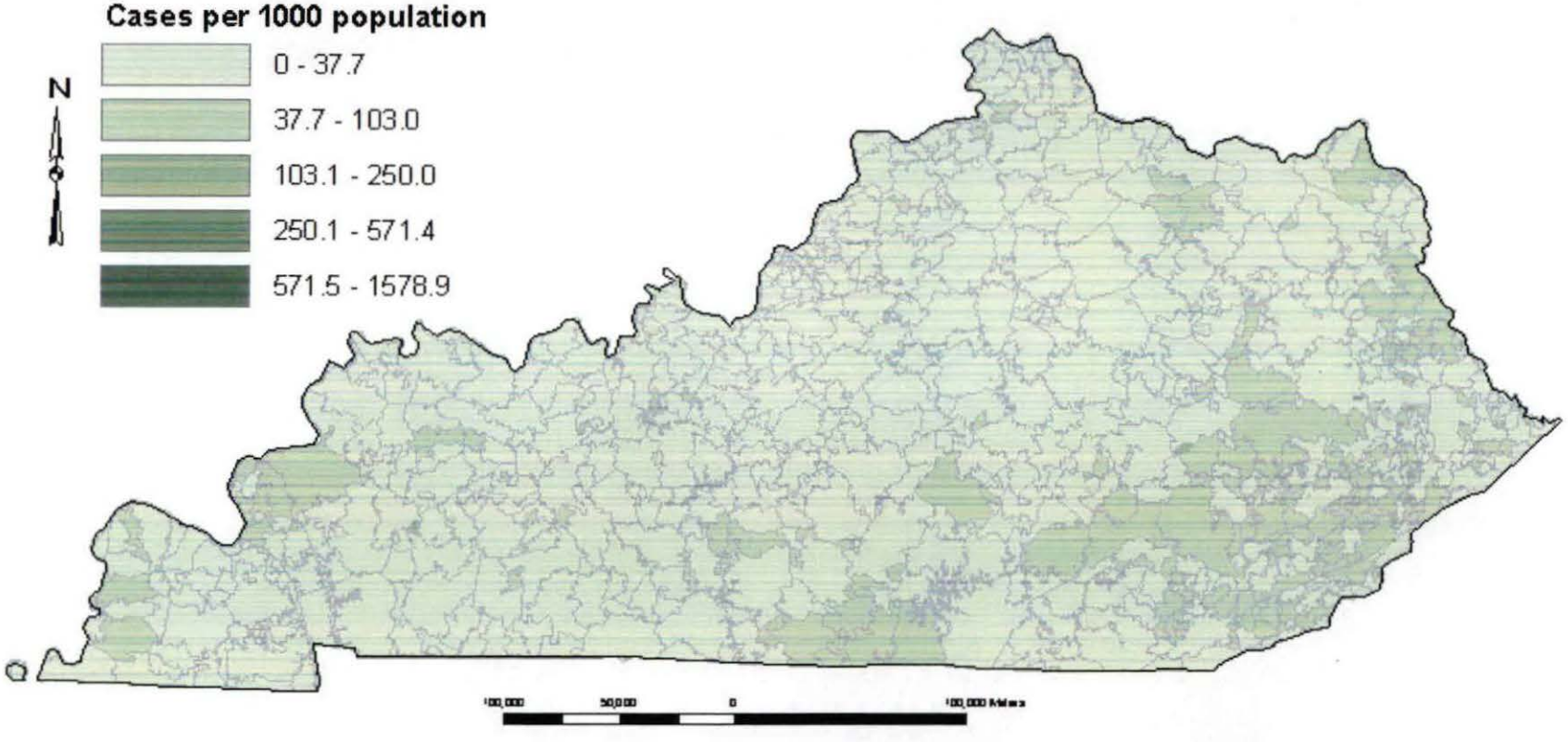
Diabetes Related Hospital Discharges per 1000 Population, 2002



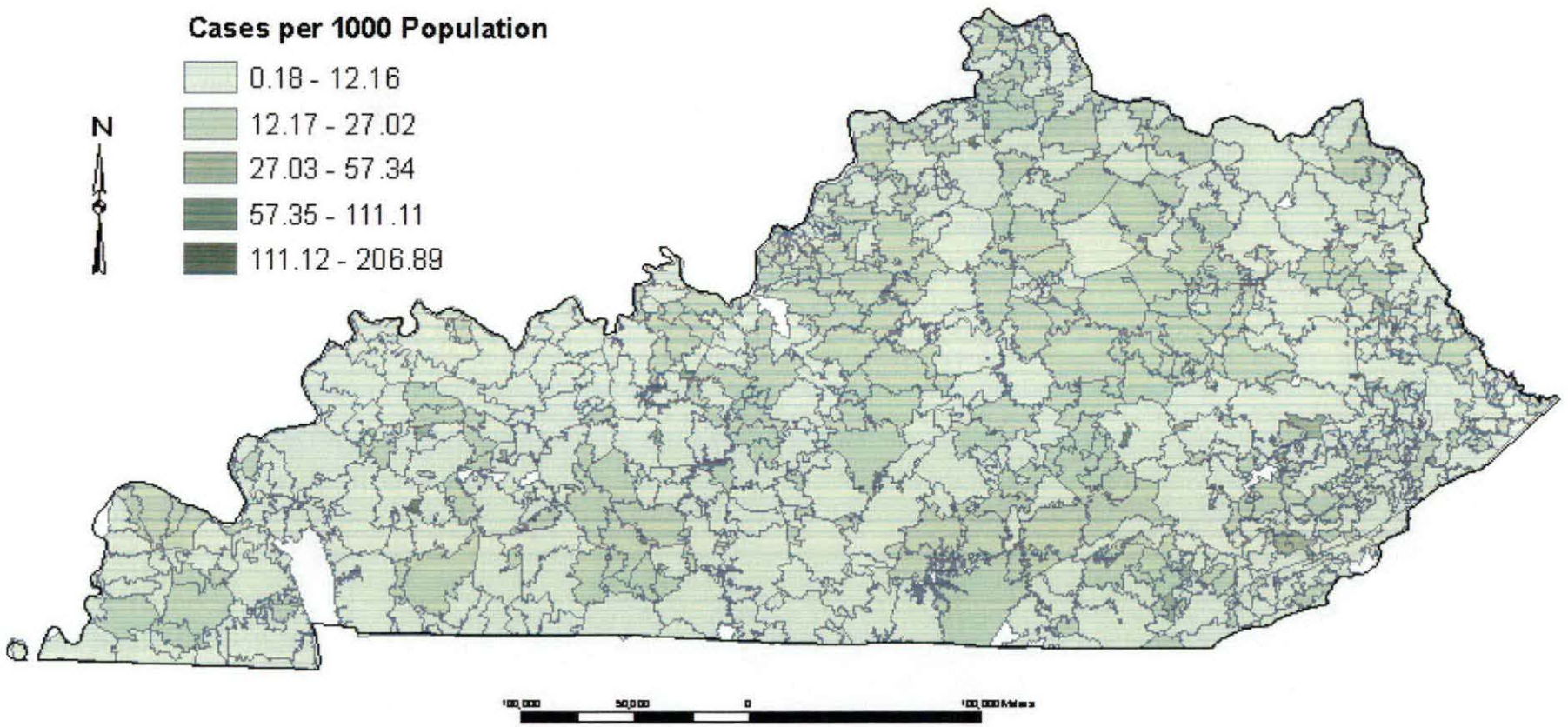
Hospital Discharges Related to Diseases and Disorders of the Respiratory System, 2002

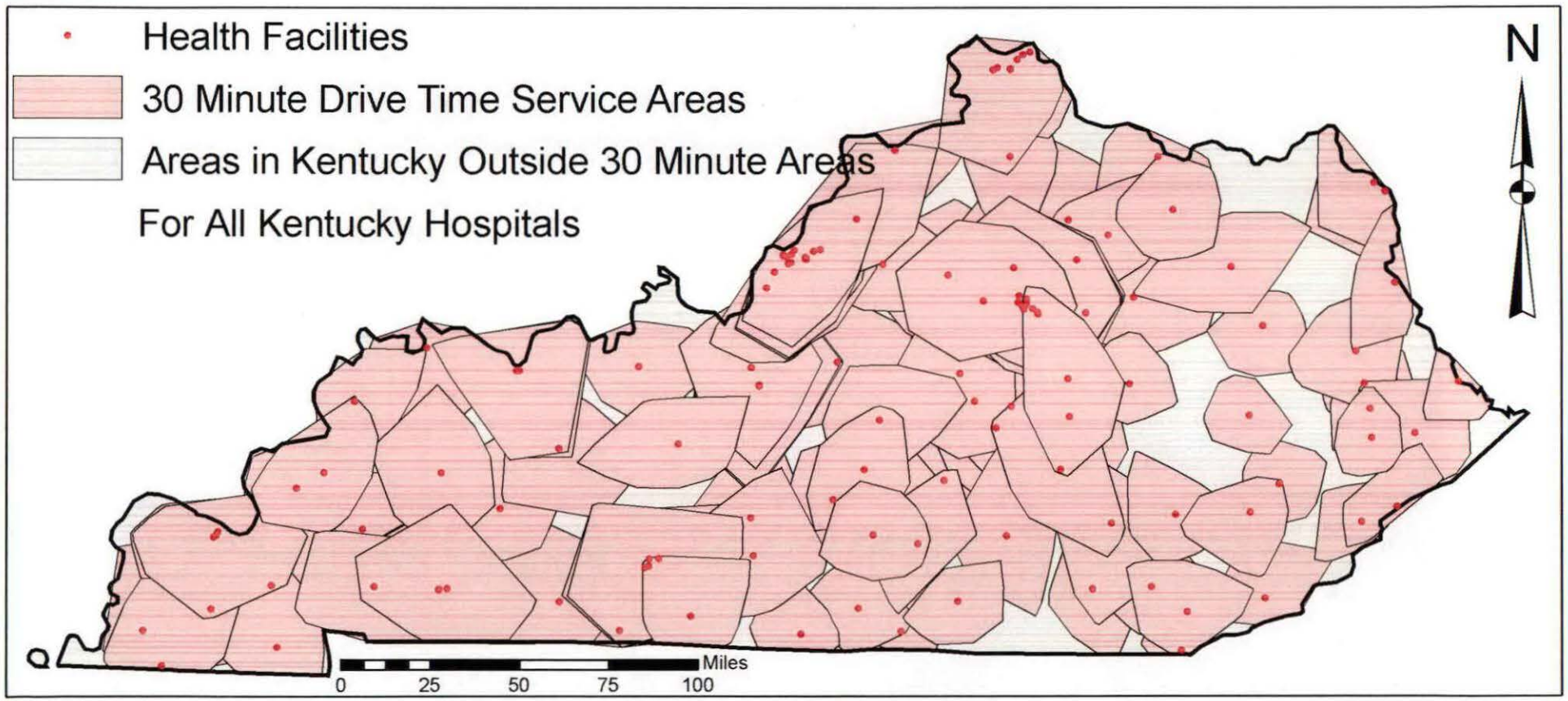


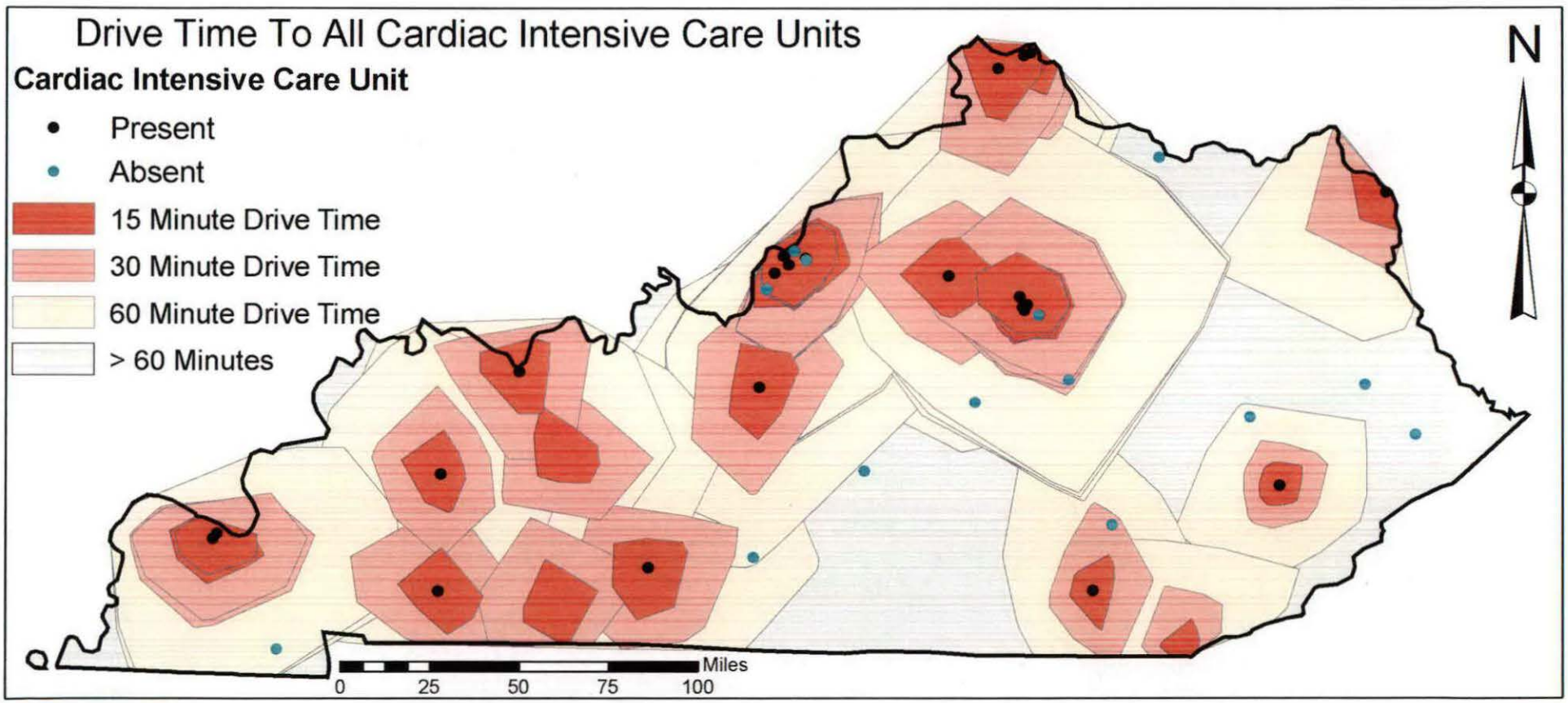
Hospital Discharges Related to Diseases and Disorders of the Circulatory System, 2002

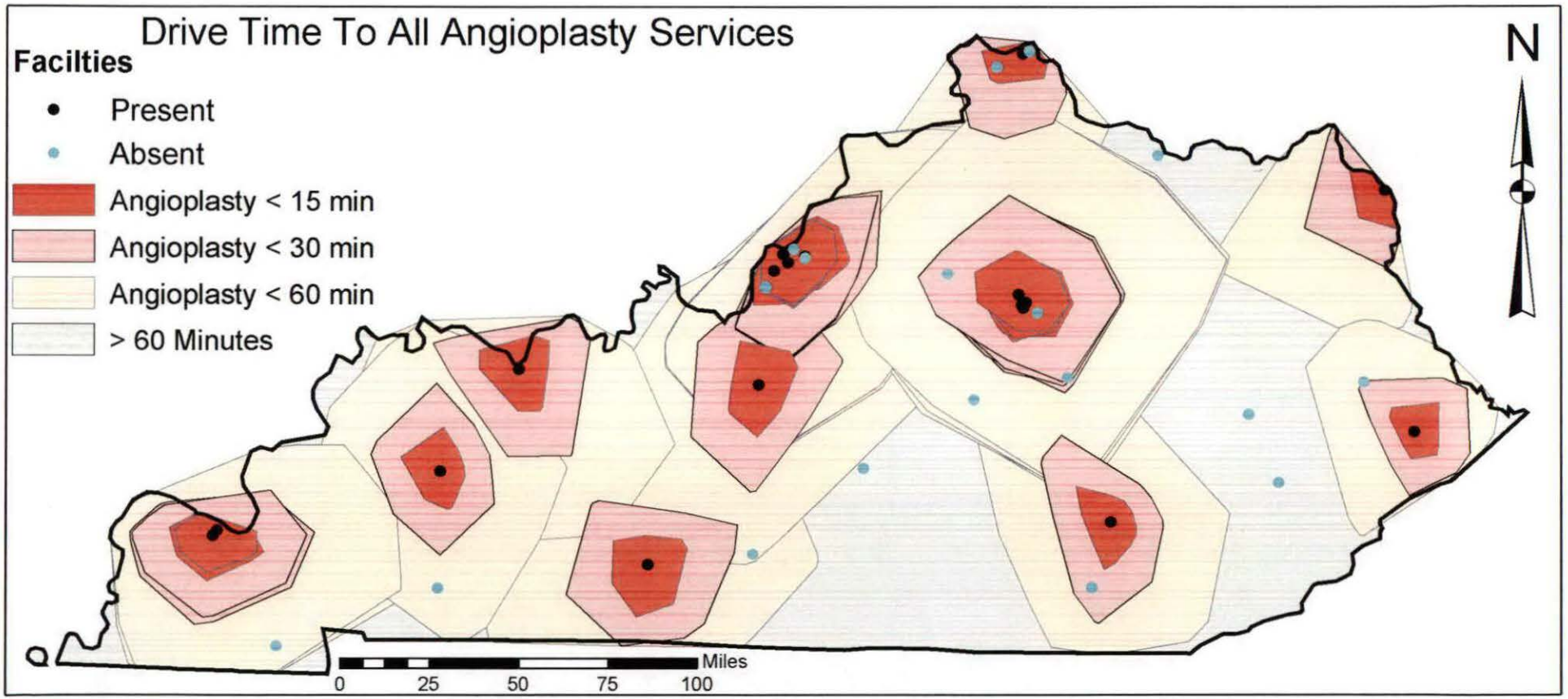


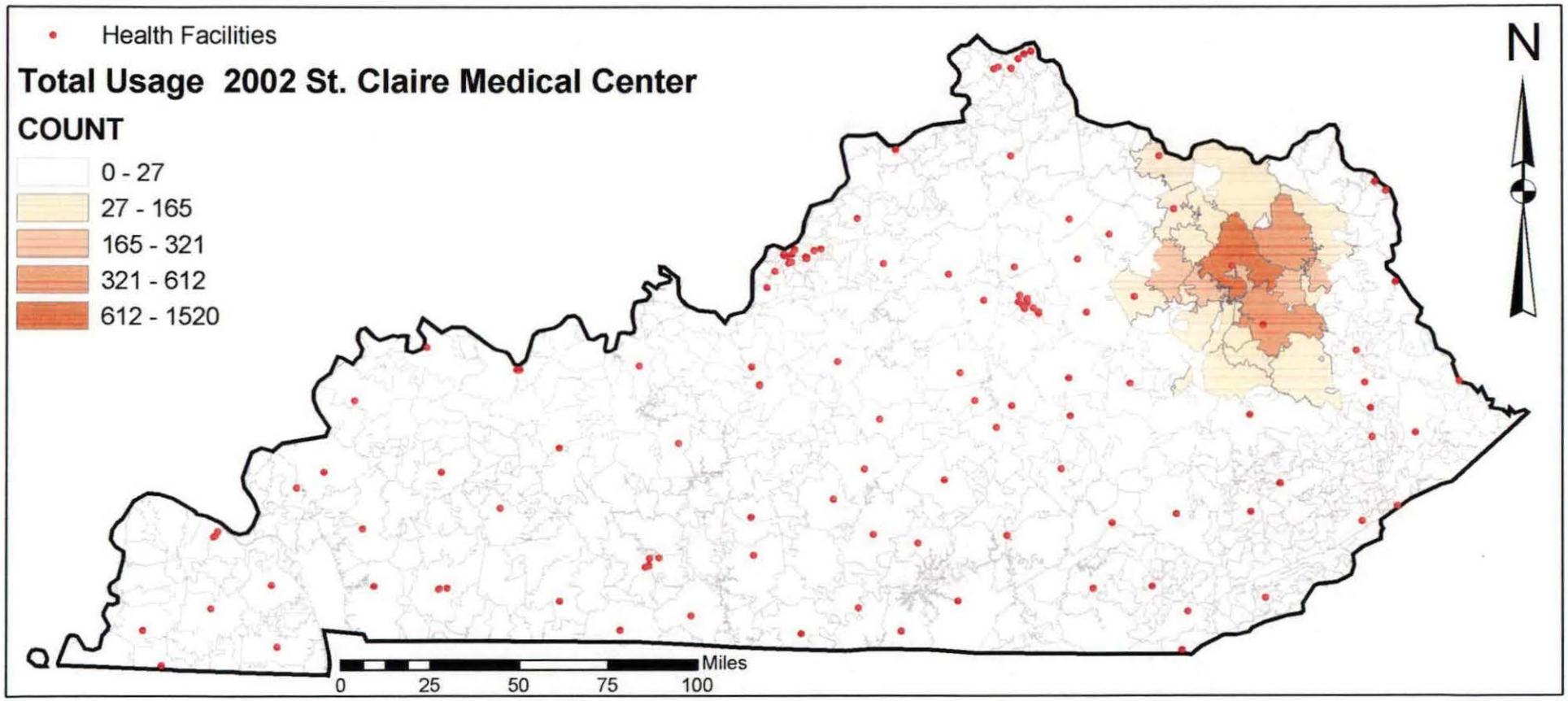
Hospital Discharges Related to Newborns, 2002



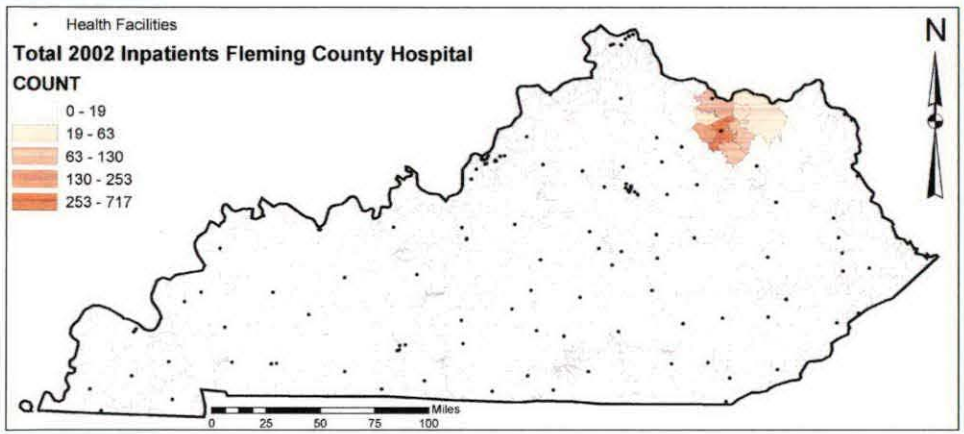

Health Facilities
30 Minute Drive Time Service Areas
Areas in Kentucky Outside 30 Minute Areas
For All Kentucky Hospitals
N
Miles
0
25
50
75
100

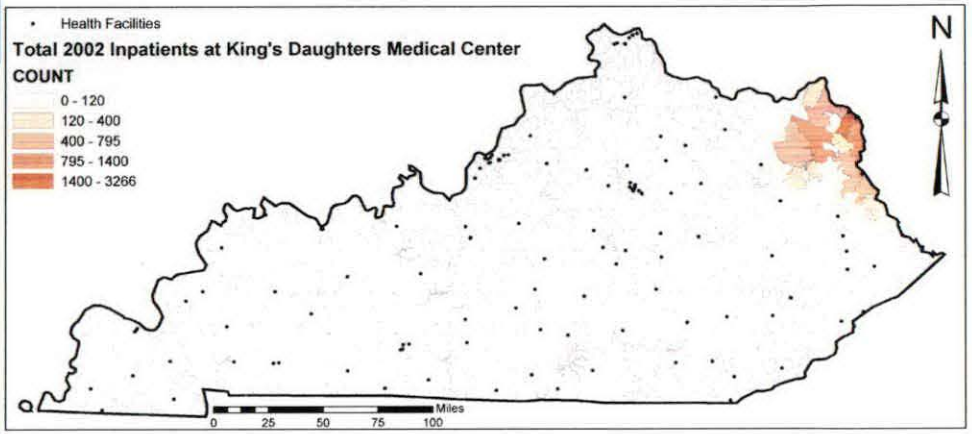

Drive Time To All Cardiac Intensive Care Units
Cardiac Intensive Care Unit
Present
Absent
15 Minute Drive Time
30 Minute Drive Time
60 Minute Drive Time
> 60 Minutes
N
Miles
0
25
50
75
100

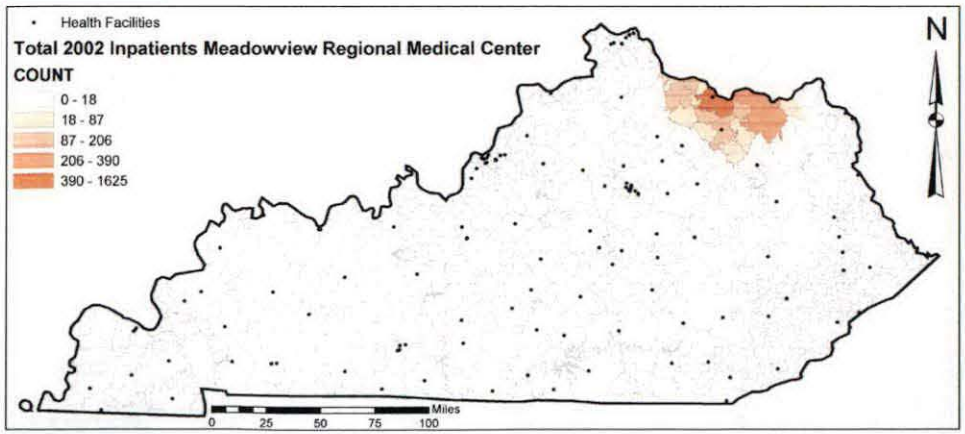

Drive Time To All Angioplasty Services
Facilties
Present
Absent
Angioplasty < 15 min
Angioplasty < 30 min
Angioplasty < 60 min
> 60 Minutes
N
Miles
0
25
50
75
100

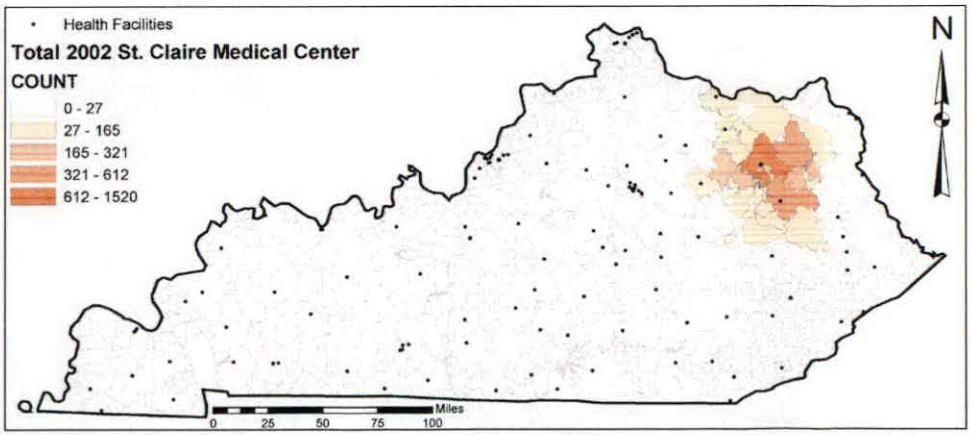

Health Facilities
Total Usage 2002 St. Claire Medical Center
COUNT
0 - 27
27 - 165
165 - 321
321 - 612
612 - 1520
N
Miles
0
25
50
75
100

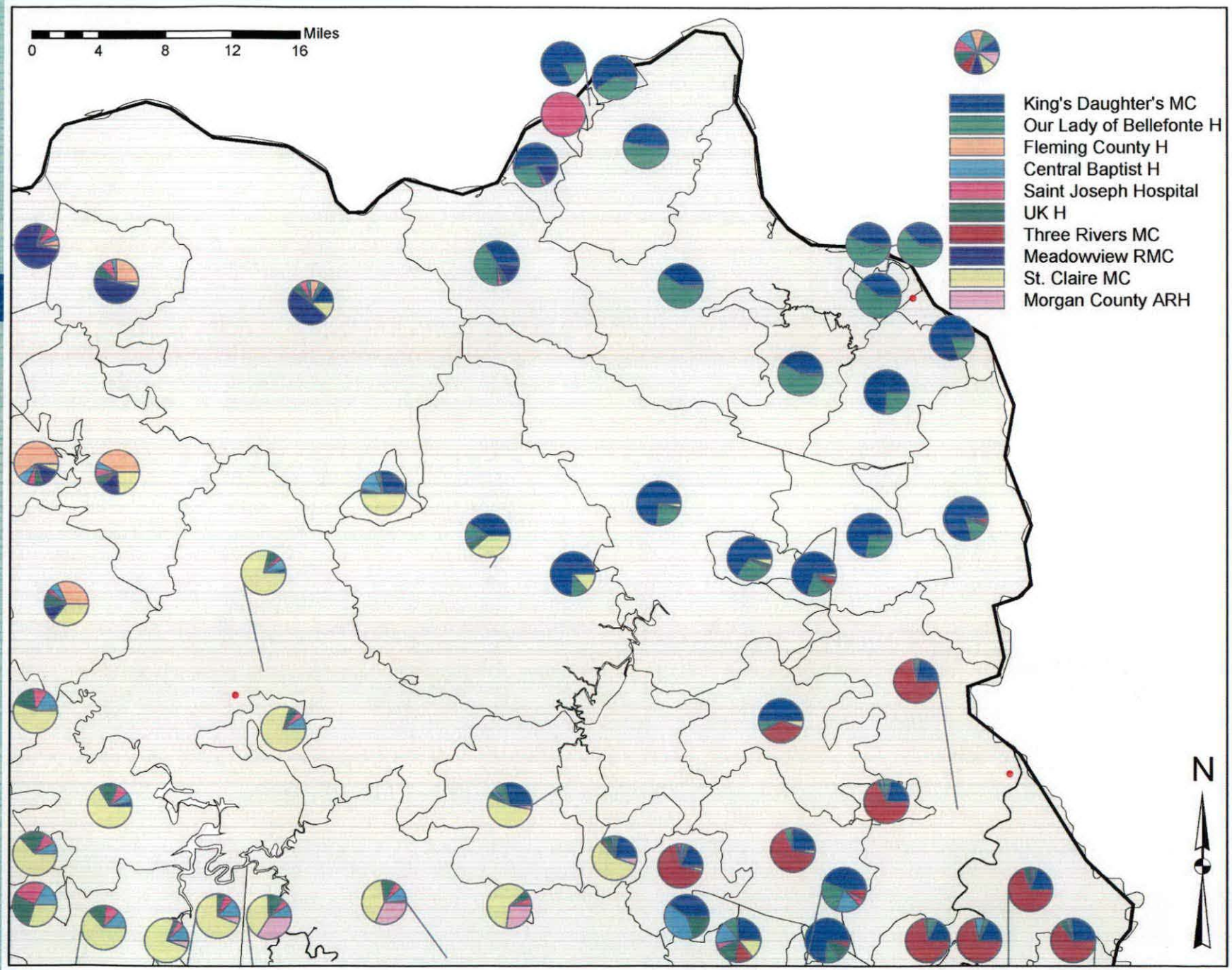
2002 Inpatient Service Areas

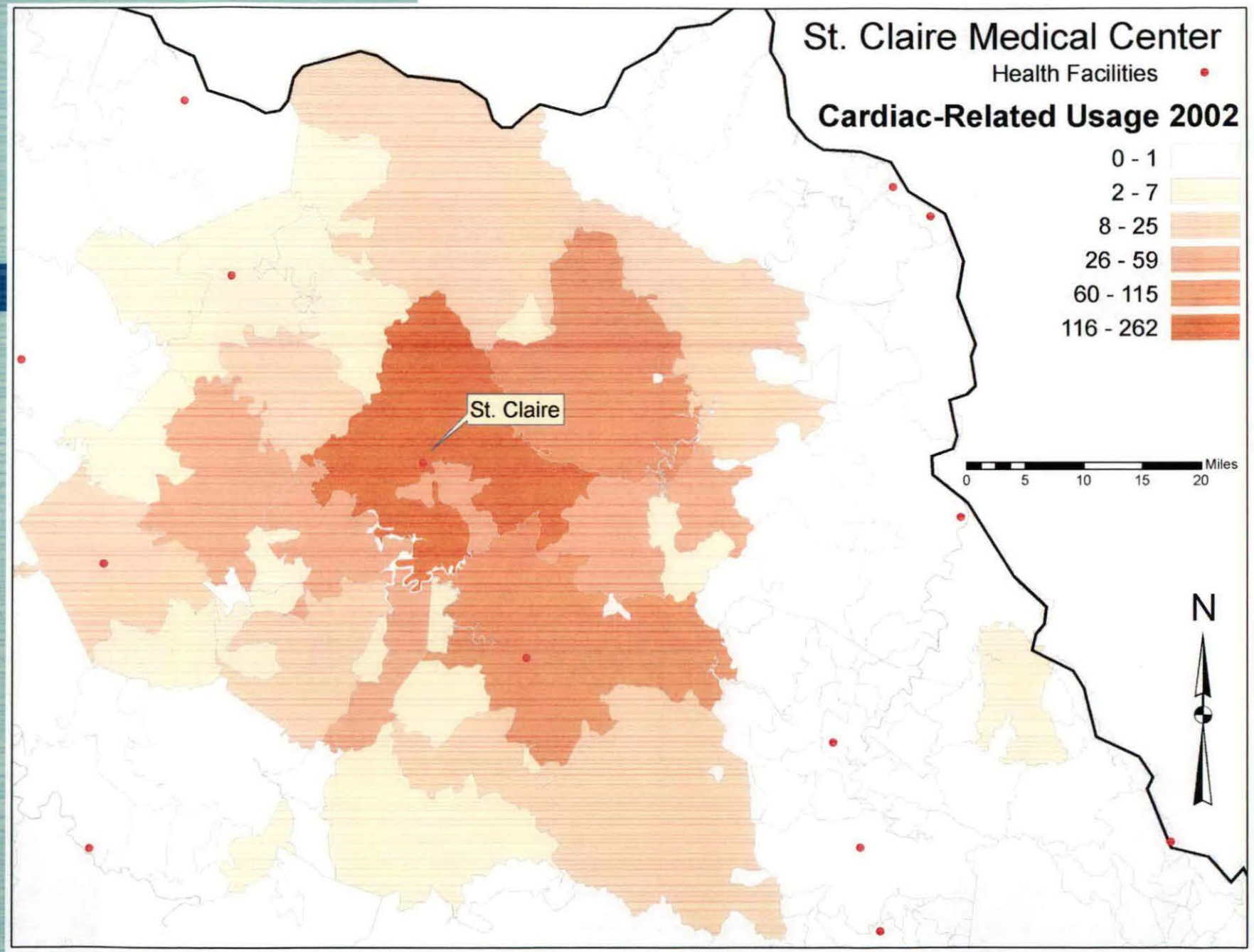


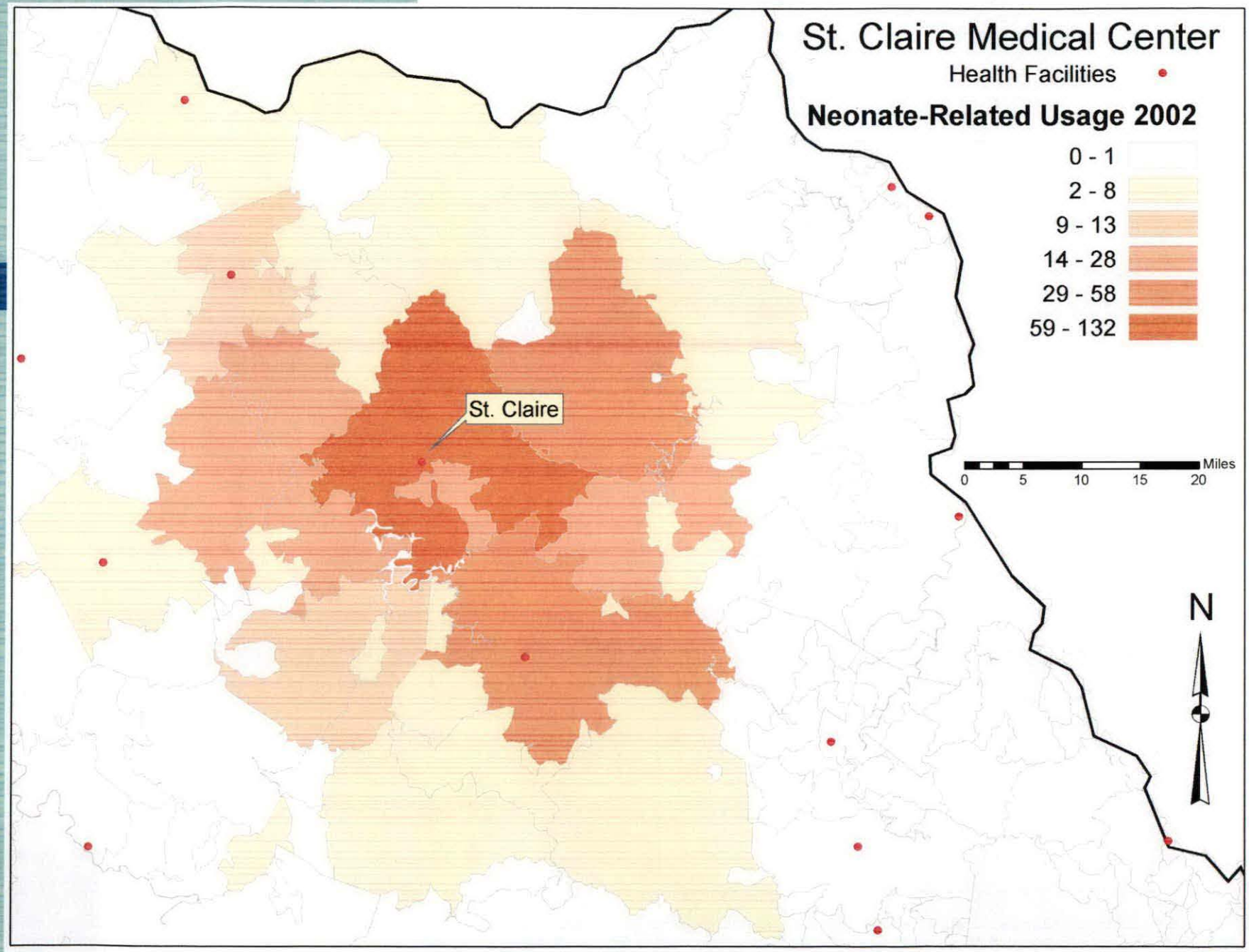


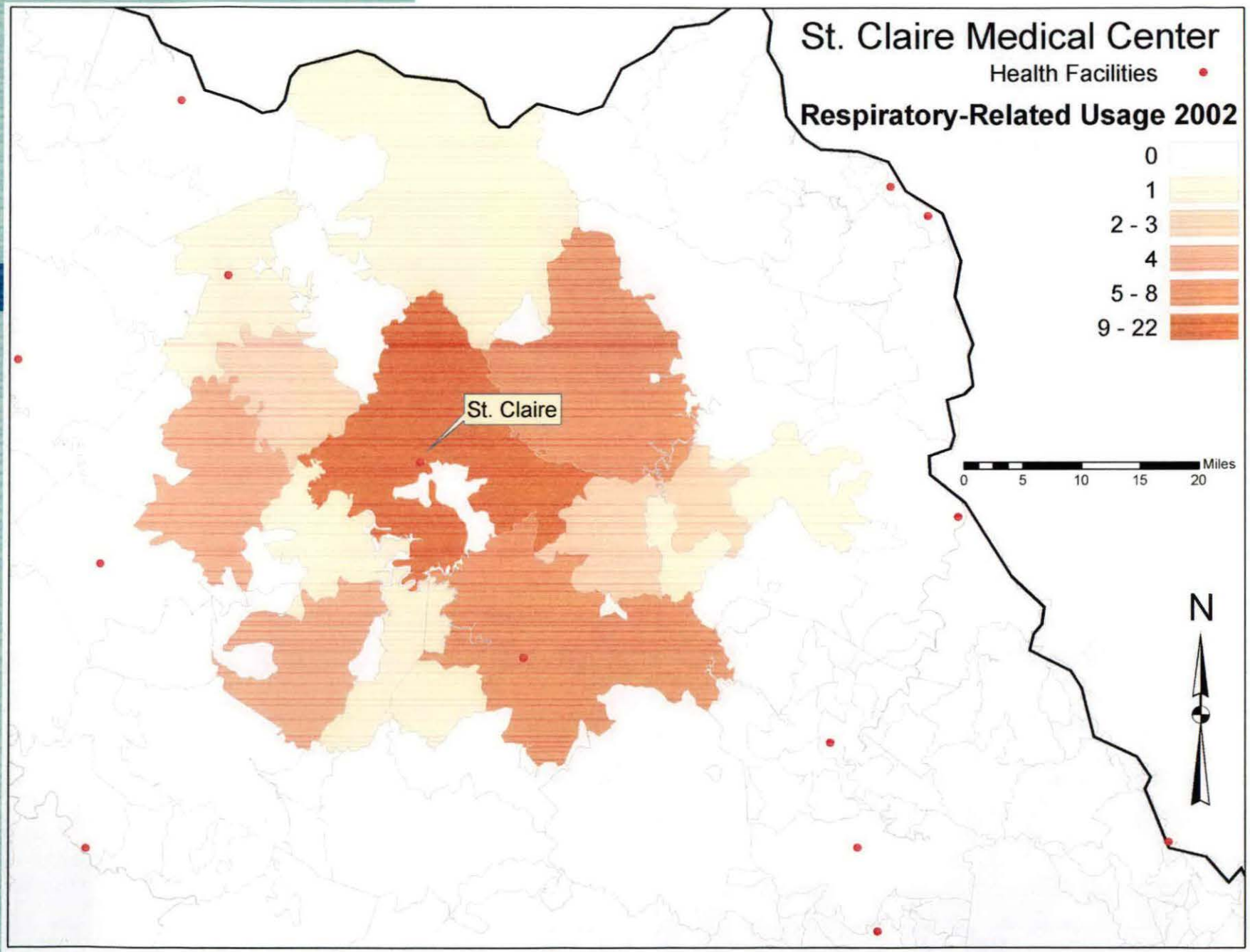


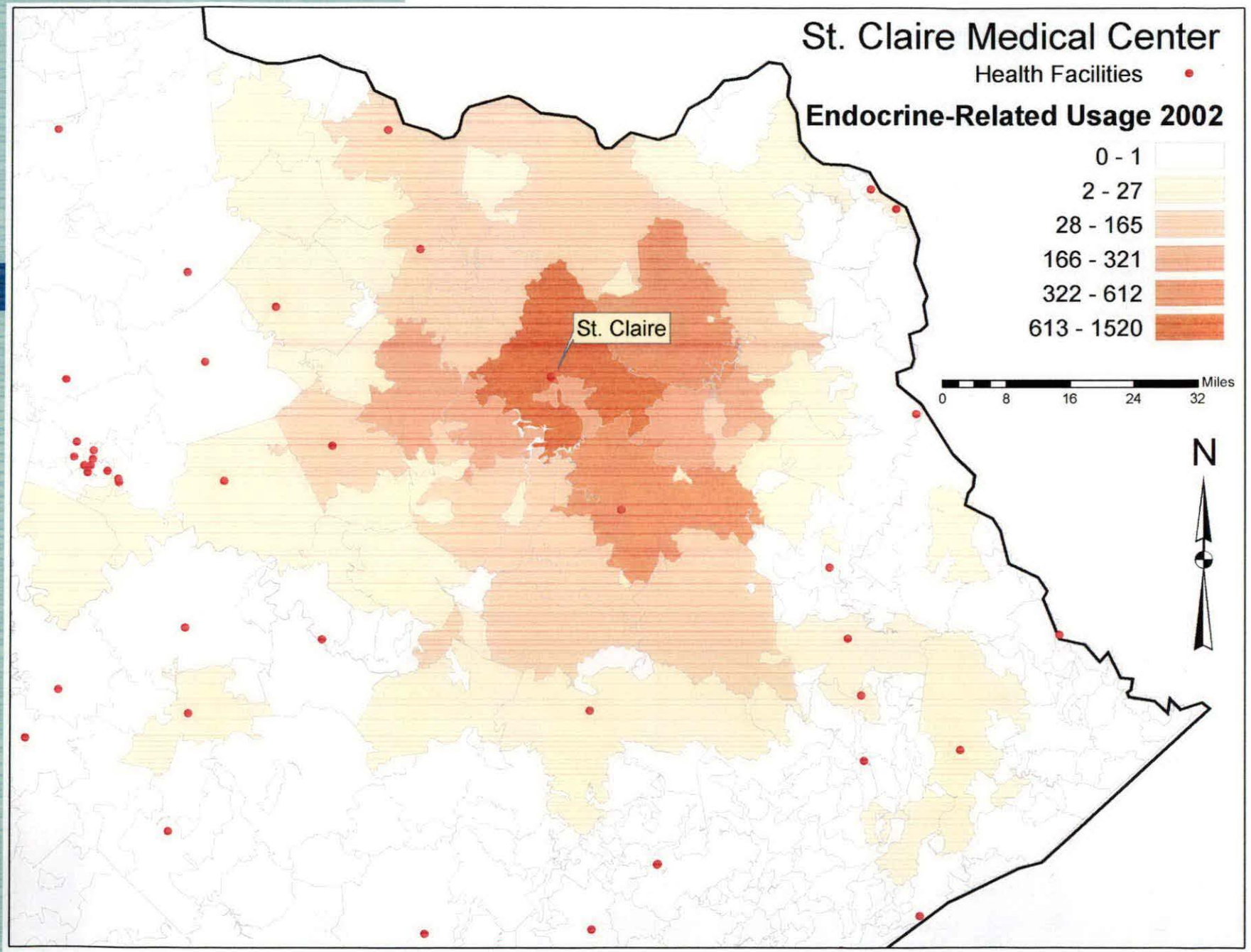



Miles
0
4
8
12
16
King's Daughter's MC
Our Lady of Bellefonte H
Fleming County H
Central Baptist H
Saint Joseph Hospital
UK H
Three Rivers MC
Meadowview RMC
St. Claire MC
Morgan County ARH
N


St. Claire Medical Center
Health Facilities
Cardiac-Related Usage 2002
0 - 1
2 - 7
8 - 25
26 - 59
60 - 115
116 - 262
St. Claire
Miles
0
5
10
15
20
N


St. Claire Medical Center
Health Facilities
Neonate-Related Usage 2002
0 - 1
2 - 8
9 - 13
14 - 28
29 - 58
59 - 132
St. Claire
Miles
0
5
10
15
20
N


St. Claire Medical Center
Health Facilities
Respiratory-Related Usage 2002
0
1
2 - 3
4
5 - 8
9 - 22
St. Claire
Miles
0
5
10
15
20
N


St. Claire Medical Center
Health Facilities
Endocrine-Related Usage 2002
0 - 1
2 - 27
28 - 165
166 - 321
322 - 612
613 - 1520
St. Claire
Miles
0
8
16
24
32
N

Conclusions

- Application of GIS techniques
- Locating
  - gaps in supply
  - pockets of demand
- Patterns of overlap in usage

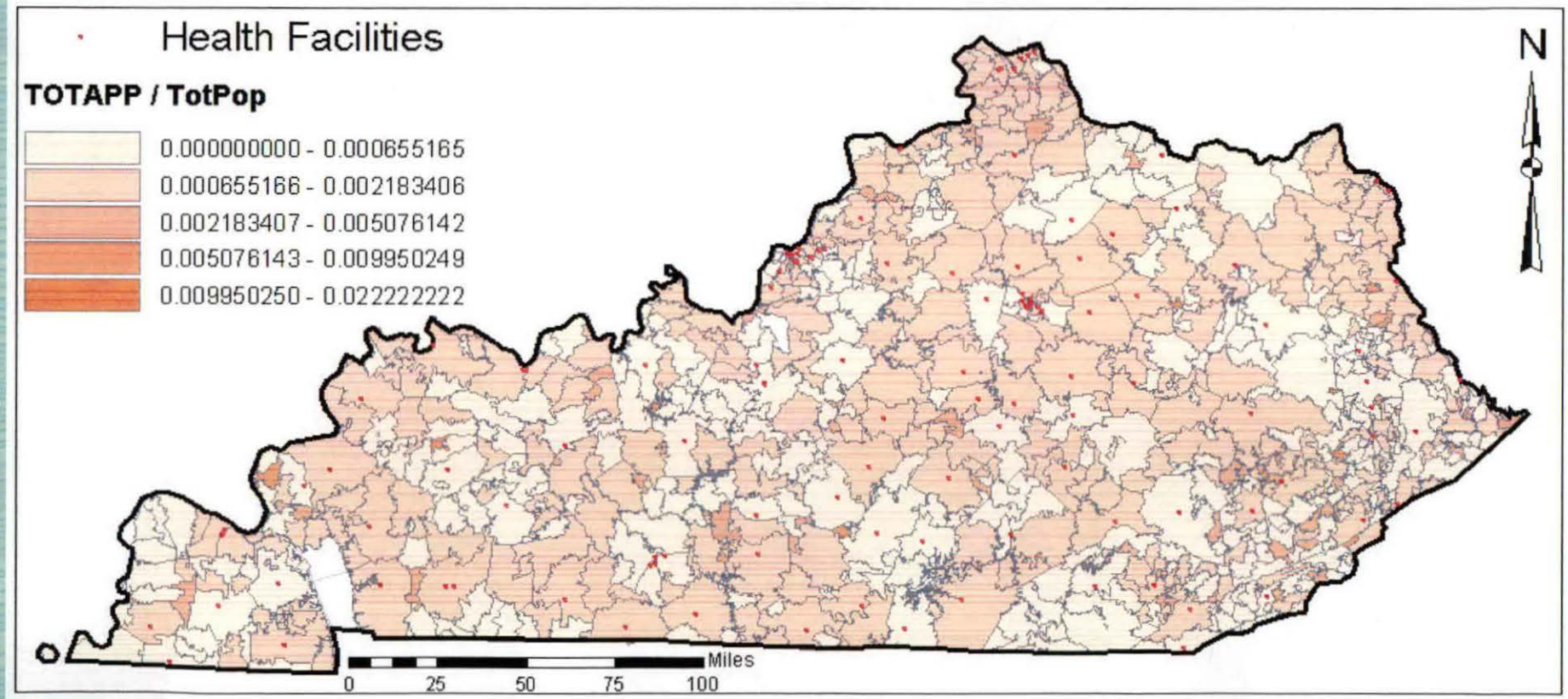
Future Directions

- Additional factors influencing patient selection of hospitals:
  - home county, insurance, particular doctors, proximity to friends and family, and transportation availability.
- Disaggregation of DRG's
- Focus on ICD9 procedures

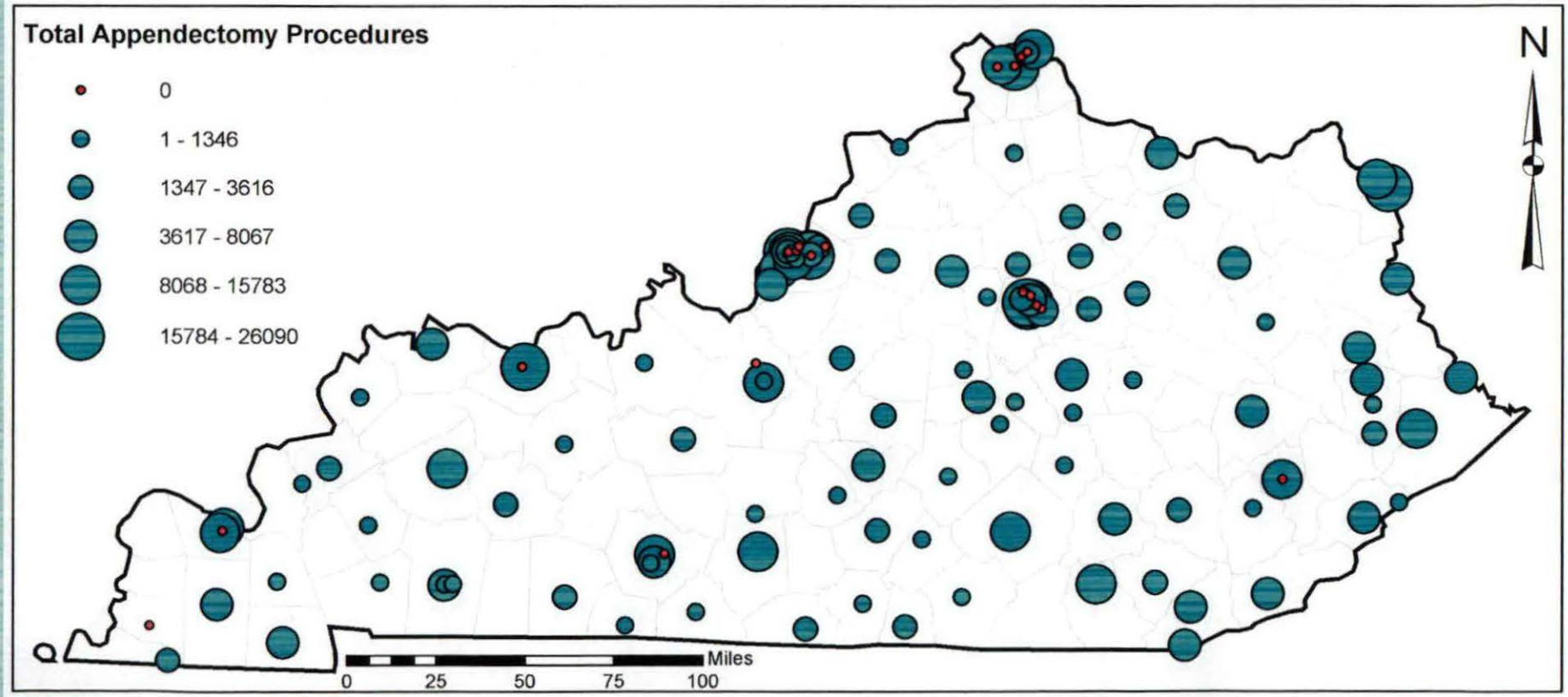
The End

Thank You

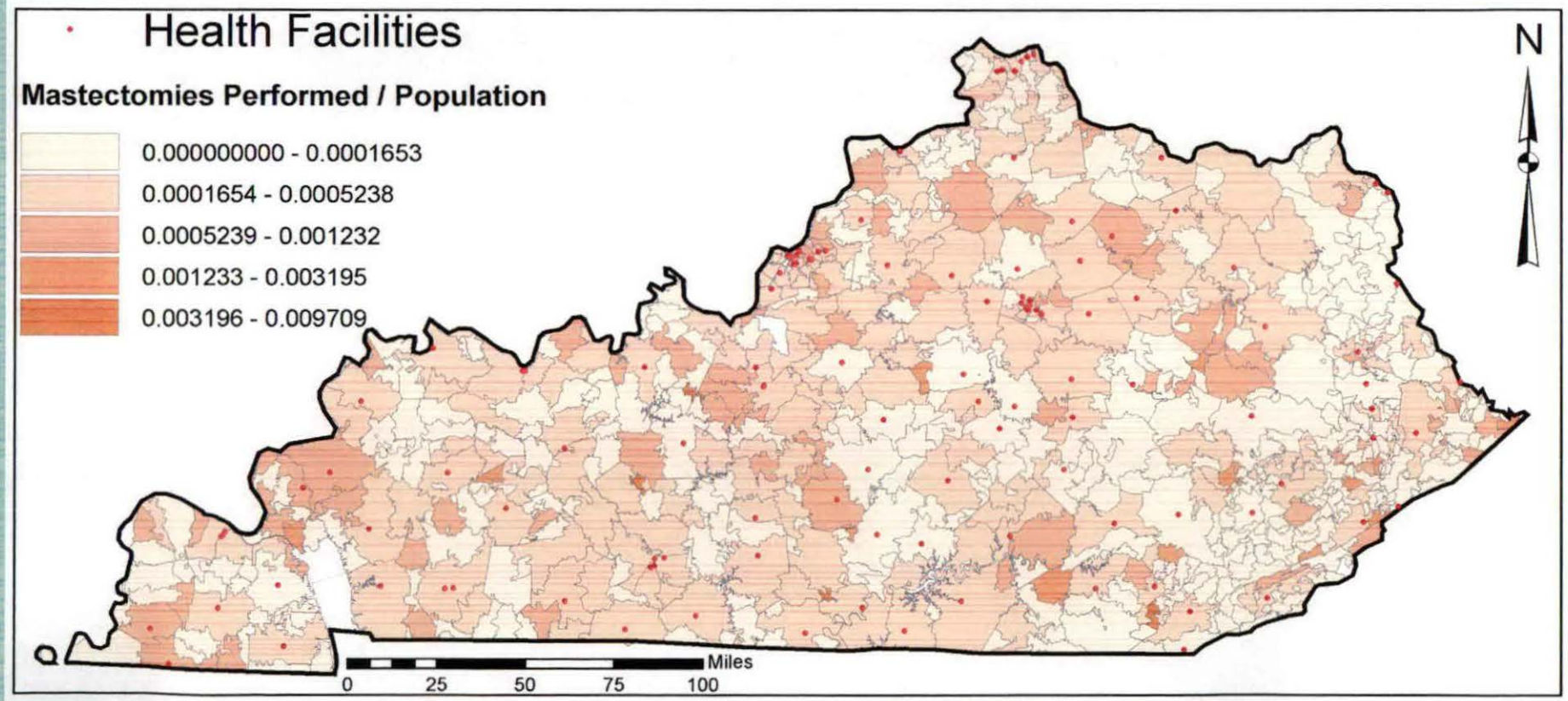
Appendectomies Per Capita



Number of Appendectomies Performed by Hospital



Mastectomies per Capita



Number of Mastectomies Performed by Hospital