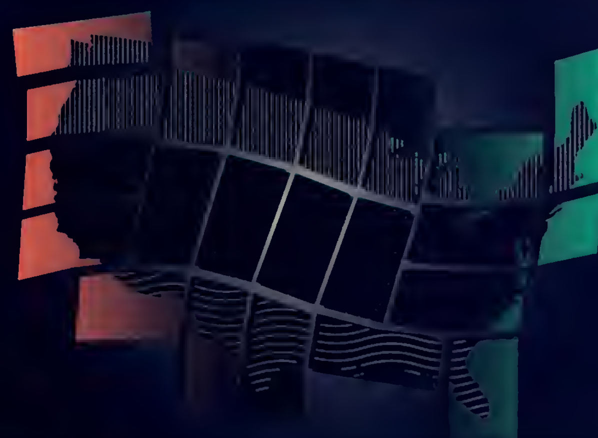
USING

GEOGRAPHIC METHODS



TO UNDERSTAND

HEALTH ISSUES

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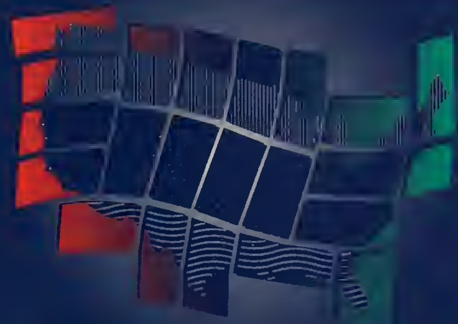
Abstract

Medical geography uses the concepts and techniques of geography to investigate health-related issues. This report aims to make the health services research community more aware of methods and approaches offered by the discipline of geography to the field of health services research. With the computer programs and applications now available, it is possible to create maps and spatial interpretations that are not complex and do not require special data or systems. Data that apply to standard geographic areas can be mapped quickly and included in almost any type of printed report or visual medium. This publication leads the reader through several commonly used methods for producing maps and visual displays that can be used for policy analysis, research, and/or planning purposes. It incorporates demonstrations and interpretations of applications using real-world examples. The applications reflect both the disease ecology and spatial analysis aspects of medical geography.

USING GEOGRAPHIC METHODS TO UNDERSTAND HEALTH ISSUES



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Overview

Maps are the basic tools that geographers use to present information. Computers have revolutionized mapmaking and placed geography at the forefront of research. *Geographic Methods for Health Services Research,* the book on which this publication is based, is the result of a multidisciplinary effort funded by the U.S. Agency for Health Care Policy and Research (AHCPR) to make the health services research community more aware of methods and approaches offered by the discipline of geography to the field of health services research. In a nontechnical format, the authors introduce tools and techniques of medical geography that apply to health services.

Medical geography uses the concepts and techniques of geography to investigate health-related issues. Although some date the field back to the time of Hippocrates almost 2,500 years ago, the term *medical geography* was first introduced by 18th and 19th century physicians who attempted to understand the relationship between the occurrence of disease and environmental conditions. The most widely used example is John Snow's hand-drawn dot map of cases of cholera (a water-borne disease) concentrated around the Broad Street well. The map, by some accounts, led authorities to remove the pump handle during the 1854 epidemic in London.

This use of medical geography can be thought of as *disease ecology,* investigating the causes of diseases, and it has played an important role in many epidemiologic and demographic studies. Medical geography also employs *spatial analysis,* the study of the distribution of discrete variables or indicators.

The three major types of spatial analysis employed to understand geographical variation in disease frequency and/or health status are:

- Descriptive analyses of the distribution of disease.
- Ecological or geographic correlation studies that seek to identify relationships between the distribution of disease and some factor of interest, such as lifestyle or environmental exposure.
- Migration studies that describe differences in the geographic variation of disease for populations, attempting to separate genetic effects from the environmental effects of place.

Another focus of medical geography relates to the spatial analysis of population-based measures of access, health care delivery, and resource allocation. These issues are particularly relevant to policymakers, health services researchers, and planners. Examples of these types of studies include:

- Studies of physician supply and demand by region or area.
- Patient origin and geographic access studies.
- Small-area analyses that evaluate geographic variations in medical outcomes and practice patterns.
- Marketing studies that analyze geographic variations in patient flows.

Effective cartography and map interpretation have been important elements in the evolution of modern medical geography from both the disease ecology and spatial analysis perspectives. The widespread adoption of maps and other geographic displays as analytic and decision-support tools has been fueled recently by the increased availability of software and databases for personal computers. These graphical displays can be powerful tools that reveal underlying relationships or processes. Maps and cartographic analyses are appearing more often in health services research journals and monographs, and their utility and ease of use are demonstrated here.

Atlases and collections of maps relevant to health are now available as reference sources and as guides for policymaking. There are thousands of data sets that can be used with hundreds of commercially available mapping software programs.

This publication leads the reader through several commonly used methods for the production of maps and visual displays that can be used for policy analysis, research, and/or planning purposes. By bridging the gap between the development and use of the tools and techniques of geography for health policy analysis, health services research, and health care planning, this effort incorporates both demonstrations and interpretations of applications using real-world examples. These applications reflect both the disease ecology and spatial analysis aspects of the field of medical geography, depicting the utility of the analytic and summary capabilities available to researchers, planners, and analysts.

Methodology

Mapping is part of the larger field of cartography (defined as the art, science, and technology of making maps and studying them), and has enjoyed a resurgence in interest as computers have made it possible to create maps and spatial interpretations. These computer programs and applications are not complex, nor do they require special data or systems to produce excellent and informative maps. Given the widespread availability of personal computers and the broad dissemination of data in electronic formats, there is no reason why data that apply to standard geographic areas cannot be mapped quickly and included in almost any type of printed report or visual medium.

Most maps depend on defined boundaries to make them recognizable and meaningful. These boundaries include physical features, such as coastlines or rivers, or political boundaries, such as State and county lines. Although drawing boundaries may seem simple and fundamental to the lay user of maps, it comprises one of the more complex tasks involved in computer mapping. Boundary definitions make up most of the data involved in the creation of a computer-drawn map, and the quality of any map depends on the quality of the boundary data.

Boundary files usually come packaged with a mapping program, but they may be bought separately when special boundaries are of interest or to update changes in boundaries such as ZIP Code areas. The U.S. Bureau of the Census produces and updates a complex boundary set called the TIGER (Topologically Integrated Geographic Encoding and Referencing) file system. TIGER incorporates most physical features of interest, including most streets and roads and a wide array of political boundaries down to the smallest census divisions. The TIGER files are often used as the source of less complex sets of boundaries.

The most common form of cartography involves creating maps that represent spatial relationships as they appear from above the earth. However, certain distortions of the physical relationship of places may more accurately represent the variables of interest and their relationship to human perception. When a map is distorted to compensate for a factor such as population density or travel time, the map is more accurately called a cartogram. (Cartograms are presentations of statistical data in diagrammatic form that resembles or relates to a map.) Many personal computer packages have the capacity to produce cartograms that adjust the size of a place to a particular factor, such as population. These distorted images require careful explanation for accurate interpretation because maps often reflect physical features.

Rural–Urban Continuum

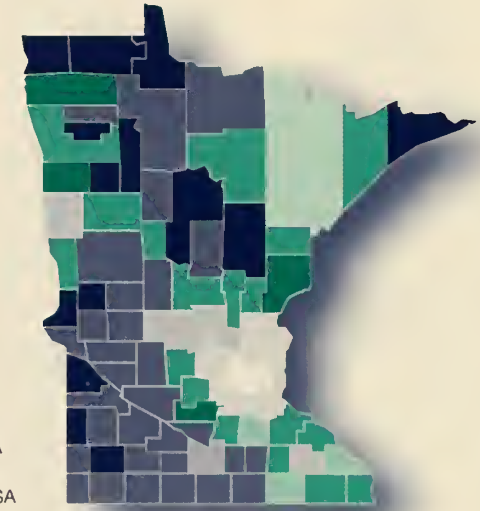
One of the most vexing problems in health care delivery in the United States is how to provide an adequate and equitable level of health care services to rural populations. Rurality is not a fixed and simple concept; some would argue that rural and urban are the two ends of a continuum of patterns of human settlement, with intermediate points along that continuum defined by population density, distance from services, and the type of economic activity prevalent in a place. To represent that continuum, one can use choroplethic maps that divide political jurisdictions by degree of rurality. (In choroplethic maps, appropriate area shadings such as value, texture, and intensity are assigned to regions based on information collected prior to mapping.)

Figure 1. Rural–Urban Continuum Categories: Minnesota, 1988

This map illustrates the application to Minnesota of a 10-tiered county-based classification of rurality. The darker the shading, the more "rural" the county is.

Continuum Code

- 0—large metropolitan core counties
- 1—large metropolitan fringe counties
- 2—medium metropolitan counties
- 3—lesser metropolitan counties
- 4—nonmetropolitan, urbanized and adjacent to MSA
- 5—nonmetropolitan, urbanized and nonadjacent to MSA
- 6—nonmetropolitan, less urbanized and adjacent to MSA
- 7—nonmetropolitan, less urbanized and nonadjacent to MSA
- 8—nonmetropolitan, thinly populated and adjacent to MSA
- 9—nonmetropolitan, thinly populated and nonadjacent to MSA



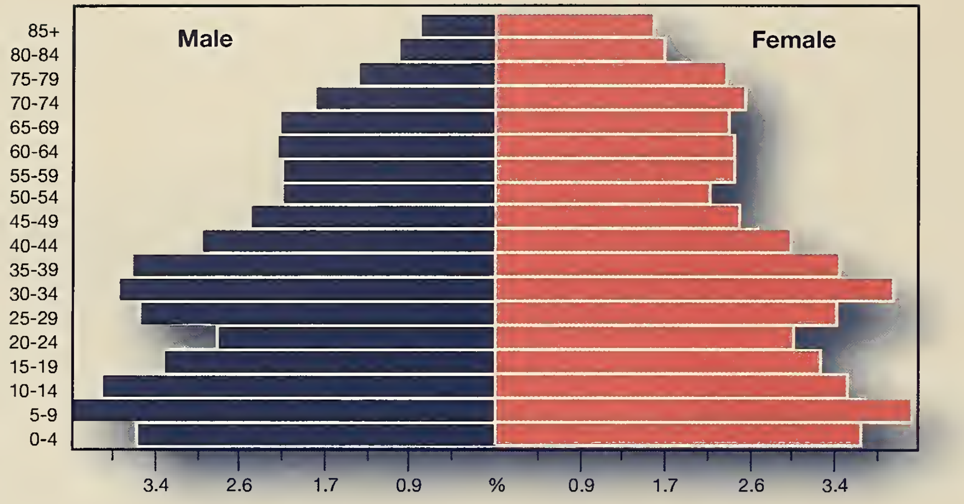
Note: MSA is metropolitan statistical area.

Data Source: Area Resource File, Office of Data Analysis and Management, Bureau of Health Professions, March 1992.

Figure 1 illustrates one such system that classifies counties using a system developed by the U.S. Department of Agriculture. The rural–urban continuum code is based on both county population size and whether a county is a core metropolitan county, some other type of metropolitan county, adjacent to or separated from a metropolitan county. The map shows that the State of Minnesota contains a mix of densely and more sparsely populated areas, with the largest concentration of population centered around Minneapolis/St. Paul in the southeast quadrant of the State and a smaller concentration surrounding Duluth in the northeast quadrant. The variation in the size and population density of the counties illustrates the expected pattern of settlement from the metropolitan centers outward.

Populations included in a county's borders may reflect a range of age, gender, and race distributions. The size of the population that is very young or very old has important implications for the delivery of health services. A county with a large pediatric population will require different specialists and services than will a county that is made up mostly of older people. To characterize the age distribution of a county, one can use the population pyramid.

Figure 2. Population Pyramid: Brown County, Minnesota, 1990



Male Population 13,068
Male Median Age = 33.3

Female Population 13,916
Female Median Age = 35.7

Total Population 26,984
Median Age = 34.5

Data Source: U.S. Bureau of the Census.

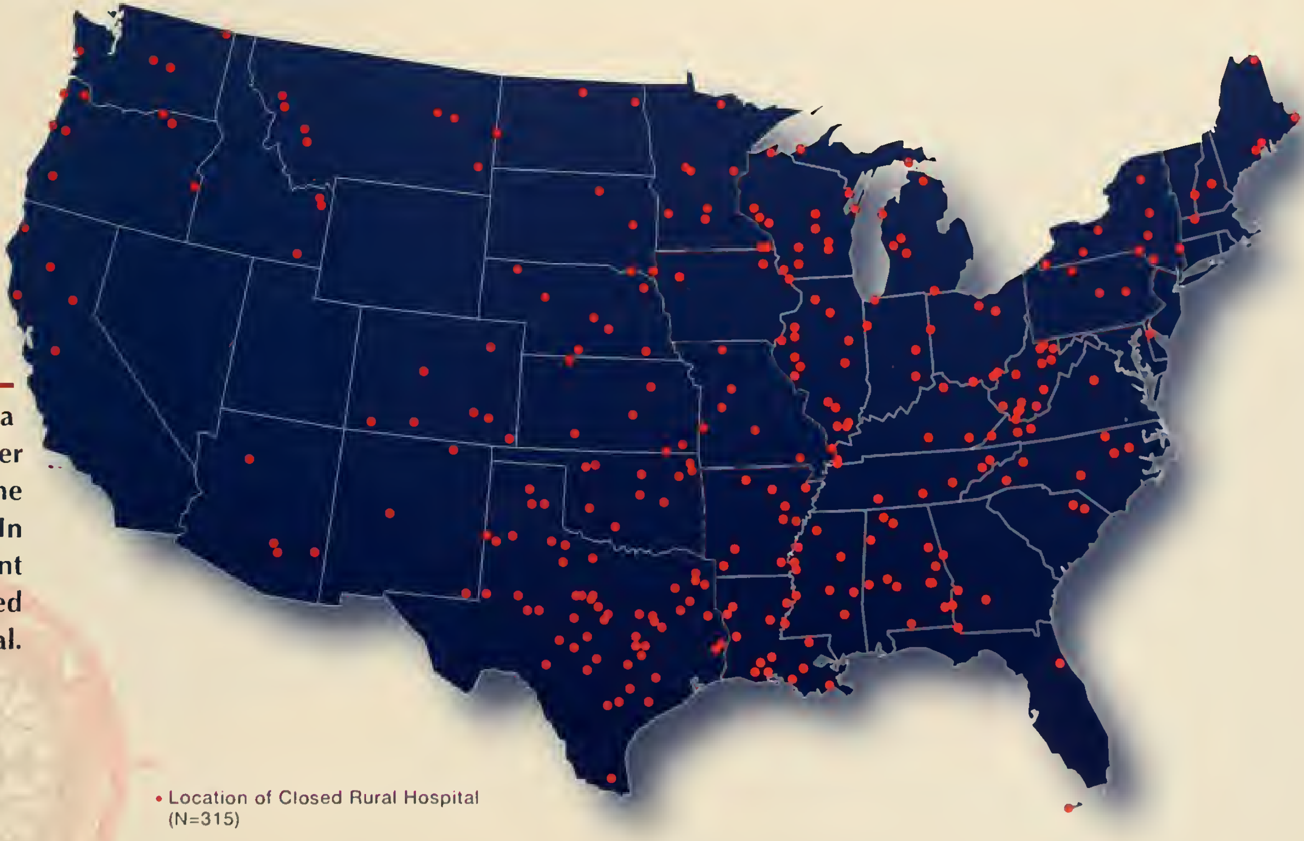
This population pyramid offers a graphic depiction of the age structure of the population of Brown County, Minnesota. The figure shows the population's age distribution concentrated in the 5-14 and 25-39 year age groupings.

The population pyramid shown in **Figure 2** breaks population into 5-year age increments and divides it by gender, then graphs each increment using horizontal bars. This pyramid, which represents Brown County in Minnesota, shows 5-to-14-year-olds and people in their mid-twenties through thirties predominating, indicating that this county probably has a high proportion of young families raising children. Population pyramids can also be used to examine other demographic variables of interest, such as race.

Often, a problem or condition is widespread, and its most important characteristic is the degree to which it is distributed across regions or concentrated in a single place. Over the past 15 years, the number of rural hospitals that have had to close their doors has been recognized as a significant problem.

Figure 3 provides a picture of the regional nature of the phenomenon using a dot map. In a dot map, point symbols are used to show the spatial distribution of some feature and give readers an idea of its magnitude. The relative concentration of closures in Texas, Appalachia, and along the Mississippi River is apparent. One broader interpretation that can be derived is that hospital closures during this time period were primarily concentrated in the East and Midwest. The dot map, unless combined with some other shading, does not convey information about

Figure 3. Rural Hospital Closures: 1980-90



Data Sources: Hospital Closure File 1980-89, Health Database Services, American Hospital Association. Hospital Closure 1990 dataset, Office of Inspector General, U.S. DHHS.

A point map uses a dot or some other shape to indicate the feature of interest. In this map, each point represents a closed rural hospital.

the denominator (in this case, the total number of hospitals), and these maps must be interpreted carefully.

Demographics and Access

From a geographical perspective, multiple dimensions of access to care can be investigated among vulnerable subpopulations residing in a given area. For example, groups can be examined based on rural or urban residence, low income/Medicaid coverage, race, ethnicity, age, gender, or transportation availability. These analyses can be compared against some societal norm or objective. However, typically internal comparisons are made that highlight inequalities or patterns that can be visually assessed through map displays. Adjusting for population density is particularly important in conducting these types of cartographic analyses.

Examples of these types of cartographic adjustments (included in this section) are demographic base maps (Figure 4), isoline maps of population potential (Figure 6), and two maps that relate access and demographics using choroplethic and vector mapping (Figures 5 and 7).

Construction of a Demographic Base Map

A demographic base map alters the representation of actual spatial units (e.g., counties) so the size of the unit is proportional to the numbers of people or resources living/located within its boundaries. This is an important adjustment when the areal size of selected spatial units varies disproportionately with the settlement patterns (or population density and dispersion) of these areas.

Figure 4 depicts an actual areal map of central North Carolina in the upper right corner, with the demographic base map reflecting the proportional differences in the residential location of the population aged 75 and over for an 11-county Health Service Area. Counties with proportionately smaller land areas (such as Durham County) can become more prominent after adjusting for population density.

Patient Origin Method of Medical Service Area Definition

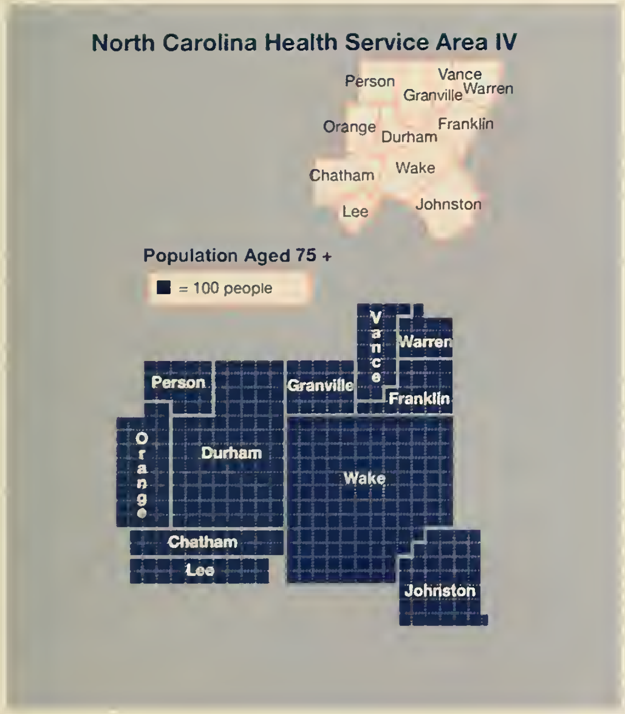
Hospital planners are often interested in evaluating service areas and geographic sources of admission for patients. This information can prove useful in planning community outreach or alliances of institutions, as well as conducting competitor analyses. One way to analyze these patterns is to calculate a commitment index, which analyzes the proportion of a hospital's admissions deriving from each discrete region within its service area. Commitment indexes are typically calculated at the county or ZIP Code level using hospital discharge information.

Figure 5 is a choroplethic map that displays the ZIP Code origins for patients admitted during a set period. Shading is used to identify a primary service area from which a set proportion of the patients come—in this case, those ZIP Code areas that contribute the first 60 percent of the hospital's patients. To make this map, values were calculated using a spreadsheet and the ZIP Code proportions were imported to a mapping software program.

Population Potential Maps

Population potential is a measure of distribution that describes the nearness or accessibility of people to a certain point or place. The general formula for population potential essentially calculates the degree of interaction or the population potential for a point (typically representing an areal centroid or geometric center). This point is equal to the population of the area divided

Figure 4. Construction of a Demographic Base Map

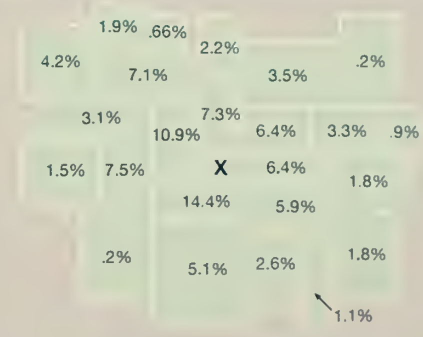


Data Source: U.S. Census of Population, 1990.

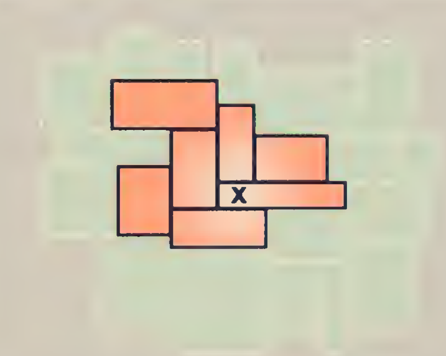
A demographic base map (DBM) employs a grid to construct a map based on population rather than land area (the basis for most maps). An area may be quite prominent on an areal map, but if it is sparsely populated it will be less prominent on a DBM.

Figure 5. Definition of Medical Service Area (MSA) Based on Patient Origin: Commitment Index (CI)

A choroplethic or shaded map (bottom) is used to display numeric information (top). This example gives a graphic depiction of hospital admissions from the hospital's perspective; shaded portions indicate the ZIP Code areas that contribute the first 60 percent of the hospital's patients.



Percent of Hospital of Interest's Total Admissions Originating in Each ZIP Code Area. Proportion of hospital of interest's patients being drawn from each ZIP Code area.
Note: Numbers may not total 100% due to rounding.



Patient Origin MSA (Shaded Area) Defined Using CI. ZIP Code areas are ranked by CI in descending order. ZIP Code areas are placed in the MSA in rank order until the MSA contains 60 percent of all admissions to hospital X.

by the distance between the area's center and another point at the center of an area summed over all points in a larger region. Population potential values can be used to measure a population's exposure or potential for the spread of a disease. Population potential computations can be created on a spreadsheet and then imported to a mapping program.

In **Figure 6**, the population 75 years of age and over in a region is displayed as an isoline map, reflecting equal levels of weighted distance from county centers compared with the region's population. This map could be incorporated into a larger needs assessment in planning for health care resource needs for an elderly population.

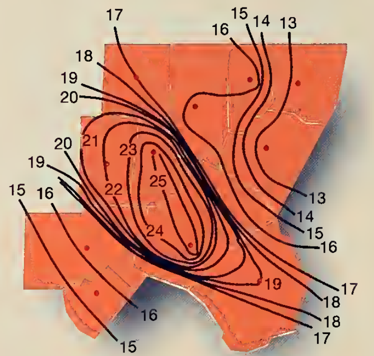
Vector Map Showing Inpatient Migration

A vector map provides an opportunity to depict the direction of movement of a population across a defined area. Vector maps use directional lines or arrows to reflect flow from an origin point to some destination across space. Variations in the width of these arrows can be used to indicate differences in the magnitude of the flow; color or shading schemes can be used to show differences in flow among subpopulations.

Population potential measures the nearness or accessibility of people to a certain point or place. In a region, the map could use isolines, as in the example on the right, to measure the influence on a particular point of all other points.

Figure 6. Population Potential Maps: Health Service Area IV, North Carolina

Location of a Geometric Center for Calculation of Distance

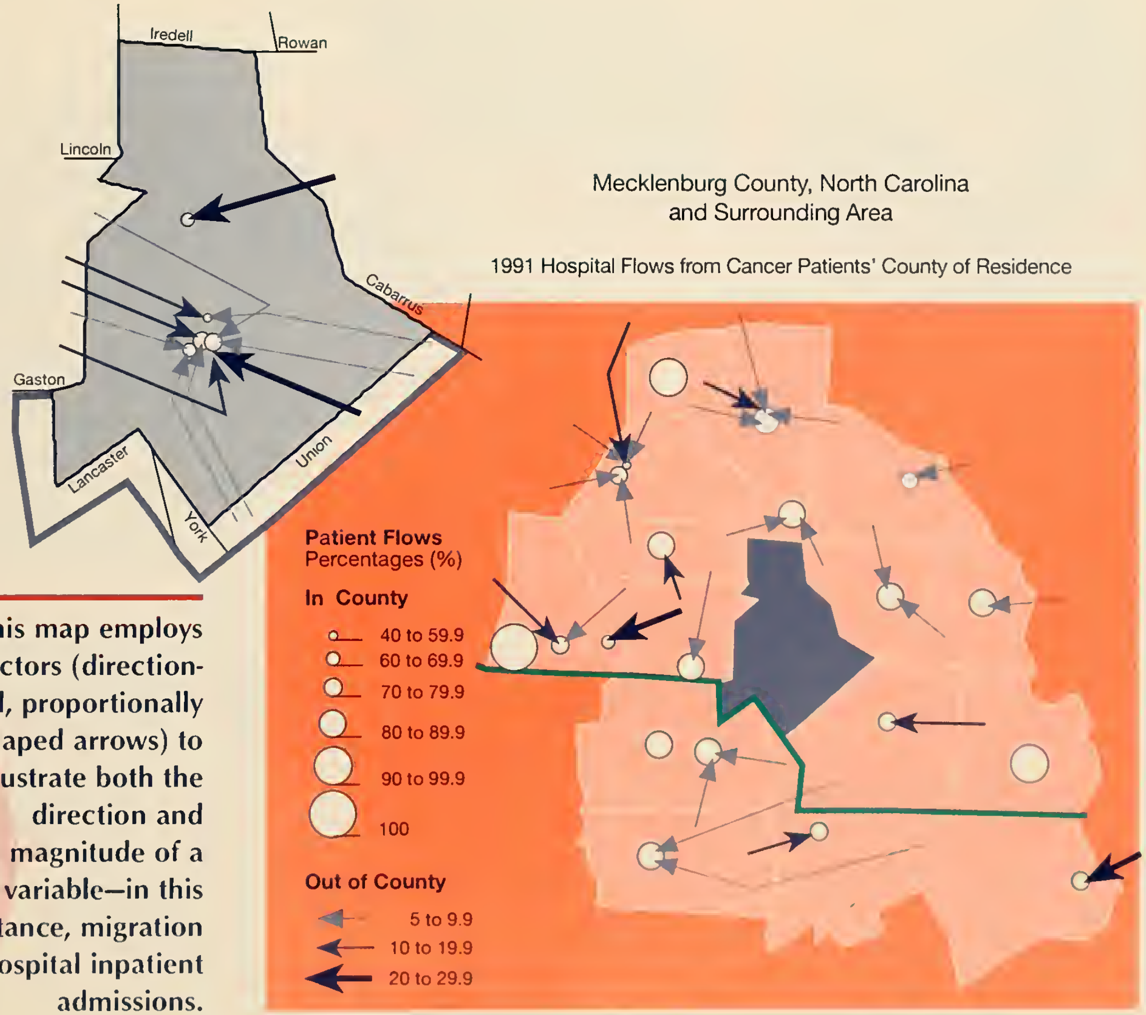


Population Potential (000)
Population Aged 75+

Data Source: U.S. Census of Population, 1990.

Figure 7 is a vector map that shows both the percentage of hospital cancer discharges treated in a given county (depicted as proportional circles) and the percentage of cross-county outmigration of cancer patients for inpatient treatment (depicted as vectors or arrows). The upper portion of the map display depicts cross-county migration to Mecklenburg County, North Carolina, for inpatient cancer care; the bottom portion shows cross-county migration for inpatient cancer care across the remaining counties in the defined area. Percentages are calculated using inpatient claims data from a uniform discharge database; in this case, data from two States are used. Providers and policy analysts can use vector maps like this to plan for regionalized delivery of oncology services.

Figure 7. Vector Map Showing Inpatient Migration



This map employs vectors (directionalized, proportionally shaped arrows) to illustrate both the direction and magnitude of a variable—in this instance, migration of hospital inpatient admissions.

Data Sources: South Carolina Department of Health and Environmental Control; North Carolina Medical Database Commission. Data compiled from reported 1991 figures.

Health Professions and Regionalization

Assessment by geographers of provider and service availability in an area can make an important contribution to studies of health care access. Geographic analysis techniques can be used to identify inequities in the distribution or to plan for a reasonable mechanism for allocation and/or regionalization of health care resources. These map displays demonstrate three alternatives: the use of choroplethic maps to depict service and provider availability in North Carolina (Figures 8 and 9), the use of map boundaries to reflect geopolitical borders for planning and resource allocation purposes (Figures 10 and 11), and the potential use of geographic techniques in regionalizing health care services across an area (Figure 12).

County Classification by Availability of Cancer Care

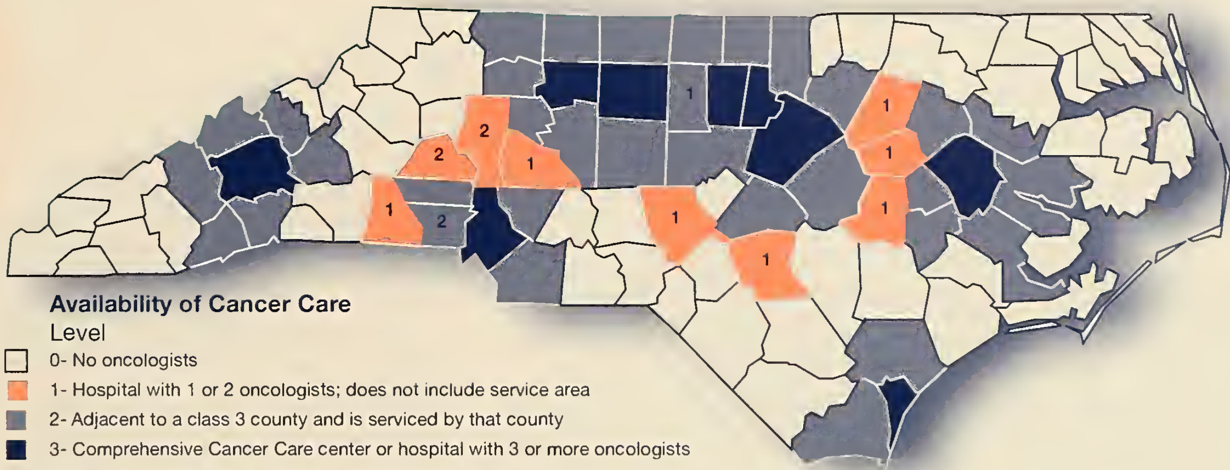
The spatial distribution of oncologists across the United States, as in North Carolina, is very uneven, with several prominent clusters. This is a possible concern for health planners and policymakers at different levels—State, regional, and local. Maps can provide a visual summary that identifies areas of underservice, which can then be addressed through provider networking and/or policy actions that encourage providers to locate in and serve a particular area.

Figure 8 shows the availability of cancer care at the county level, based on a classification scheme that integrates provider and facility resources for oncology services. In this choroplethic map, more darkly shaded areas reflect a greater intensity of service availability. Superimposed on shaded areas are the numbers of practicing oncologists located in each county. This map illustrates that while some counties appear to be well served, others have poor potential access to oncologists.

In contrast to Figure 8, **Figure 9** displays the absolute number of oncologists at the county level. Although this choroplethic map provides useful information about the distribution of providers across the State, it does not fully depict geographic access to cancer care services.

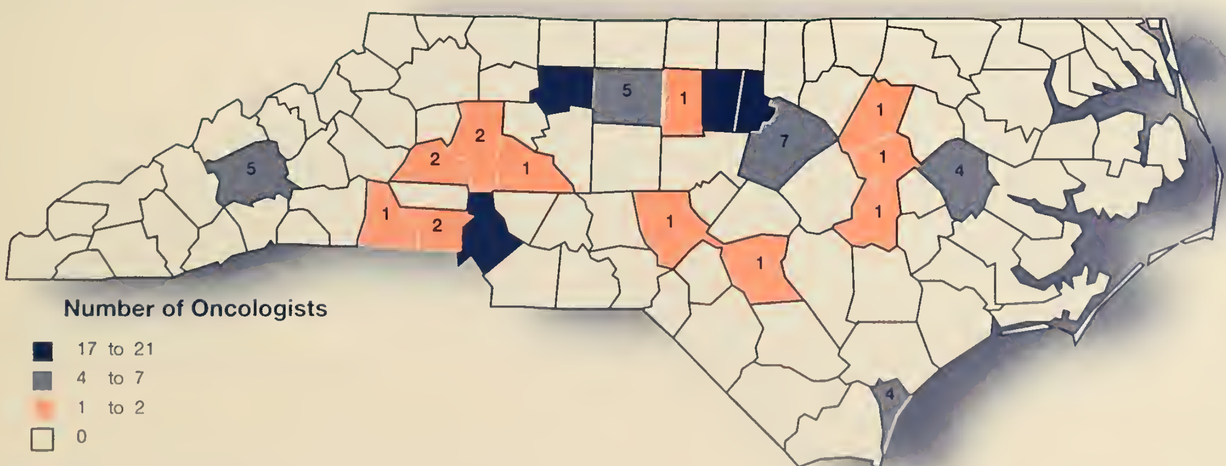
Figure 8. Level of Cancer Care Available, by County: North Carolina, 1990

This county map describes the availability of cancer care by using shading to depict a combination of hospital and physician data.



The number of oncologists is shown within county boundaries.
Data Source: 1990 NC Board of Medical Examiners Licensing Data, maintained by the Cecil G. Sheps Center for Health Services Research.

Figure 9. Number of Oncologists, by County: North Carolina, 1990



The number of oncologists is shown within county boundaries.
Data Source: 1990 NC Board of Medical Examiners Licensing Data, maintained by the Cecil G. Sheps Center for Health Services Research.

In contrast to Figure 8, this map includes only information about the number of physicians, in this case oncologists, in each county. The shading emphasizes the differences in numbers.

Health Service Area Regionalization Plans

Regionalization of health care resources has not been a leading feature in the organization of health care in the United States. However, in several cases, planning and resource allocation occur in a regional structure. The VA (Department of Veterans Affairs, formerly Veterans Administration) system of health care delivery is the clearest example of a national system implemented and administered through a regional model.

Figure 10 shows VA medical service areas in North Carolina. Boundaries for these service areas were determined more by expected patterns of use than by established boundaries. This type of map, together with a patient origin map, such as Figure 5, as an overlay, could be used to suggest periodic boundary redefinitions to compensate for shifts in utilization patterns and population migration.

Similar to Figure 10, **Figure 11** depicts service areas for the Area Health Education Centers (AHEC) Program in North Carolina. The AHEC Program was established in 1971 to encourage the establishment and support of regionalized training programs to alleviate health professional shortages in rural areas. The AHECs link health care providers to central health sciences centers. In the North Carolina AHEC Program, staff from the central medical schools visit regional AHEC hospitals to provide both training and health care. The AHEC regions are strongly hierarchical and are focused on university medical centers. Program boundaries follow county lines and, in almost all cases, State borders.

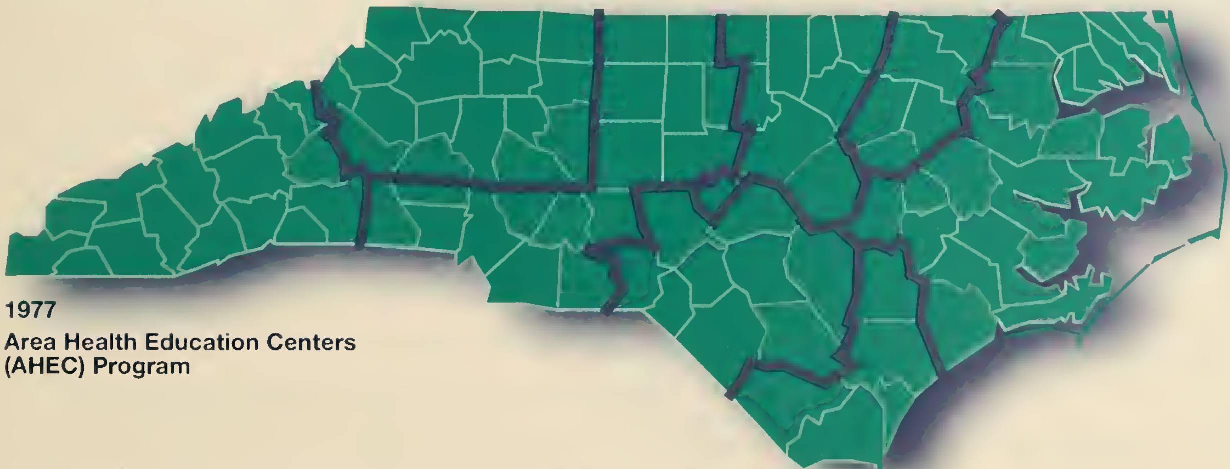
Figure 10. Health Service Area Regionalization Plan Developed Under Categorical Grant: North Carolina, 1946

This map depicts patient service areas constructed by the VA to regionalize the administration of its hospitals.

1946
Veterans Administration (VA) Patient Service Areas

Source: Florin, 1980, in: *Conceptual and Methodological Issues in Medical Geography.*

Figure 11. Area Health Education Center Regions: North Carolina, 1977



1977
Area Health Education Centers (AHEC) Program

This map shows another regional plan for North Carolina: in this case, the regional boundaries for the Area Health Education Centers (AHEC) Program.

Sources: Florin, 1980, in: *Conceptual and Methodological Issues in Medical Geography;* Odegaard, 1980: *Eleven Area Health Education Centers: The View From the Grass Roots.*

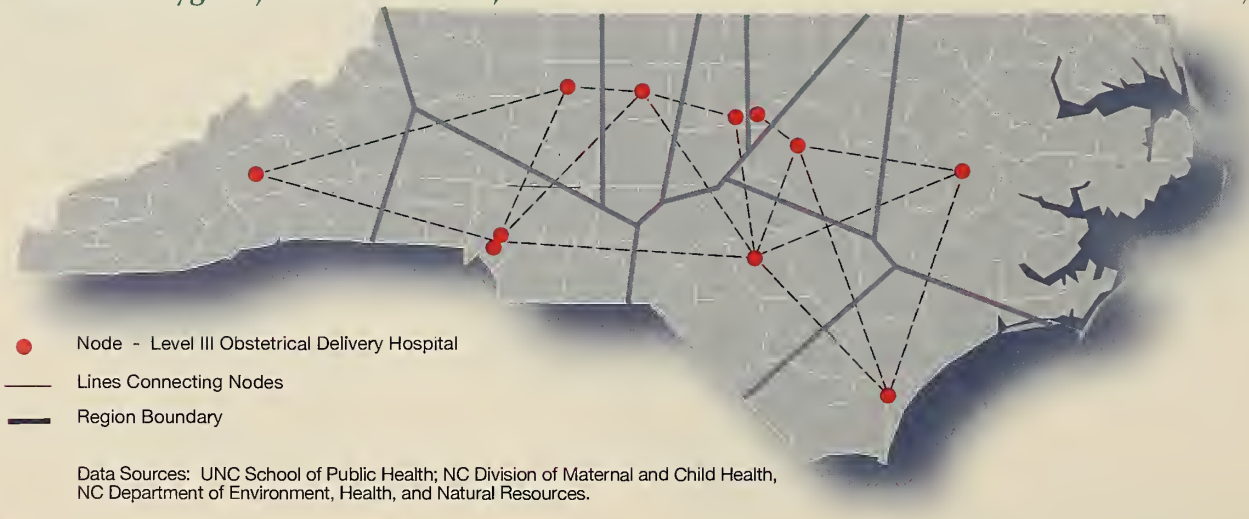
Obstetrical Delivery Hospital Regions

Many States constructed Perinatal Care Regions in the 1970s and 1980s to reduce perinatal and maternal mortality and to improve the health prospects of perinatal survivors. The delivery system that evolved was strongly hierarchical, with more difficult cases routinely referred to higher order centers in a three-tiered system. Given a need to minimize distance to these services, a variety of methods can be used to construct regions. One simple technique is the use of Thiessen polygons.

Thiessen polygons are used in **Figure 12** to define Level III Obstetrical Delivery Regions in North Carolina. (Level III is the highest service level and includes a neonatal intensive care unit.) Boundary location is a major problem with regional delimitation, and this technique provides a method of roughly anticipating regional boundaries with very little data. It is particularly appropriate when considering regions surrounding a number of nodal centers, Level III nurseries in this example. The 11 hospitals with Level III nurseries are located in 10 communities.

Polygon construction demands some decisionmaking that is best informed by analysts familiar with the travel and practice patterns in the area. It begins with the construction of lines connecting each adjacent or nearby pair of nodal centers. Once the join lines are drawn, perpendicular lines bisecting each join line at its midpoint are added. These perpendiculars are extended until they meet another perpendicular line. The perpendiculars form the Thiessen polygon regional boundaries and thus map the regional pattern. It is often necessary to construct a regional boundary system several times to achieve an acceptable regionalization. Some join lines may be inappropriate because of topographical barriers, cultural or linguistic patterns, or a misreading of the equivalence of the nodes. In constructing regions, it is particularly important to consider features of the physical geography, concerns of spatial contiguity, existing political borders, settlement patterns of the population, existing patterns of utilization, and relevance and logic.

Figure 12. Obstetrical Delivery Hospital Regions (Constructed Using Thiessen Polygons): North Carolina, 1989



This map uses Thiessen polygons to construct regions: in this case, obstetrical delivery hospital regions. This technique can be utilized with little technology, using nodal points to construct polygons and, ultimately, regions.

Health Conditions

Maps are uniquely able to display incidence data for contagious diseases because physical proximity and human interaction are key elements in their spread. Likewise, many chronic diseases are restricted to certain populations or caused or exacerbated by environmental factors that have a particular physical or geographic distribution. Mapping can graphically track the spread of a disease or be used to search for causal agents in the environment and help understand the origins of a disease or condition.

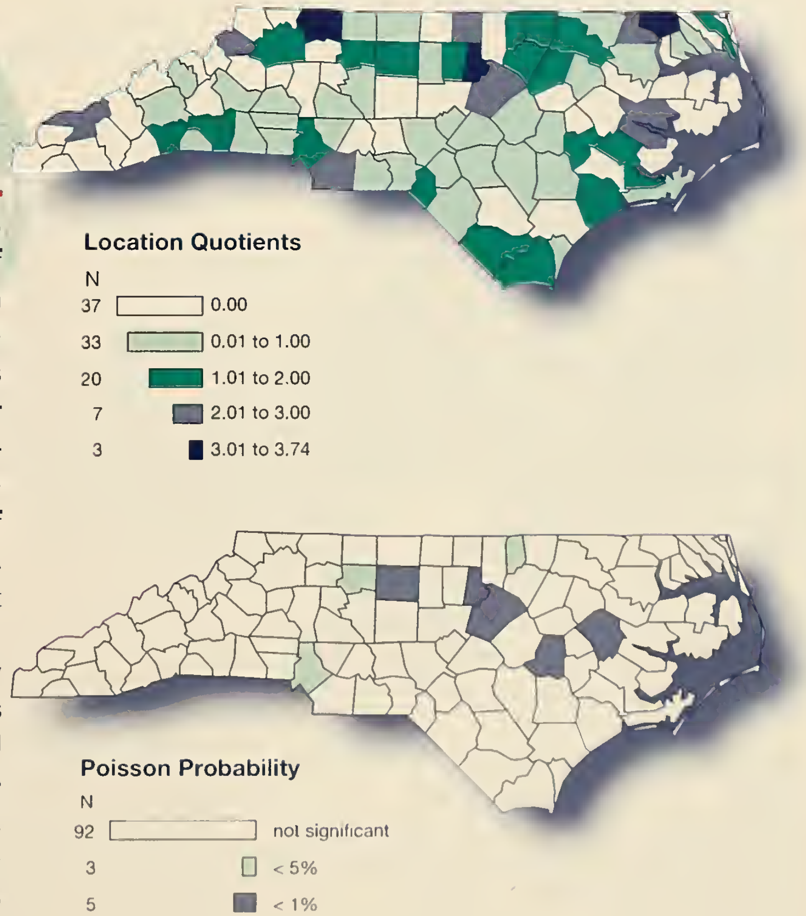
AIDS and Location Quotients

Acquired immunodeficiency syndrome (AIDS) has, over a brief span of time, become the deadliest contagious disease in the Nation. AIDS began as a primarily urban disease but soon began to make inroads in almost every community in the Nation. **Figure 13** depicts the relative incidence of AIDS cases in counties in North Carolina using location quotients to identify high-incidence areas. The location quotient is a ratio of proportions.

The quotient for each county is shown in the top map of Figure 13. To arrive at this

These two maps describe aspects of the spread of AIDS in North Carolina. The top map uses location quotients, or a ratio of proportions, to illustrate the relative incidence of AIDS by county. A location quotient greater than 1 indicates the county has more than its share of cases based on population. The bottom map uses a Poisson distribution to identify counties where incidence is higher than would be expected to occur by chance.

Figure 13. AIDS Location Quotients and Poisson Probability: North Carolina, 1990



quotient, first, the number of cases in the county is divided by the county population. Second, that figure is divided by the number of cases in North Carolina divided by the total population of the State. A location quotient greater than one indicates that a county has more than its share of cases based on its population; less than one indicates a lower share. The bottom map of Figure 13 indicates the probability that the observed quotient is higher or lower than expected due only to chance. It shows that the higher rates in the two pairs of adjacent counties in the center of the State are probably not due to random distribution of cases.

Threshold Tuberculosis Rates and Regional Impact

Tuberculosis has reappeared as an important threat to the health of both rural and urban populations. Its incidence and prevalence show marked geographic characteristics.

Figure 14 illustrates a regional pattern of incidence for one year using simple population rates to create a choroplethic map. In this map, the divisions of the rates at certain cut points dramatize the regional nature of the disease. The cut points for the shading were arbitrarily chosen based on the distribution of the rates in steps of 10 cases per 100,000. Such thresholds may relate to specific policies or targets set by policymakers, but they are essentially arbitrary.

Cancer Clusters and Synthetic Regional Analysis

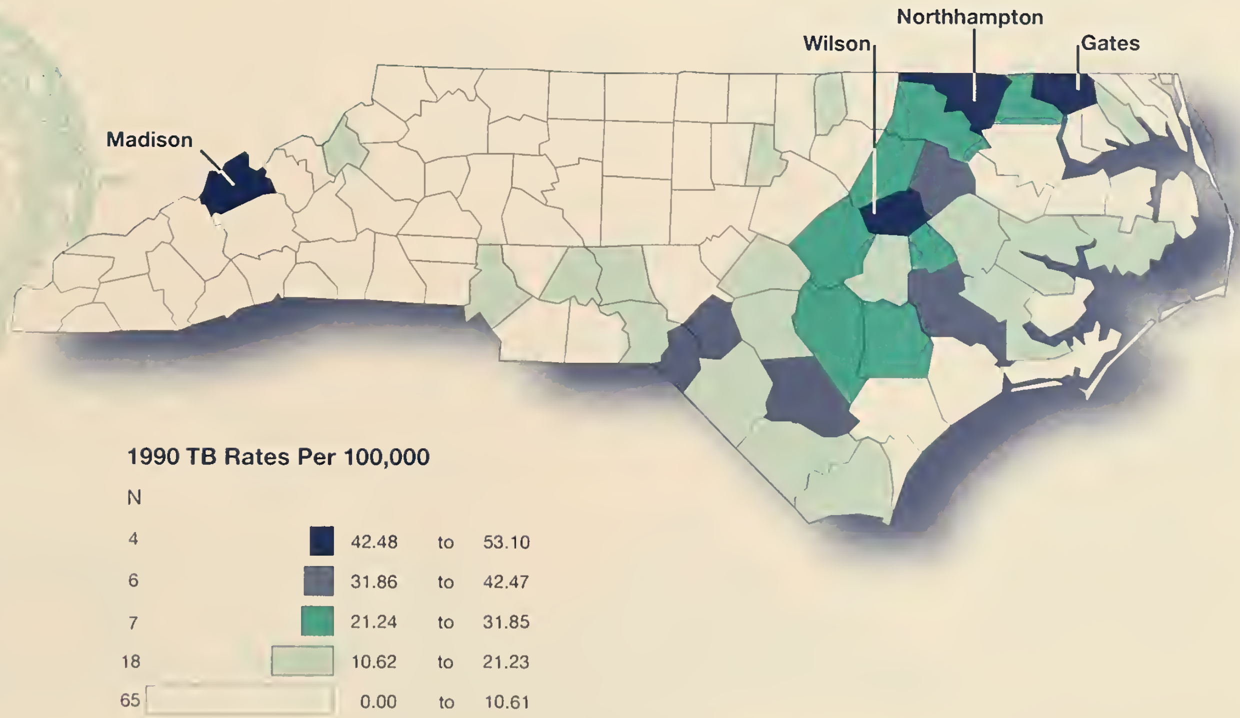
The modes of transmission of tuberculosis and AIDS are relatively well understood compared with the etiology of cancer. Occasionally, several cancer cases appear in the same general area, giving rise to fears that there is a proximate cause for this "cluster" of cases. Geographic methods are used to determine if the observed cluster is a result of coincidence or random clustering or if there is a probability that there is some specific cause.

Figure 15 illustrates the arbitrary division of a two-county region into synthetic regions to identify high- and low-incidence areas for pancreatic cancer. The synthetic regions described in this map by the dotted lines are based on perceptions of natural areas in the counties and were drawn without prior knowledge of the cancer case locations. They may also be drawn randomly to focus attention on specific parts of an established area, such as a county. The degree of cluster in these synthetic areas can be assessed statistically. In this example, surveillance for any change in rates continued. Five cases occurred in 1990, two in Alleghany and three in Ashe County. Their occurrence had no significant impact on the regional crude rates.

Cancer Clusters and Overlays of Controls

Certain factors in the environment may be overlaid on an incidence map to visually test for relationships between disease and the factor of interest. **Figure 16** includes the locations of power transmission lines (greater than 100 kilovolt), the residences of persons dying of brain cancer during the period 1980-89, and the residences of an equal number of people whose deaths during the same period were caused by a disease that had a similar population rate—in this case, septicemia. The mapping is one part of a test of clustering that also involves analysis of incidence over time and statistical analysis of the relationships between the variables involved. In this instance, the process concluded that the rates were not due to clustering around power transmission lines because their incidence was very much the same as the incidence for a disease that has no apparent relationship to electromagnetic field strength.

Figure 14. Tuberculosis Rates per 100,000 Population: North Carolina, 1990

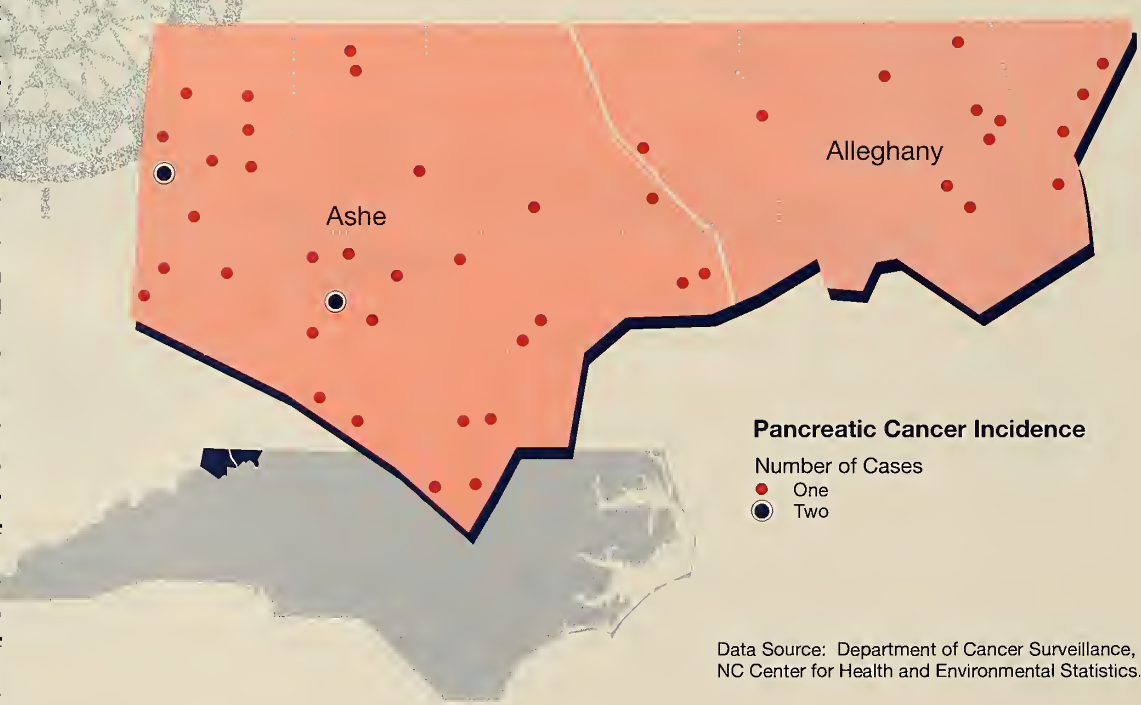


Data Source: NC Department of Environment, Health, and Natural Resources, Division of Epidemiology, 1991.

This choroplethic map shows rates of tuberculosis per 100,000 population in North Carolina by county. The darkest shading is generally assigned to those areas which are the intended focus of the map—in this case, counties with the highest rates.

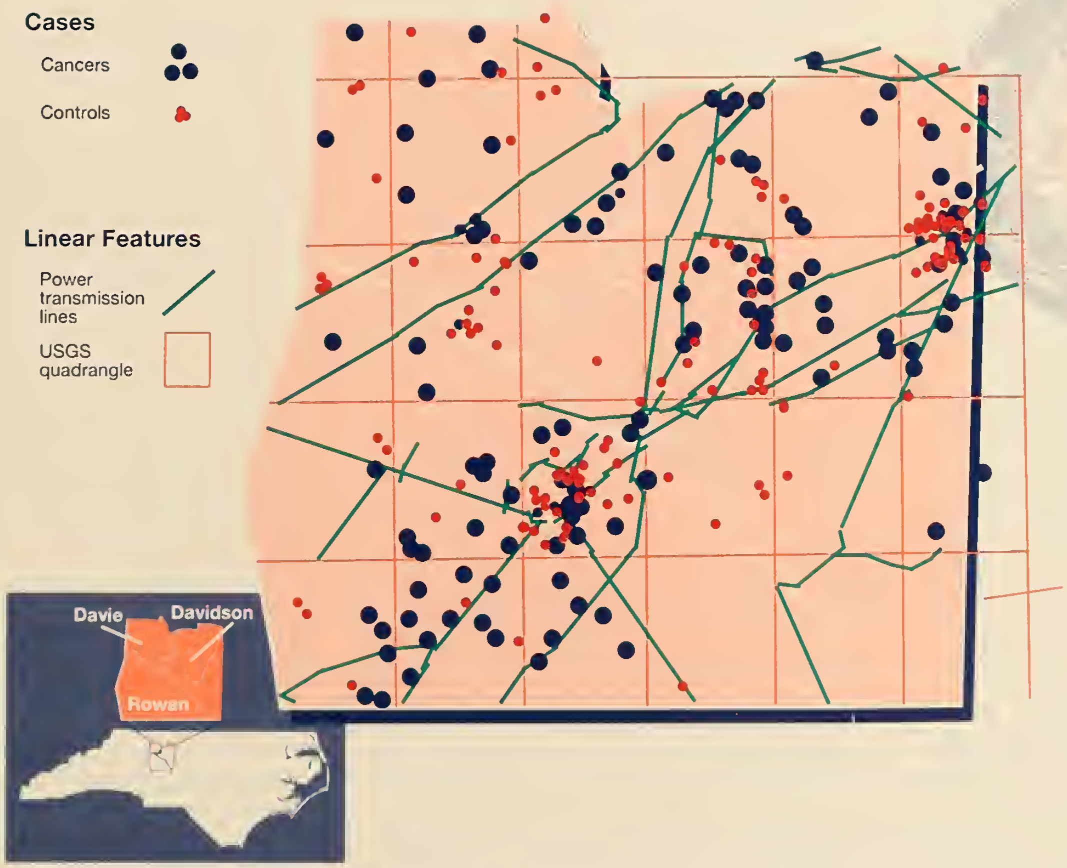
Figure 15. Residence at Diagnosis: Pancreatic Cancer Cases Studied Using Arbitrary Boundaries Within Ashe and Alleghany Counties, North Carolina

Semi-arbitrary subdivision of a set area, such as a county, into smaller areas can assist in more closely examining disease patterns. In this map, a two-county region has been subdivided into synthetic regions based on general knowledge of the area to identify areas of higher and lower incidence of pancreatic cancer. This is done with no prior knowledge of cancer case locations.



Data Source: Department of Cancer Surveillance, NC Center for Health and Environmental Statistics.

Figure 16. Brain Cancer Cases and Controls Shown by Proximity to Power Transmission Lines: Three-County Area of North Carolina, 1980-89



Data Source: Department of Cancer Surveillance, NC Center for Health and Environmental Statistics.

Figure 16.
U.S. Geological Survey (USGS) quadrangles are used as internal boundaries in this map analyzing cancer clusters and their proximity to power transmission lines.

Conclusion

This general introduction to the use of geography and cartography in health services research—especially in the field of rural health services—was designed to illustrate how geographic methods can be applied to a wide range of data sets using a variety of commercially available mapping software programs. (See Technical Notes.)

Most of the methods and techniques introduced here do not demand sophisticated computer software or hardware, nor do they require a substantial background in either geography or statistics. The health care issues selected are mostly common ones dealt with by providers and planners across the rural–urban continuum. We are confident that the user can identify other appropriate applications.

For Further Study

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Technical Notes

The development of *Geographic Methods for Health Services Research: A Focus on the Rural–Urban Continuum*, the book on which this publication is based, is an example of the use of multiple operating systems, software packages, and machine configurations. The editorial team and the authors of the chapters made use of many different commercially available products to illustrate the techniques discussed and to bring the final document to publication.

The final text and illustrations for the book were produced using PageMaker® versions 4.2a and 5.0. The text and graphics were processed on a Macintosh IIfx, Macintosh IIcx, and Macintosh Centris 650, using 20, 8, and 24 megabytes of internal memory, respectively, with operating systems 6.4, 7.0.1, and 7.1. Because software and operating systems evolve so rapidly, there have been multiple changes in versions of the operating system as well as the application software packages used. The camera-ready pages were imaged on an Apple LaserWriter Pro 630 at 600 dots per inch and used by University Press of America for final page makeup.

To create the maps used in the text, the authors and cartographers used several packages, mostly working within the Macintosh environment, although occasionally maps were created originally using DOS or Windows software. We refer to full-size GIS systems (Geographic Information Systems) in the book, and the authors from the Department of Geography at the University of North Carolina at Chapel Hill made use of the ARC/INFO® system installed at the Geography Department to develop maps and analyses summarized here. This system is mounted on SUN workstations, using the UNIX operating system, with 48-64 megabytes of internal memory per workstation. Data sets for the mapping and analysis examples were generally manipulated on the mainframe computer at the University of North Carolina at Chapel Hill, which includes an IBM 3090-170 mainframe computer, several VAX 6330 minicomputers and a Convex C240 supercomputer. All of these are network accessible and are maintained by the University of North Carolina at Chapel Hill's Office of Information Technology. The interface with the mainframe was through WYLBUR, and most data sets were managed using the SAS® system.

Data sets were downloaded to mapping and graphics packages in text (ASCII) format and were occasionally manipulated using statistical packages such as StatView® or JMP® on microcomputers. Graphing of data was primarily done using DeltaGraph Professional®; the population pyramids were created using IPSS®. Final imaging for inclusion in PageMaker format used FreeHand®, SuperPaint®, and MacDraw II®. Maps were produced using MapInfo® versions 1.0 and 2.0, Atlas Mapmaker® version 1.5, Atlas Pro® version 1.0, and Geoquery®. MapInfo® was used in both the Macintosh and Windows environments. For information on training sessions, call the customer service numbers listed in the next section, Selected Software Manufacturers.

Data from the U.S. Bureau of the Census were obtained from CD-ROM disks and downloaded using FoxBase®. Some detailed maps were produced from TIGER line files (1990 version) and were transported into the graphics environment using TIGER Massage®.

Special data sets were used for some maps and analyses or were discussed in the chapters as potential sources for baseline maps or for basic levels of data to be used in GIS applications. These ranged from the generally applicable Census files such as the Summary Tape Files (STF), which include the entire U.S. population and special samples of the population, to special-use tapes and data sets, including the AIDS Public Information Data Set available from the National Center for Infectious Disease, Centers for Disease Control and Prevention, in Atlanta, Georgia.

To explore maps in more depth, consult *The Map Catalog: Every Kind of Map and Chart on Earth and Even Some Above It,* Third Edition, published by Vintage Books. Another guide to the use of mapping that readers might find useful is *Analytical Mapping and Geographic Databases,* by G. David Garson and Robert S. Biggs, published by Sage as part of their series on Quantitative Applications in the Social Sciences.

Those interested in listings of mapping programs should refer to the *GIS World Sourcebook,* 1996, published by GIS World, or review recent issues of *GIS World,* a monthly magazine aimed at the more complex system user. Local college and university geography and social science departments can also offer a wealth of information, guidance, and resources in medical geography.

Selected Software Manufacturers

Adobe Illustrator®, Adobe PageMaker®, and Adobe SuperPaint®: Adobe Systems Incorporated, 1585 Charleston Rd., Mountain View, CA 94039; (415) 961-4400.

Atlas GIS® 3.0 for Windows: Strategic Mapping, Inc., 3135 Kifer Rd., Santa Clara, CA 95051; (408) 970-9600.

DeltaGraph Professional®: DeltaPoint, Inc., 2 Harris Court, Suite B-1, Monterey, CA 93940; (408) 648-4000.

FoxBase+®: Microsoft Corporation, One Microsoft Way, Redmond, WA 98052-6399; (800) 426-9400, (206) 882-8080.

GeoQuery®: P.O. Box 206, Naperville, IL 60566-0206; (708) 357-0535.

IPSS®: Senecio Software, Inc., 525 Ridge St., Bowling Green, OH 43402; (419) 352-4371.

JMP®: SAS Institute Inc., SAS Campus Drive, Cary, NC 27513; (919) 677-8000.

MacDraw Pro®: Claris Corporation, 5201 Patrick Henry Drive, Box 58168, Santa Clara, CA 95052-8168; (408) 987-7000.

MacroMedia FreeHand®: MacroMedia, Inc., 600 Townsend, San Francisco, CA 94103; (415) 252-2000.

MapInfo®: MapInfo Corporation, One Global View, Troy, NY 12180; (800) 327-8627.

StatView®: Abacus Concepts, Inc., 1918 Bonita Avenue, Berkeley, CA 94704; (510) 540-1949.

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