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Temporal Changes of Access to Primary Health Care in Illinois (1990–2000) and Policy Implications

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This paper examines temporal changes of access to primary health care in Illinois between 1990 and 2000 in a Geographic Information System (GIS) environment. Census data at the census tract level in 1990 and 2000 were used to define the population (demand) distribution and related socioeconomic attributes, and the Physician Masterfile of American Medical Association in corresponding years was used to define the physician (supply) distribution at the zip code level. A two-step floating catchment method was employed to measure the spatial access*, considering locations of physicians and population and travel times between them. Various socioeconomic and demographic variables were consolidated into three factors (i.e., socioeconomic disadvantages, sociocultural barriers, and high healthcare needs) for measuring the* nonspatial access. *Spatial and nonspatial factors were finally integrated together to assess the primary care physician shortage areas. The study shows that spatial accessibility to primary care physician for the majority of the state improved from 1990 to 2000. Areas with worsened spatial accessibility were primarily concentrated in rural areas and some limited pockets in urban areas. The worst among these worsened areas appeared to be associated with populations with high scores of socioeconomically disadvantages, sociocultural barriers, and healthcare needs. Improving the accessibility of those socioeconomically disadvantaged population groups is critical for the success of future policies.*

KEY WORDS: temporal change; health care access; GIS; spatial and nonspatial access.

The United States spends more than 13% of its GDP on health care.(1) With approximately 44 million individuals uninsured, many of them the working poor, policies to increase access in general, and for the most needy in particular, are in demand.(2) Access to health care varies across communities because of uneven distributions of physician supply and population demand (spatial factors), and also varies among population groups because of their different socioeconomic and demographic

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characteristics (nonspatial factors). Since 1960s, health policymakers in the United States have attempted to improve the access to health care for the citizenry by considering aspects of both spatial and nonspatial factors.[3] Such efforts are exemplified in designations of Health Professional Shortage Areas (HPSA) and Medically Underserved Areas or Populations (MUA/P) by the U.S. Department of Health and Human Services (DHHS), for the purpose of determining eligibility for certain federal programs designed to alleviate poor access and encouraging physicians to practice in these designated areas. Examples of federal programs include the National Health Service Corps (based on HPSA designation), the Community Health Center Program (designated by MUA/P status), and Titles VII and VIII funding for graduate medical education and training grants (given to institutions the serve areas designated as HPSA and MUA/P). In addition, these designations are related to reimbursement through Medicare and Medicaid, in part, as the result of being certified as Rural Health Clinics.[4]

This paper examines the temporal change of access to primary care physician services from 1990 to 2000 in the state of Illinois, which perhaps to some extent reflects whether these federal programs have helped alleviate the problem of health care access. By integrating both spatial and nonspatial factors in a Geographic Information System (GIS) environment, this study analyzes where the spatial access improved or worsened over time, and whether the change was associated with nonspatial factors such as populations with socioeconomic disadvantages, sociocultural barriers, and high health care needs. As some of the related methodology has been discussed elsewhere,[5] this paper focuses on the analysis of temporal changes and policy implications.

DATA SOURCES AND PROCESSING

The population data were extracted from the 1990 and 2000 Census,[6,7] and the corresponding spatial coverages of census tracts and blocks were generated from the 1990 and 2000 Census TIGER/Line files.[8,9] Census tract is chosen as the analysis unit for population distribution, since it is the lowest areal unit used in the current practice of shortage area designation, and the number of tracts is computationally manageable for travel time estimation and accessibility modeling. Since the population is seldom distributed homogeneously within a census tract, the population-weighted centroid (using block level population as weight) instead of the simple geographic centroid of a census tract is used to represent the location of population within a tract more accurately[10] (hereafter simply referred to as centroid).

The primary care physician data of Illinois in 1990 and 2000 were purchased from the Physician Masterfile of the American Medical Association (AMA) via Medical Marketing Service Inc. Primary care physicians include family physicians, general practitioners, general internists, general pediatricians, and some obstetrician-gynecologists.[11] This case study focuses on primary care physicians because these physicians are an integral component of a rational and efficient health delivery system and they are critical for the success of preventive care.[12] Most of the HPSAs designated by the U.S. Department of Health and Human Services are also for primary medical cares (others are mental health and dental HPSAs). Similar analysis can be easily conducted for other health care specialties at national levels. Ideally, the physician locations should be geocoded by their street addresses with GIS software, a process of converting the address information to x and y coordinates of a point on the map by matching address name and interpolating the address range to those stored in a digital map (e.g., TIGER/Line file). However, a significant number of records in the Physician Masterfile only have "P.O. Box" addresses, which are not feasible for geocoding. Since physicians also tend to practice at populated places, this study simply used the population-weighted centroid of the zip code area of a physician's office address to represent the physician's location. This is not the best solution(13) but nonetheless an improvement over large administrative units such as county. Zip code has been used extensively in health research.(14)

MEASURING SPATIAL AND NONSPATIAL ACCESS

The spatial factors are evaluated using a *two-step floating catchment method*,(5) considering physician supply, population demand, and simulated road network travel time between them. In the first step of the method, for each physician location, the ratio of physicians practicing at that location to population within a threshold travel time (say 30 min) from that physician location (i.e., a 30-min catchment) is computed. In the second step, for each census tract centroid, the physician to population ratios (derived in first step) for those physician locations that are within the threshold travel time of the census tract centroid are summed as the spatial accessibility measure of that tract. The first step above assigns an initial ratio to each service area centered at a physician location (also considered a measure of physician availability for the supply location), and the second step sums up the initial ratios in the overlapped service areas to measure accessibility for a demand location, where residents have access to multiple physician locations. The method considers interaction between patients and physicians across administrative borders based on travel times, and computes an accessibility measure that varies from one tract to another. In a GIS environment such as ArcGIS as used in this study, this method can be implemented easily by using a series of "join" and "sum" functions. The spatial accessibility derived from this method is basically the ratio of physician to population (filtered by a threshold travel time), and thus can be interpreted the same way. This approach has all the essential elements of a gravity model. In fact, it is a special case of gravity model.(5) The gravity model is not used as it tends to underestimate the spatial accessibility for those areas with poor access.(5) In general, urban areas had higher values of (better) spatial accessibility than rural areas in both 1990 and 2000.

Population subgroups differ in terms of healthcare needs and accessibility according to their age, sex, social class, ethnicity, and other nonspatial characteristics. On the basis of a literature review,(15) this research selected 11 sociodemographic variables to measure nonspatial accessibility. As these variables may be correlated, principal component and factor analyses were conducted to consolidate these variables into three independent factors that capture the majority (~75%) of the total variance. The loadings of the each factor for the 2 years are shown in Tables I and II.

Table I. Factor Structre of Nonspatial Factors 1990

	Factor 1: Socioeconomic disadvantages	Factor 2: Sociocultural barriers	Factor 3: High healthcare needs
Population in poverty (%)	0.91812	0.06954	−0.1092
Female-headed households (%)	0.90533	−0.04198	−0.11357
Households w/o vehicles (%)	0.88464	0.22587	−0.02291
Non-white minorities (%)	0.78543	0.16259	−0.3
Median income ($)	−0.75888	−0.13453	−0.21871
Home ownership (%)	−0.74958	−0.37929	−0.07481
Population w/o high-school diploma (%)	0.70476	0.41697	−0.02487
Households with linguistic isolation (%)	0.0691	0.94557	0.03196
Households with >1 person per room (%)	0.54087	0.64568	−0.27161
Population with high needs (%)	0.23102	−0.12508	0.86853
Housing units' lack of basic amenities (%)	0.30066	−0.06247	−0.48887
Total variance explained (%)	46.71	15.91	11.25
Variance explained by the 3 factors (%)	63.23	21.54	15.23

Note. Total number of tracts = 2844. Shaded areas indicate variables with high loading on each factor.

Although there were slight differences in the loadings between the 2 years, they were generally consistent. On the basis of the loadings, factors 1 through 3 are labeled as socioeconomic disadvantages, sociocultural barriers, and high healthcare needs, respectively. In both 1990 and 2000, higher scores of socioeconomic disadvantages (i.e., the first nonspatial factor) were mostly found in inner cities of large metropolitan areas such as Chicago and East St. Louis. Higher scores of sociocultural barriers (i.e., the second nonspatial factor) were mostly scattered in Chicago region and its suburbs. Higher scores of health care needs (i.e., the third nonspatial factor) were scattered in both rural and urban areas across the state.

Both spatial and nonspatial factors were then integrated in a GIS environment to assess the primary care physician shortage. The "spatial accessibility measure" was used as the primary indicator and the factor of "high healthcare needs" as the secondary indicator to identify the first type of physician shortage areas (i.e., *geographic*

Table II. Factor Structre of Nonspatial Factors 2000

	Factor 1: Socioeconomic disadvantages	Factor 2: Sociocultural barriers	Factor 3: High healthcare needs
Female-headed households (%)	0.9089	−0.0058	0.0504
Population in poverty (%)	0.8662	0.1642	0.2405
Non-white minorities (%)	0.8481	0.2153	−0.0153
Households w/o vehicles (%)	0.8231	0.1905	0.2699
Home ownership (%)	0.6686	−0.3362	−0.3922
Housing units lack of basic amenities (%)	0.4278	0.2703	−0.0323
Households with linguistic isolation (%)	0.0479	0.9561	−0.0164
Households with >1 person per room (%)	0.4464	0.7966	−0.0631
Population w/o high-school diploma (%)	0.5800	0.6406	0.1219
Population with high needs (%)	0.0316	−0.1050	0.9186
Median income ($)	−0.5491	−0.2053	−0.5605
Total variance explained (%)	40.40	20.98	13.32
Variance explained by the 3 factors (%)	54.08	28.09	17.83

Note. Total number of tracts = 2964. Shaded areas indicate variables with high loading on each factor.

Table III. Criteria for Defining Physician Shortage Areas

HPSAs	Criteria	Primary	Seconday
Geographic areas	GA1	Spatial acc. < 1/3500	
	GA2	Spatial acc. ∈ [1/3500, 1/3000)	High need > mean + SD
Population groups	PG1	Socioecon. disad. > mean + SD	
	PG2	Socioecon. disad. ∈ [mean + 0.75 SD, mean + SD	Soc. cul. barr. > mean + SD

Note. Geographic Area Criterion 1 (GA1) corresponds to areas of poor spatial access; Geographic Area Criterion 2 (GA2) corresponds to areas of marginally poor spatial access with high healthcare needs; Population Group Criterion 1 (PG1) corresponds to areas of disadvantaged population; Population Group Creterion 2 (PG2) corresponds to areas of marginally disadvantaged population with sociocultural barriers.

areas as in the official HPSA designation guidelines). A tract would be defined as geographic shortage area if the spatial accessibility score was less than 1:3500 (DHHS standard) or if the spatial accessibility score was greater than 1:3500 but less than 1:3000 and the score for high healthcare needs was greater than 1 standard deviation above its mean. The factor of "socioeconomic disadvantages" was used as the primary indicator and the factor of "sociocultural barriers" as the secondary indicator to identify the second type of physician shortage areas (i.e., *population groups* as in the official HPSA designation guidelines). A tract would be defined as population shortage area if its score for socioeconomic disadvantages was greater than 1 standard deviation above the mean, or if the score for socioeconomic disadvantages was less than 1 standard deviation above the mean but greater than $\frac{3}{4}$ standard deviation above the mean, and the score for sociocultural barriers was greater than 1 standard deviation above the mean. The criteria used in this research are summarized in Table III.

This integrated approach has at least three advantages. First, it defines physician shortage areas systematically, unlike the current designation process that often follows a case-by-case approach. Secondly, the quantitative criteria are consistent and precise with sound theoretical foundations corresponding to spatial and nonspatial factors. Finally, it is flexible and allows expansion (or contraction) of physician shortage areas to be designated according to available resources. The results of defining shortage areas for the two study years based on the integrated approach considering both spatial and nonspatial factors are shown in Figs. 1 and 2. The geographic shortage areas are primarily concentrated in rural areas with large areas but sparse population, whereas the population group shortage areas are primarily concentrated in inner-city neighborhoods with large populations occupying small areas. This is consistent with the existing designations by the Illinois Department of Public Health. Using census tracts as the basic unit, the integrated approach revealed where within a county the shortage areas existed.

TEMPORAL CHANGES OF HEALTH CARE ACCESS

From 1990 to 2000, the overall access to primary health care improved in general as evidenced by less shortage areas in 2000 (Fig. 2) than those in 1990 (Fig. 1). Table IV summarizes the temporal changes over the decade 1990–2000, such as the numbers of census tracts defined as physician shortage areas, their corresponding total area sizes

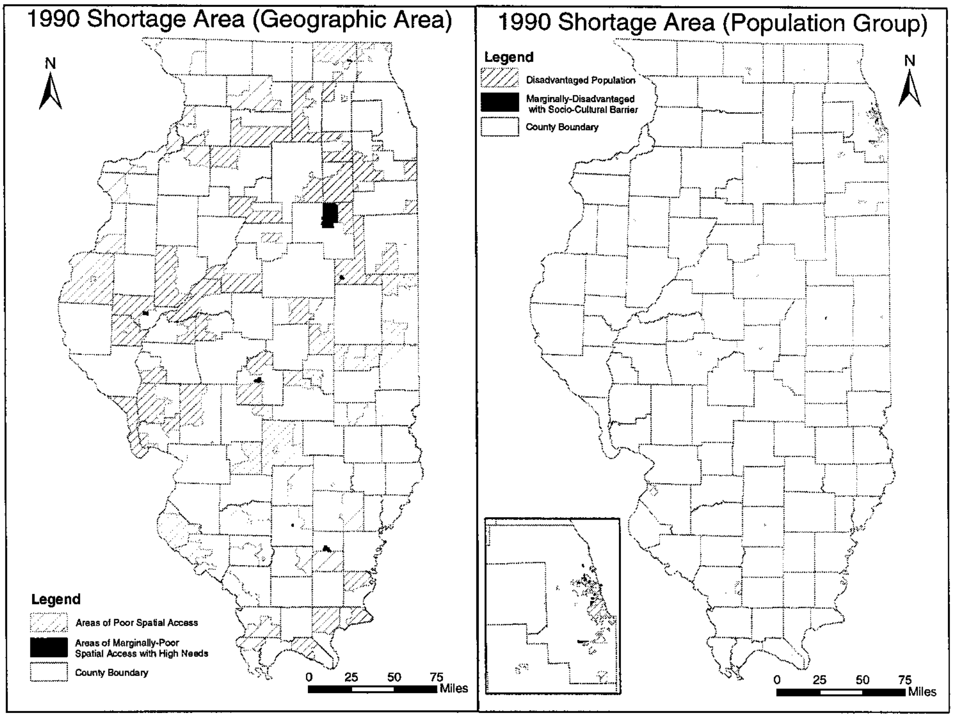


Fig. 1. Primary care physcian shortage area for 1990 defined by integrated method. Chicago area is enlarged in inset.

and population sizes. The total number of tracts defined as shortage areas decreased from 606 in 1990 to 518 in 2000. The corresponding total area size also dropped from 44,569 km^2 in 1990 to 24,900 km^2 in 2000, and the population declined from about 1.9 million in 1990 to 1.5 million in 2000. However, for the population groups with socioeconomic disadvantages (PG1 in Table IV), the number of tracts increased from 379 in 1990 to 418 in 2000, and its corresponding population increased from less than 1 million in 1990 to about 1.2 million in 2000. That is to say, the overall accessibility to primary health care improved in Illinois, but the increase of population groups with socioeconomic disadvantages suggests that challenges remain for policymakers to adopt more favorable policies so that the federal resources and benefits can be more effectively directed to the most needy population.

In order to reveal where the changes occurred, differences in accessibility need to be computed. The values of nonspatial factors were not directly comparable since the loadings on each factor were different between 1990 and 2000. This study focuses on the change of spatial accessibility and its relationships with various nonspatial factors. One difficulty in assessing temporal changes is the variation of census tract boundary over time. As shown in Fig. 3, a tract in 1990 may be split to multiple tracts in 2000, and three tracts in 1990 may be reconfigured into two tracts in 2000. The strategy adopted for this research to address the differences was to aggregate the smaller tracts (subdivided or reconfigured) to larger units (regardless of year) so

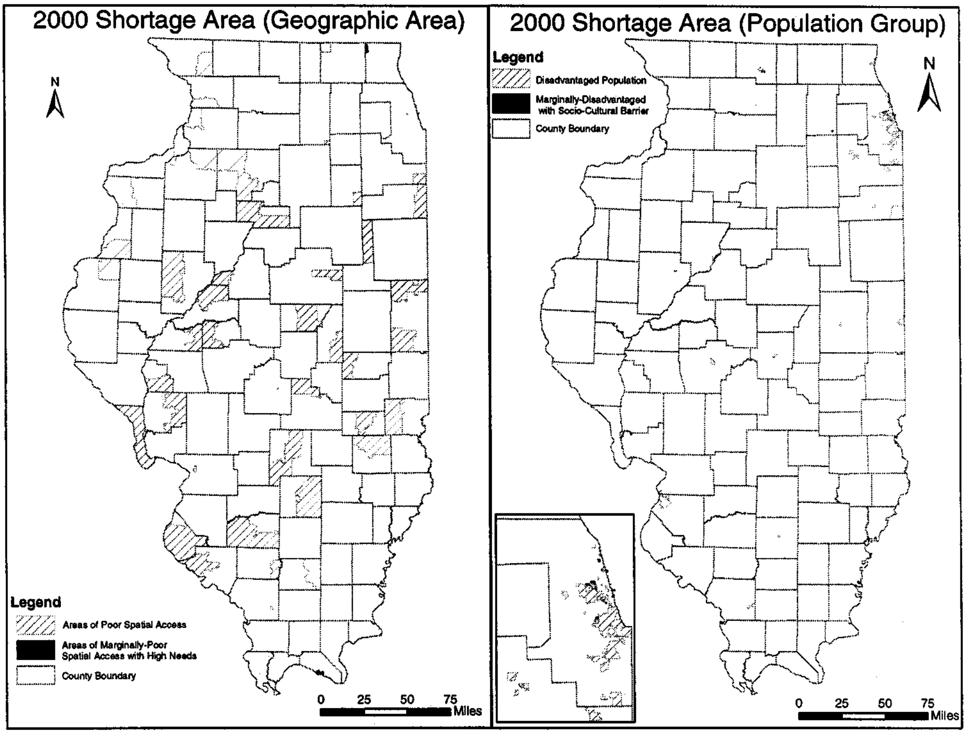


Fig. 2. Primary care physician shortage area for 2000 defined by integrated method. Chicago area is enlarged in inset.

that both years have the same common units. In other words, we created a common coverage (consisting of tracts whose boundaries did not change over time and new tracts merged from smaller tracts whose boundaries did change). All the accessibility information from 1990 and 2000 were overlaid and aggregated onto the common coverage. There are 2844 tracts in 1990, 2964 tracts in 2000, and 2782 tracts in the merged common coverage. The spatial accessibilities and nonspatial factors of the merged new tracts were computed as the population-weighted average of the original (smaller) tracts.

On the basis of the new common coverage, the spatial accessibility of 2000 minus the spatial accessibility of 1990 yielded the difference. Figure 4 shows the areas whose spatial accessibility worsened from 1990 to 2000 (i.e., negative diffrences). These areas were mostly in rural areas with a few isolated spots mostly in Chicago. Other (unshaded) areas were those whose spatial accessibility improved from 1990 to 2000. Comparing Fig. 4 to the 1990 shortage areas in Fig. 1 shows that spatial accessibility for most of shortage areas in 1990 have improved. Comparison of Fig. 4 and the 2000 shortage areas in Fig. 2 indicates that most of areas with worsened spatial accessibility became shortage areas in 2000, and a few of the lightly worsened areas (light gray) did not turn into shortage areas.

To further examine the relationship between changes in spatial accessibility and nonspatial factors, we conducted regression between the spatial accessibility

Table IV. Comparison of the Shortage Areas Defined by Integrated Approach Between 1990 and 2000

	Tracts				Area				Population			
	1990		2000		1990		2000		1990		2000	
Shortage areas	No.	%	No.	%	km^2	%	km^2	%	No.	%	No.	%
GA1	190	6.68	63	2.13	43,516.56	29.81	18,684.14	12.80	841,742	6.95	215,367	1.73
GA2	10	0.35	3	0.10	424.35	0.29	31.09	0.02	39,698	0.33	9,591	0.08
PG1	379	13.32	418	14.10	615.29	0.42	639.18	0.44	952,367	7.87	1,176,085	9.47
PG2	27	0.95	17	0.57	13.01	0.01	7.49	0.01	61,677	0.51	49,734	0.40
Total	606	21.3	518	17.5	44,569.21	30.54	24,899.6	17.1	1,895,484	15.66	1,505,369	12.1

Note. See table III for definition criteria.

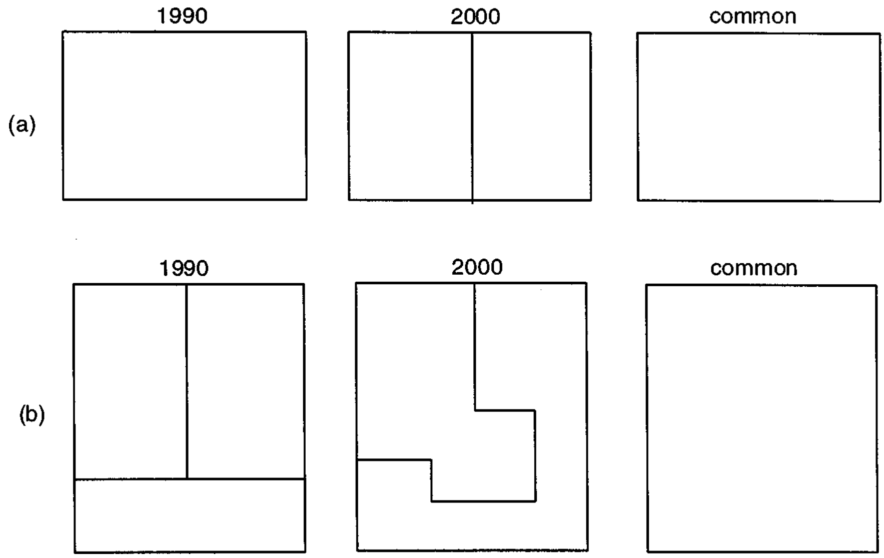


Fig. 3. Schematic diagram showing how differences in census tract between the two study years were aggregated to a common unit for easy comparison.

difference and each of the three nonspatial factors in 1990 (see Table V). When including all the tracts in the regression, spatial accessibility difference generally increases with the scores of socioeconomic disadvantages and sociocultural barriers (i.e., positive slopes in Table V), which means overall the spatial accessibility has improved for those disadvantaged groups. The relationship with high health care needs is weakly negative but statistically significant, which suggests that overall the spatial accessibility for the population with high health care needs has slightly declined. However, the situations are quite different when including only the spatial accessibility worsened tracts in the regression (see Fig. 5 and Table V). In general, the areas that are more socioeconomically disadvantaged have experienced more deterioration in spatial accessibility; so have the areas with high scores of sociocultural barriers and high health care needs.

DISCUSSION AND CONCLUSION

The GIS-based approach integrating both spatial and nonspatial factors for defining medically underserved areas intends to overcome some of the past obstacles that policymakers and researchers have encountered including measurements that were not timely and/or were not measured consistently across government agencies.[16] As the population distribution is defined down to census tracts, the method reveals geographic details of shortage areas that exist within larger units such as county. For administrative convenience, the results may be overlaid with a county (or township) coverage to designate a whole county (township) as a shortage area if all (or almost all) census tracts in the county (township) are shortage areas. However, the geographic details at the census tract level do offer valuable information for the

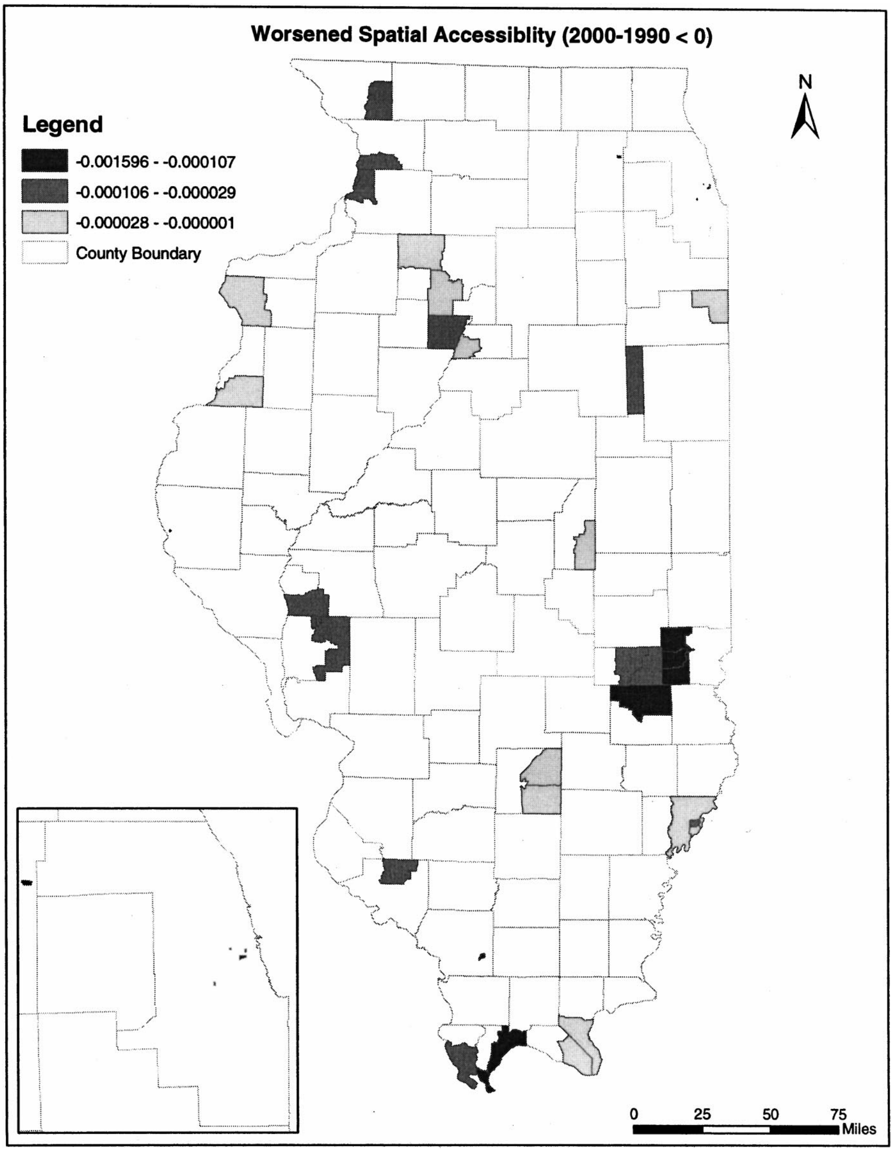
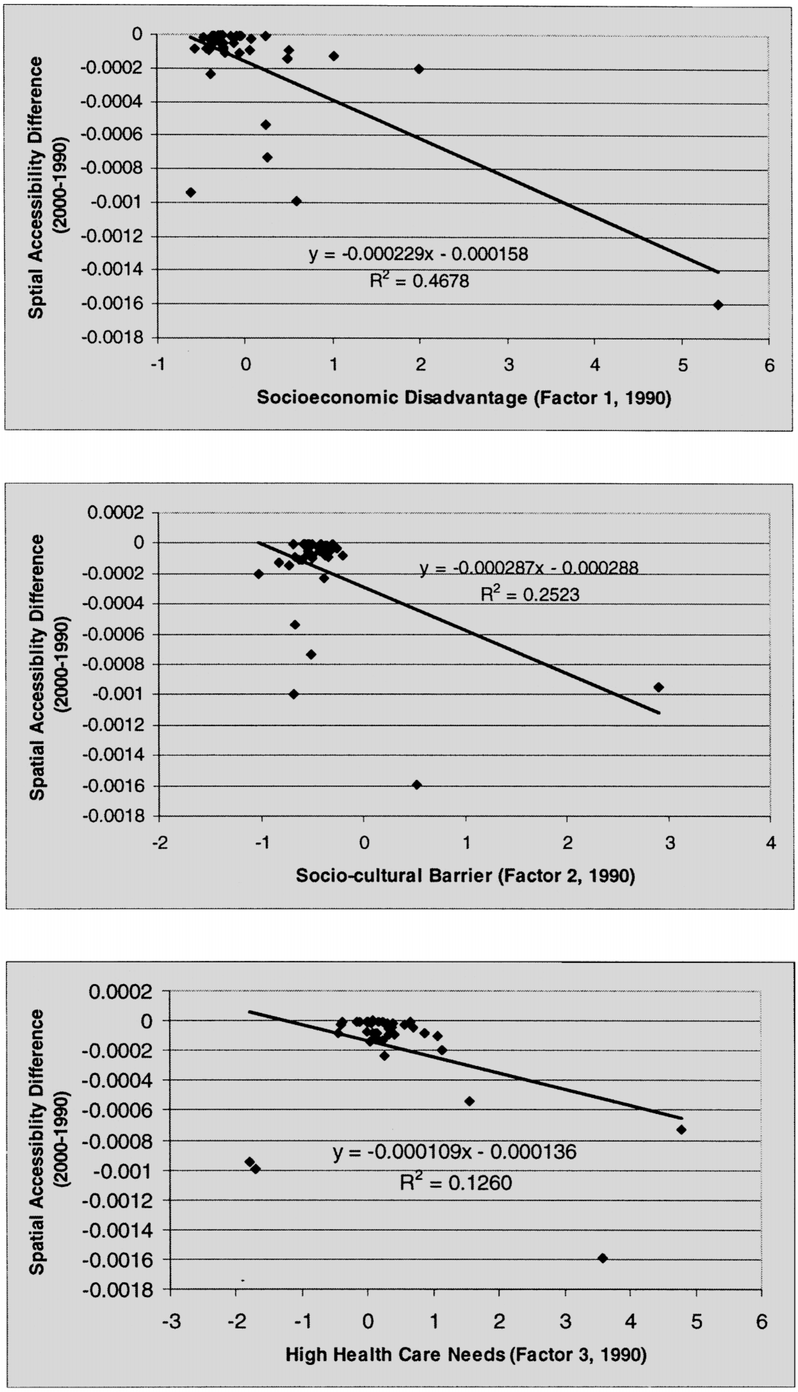


Fig. 4. Worsened spatial accessibility (i.e., spatial accessibility difference between 2000 and 1990 is negative).

Table V. Regression Results Between Spatial Accessibility Difference and Nonspatial Factors of 1990

	All tracts (n = 2768)			Worsened tracts only (n = 39)		
	Slope	t value	R^2	Slope	t value	R^2
Difference vs. Factor 1	0.000242	15.6843	0.08167	−0.000229	−5.7031	0.4678
Difference vs. Factor 2	0.000329	22.3487	0.15295	−0.000287	−3.5331	0.2522
Difference vs. Factor 3	−5.3E-05	−3.2414	0.00378	−0.000109	−2.3093	0.1260



(a)

(b)

(c)

Fig. 5. Plots of spatial accessibility difference vs. 1990 nonspatial factors.

government officials to direct limited resources to the most needy. Furthermore, both spatial and nonspatial access are measured quantitatively, providing greater managerial flexibility as the state may expand (or reduce) designation of physician shortage areas according to available resources. The use of the GIS-integrated approach could be expected to strengthen the impact of programs such as the National Health Services Corps, Titles VII and VIII funding for graduate medical education and training grants, Community Health Centers and Rural Health Care Clinics through greater precision and flexibility.

This temporal comparison suggests that the overall access to primary care in Illinois improved. The defined shortage areas in terms of both total area and total population sizes decreased from 1990 to 2000. However, the population groups with socioeconomic disadvantages increased over time. The overall spatial accessibility slightly declined for those populations with high health care needs. The spatial accessibility worsened in a number of local areas. These are primarily concentrated in rural areas and a few inner-city neighborhoods. It is particularly alarming that areas with higher concentration of socioeconomically disadvantaged population experienced deteriorating spatial accessibility over time. These results suggest that previous policies helped to improve the access to primary health care of the state as a whole. However, at the local level, some rural areas and inner-city neighborhoods remained underserved, and the situation has worsened in some areas. Improving the accessibility of those socioeconomically disadvantaged population groups is critical for the success of future policies.

Finally, we should point out that in Figure 4, several areas with worsened accessibility are located near the state border. The accessibility measure near the border areas is less reliable as data from neighboring states were not included in this study. Future studies need to include data from neighboring states in order to evaluate the accessibility in these areas more accurately.

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