PERGAMON

Social Science & Medicine 58 (2004) 1271–1284

SOCIAL SCIENCE & MEDICINE

www.elsevier.com/locate/socscimed

Spatial access to health care in Costa Rica and its equity: a GIS-based study

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Abstract

This study assembles a geographic information system (GIS) to relate the 2000 census population (demand) with an inventory of health facilities (supply). It assesses the equity in access to health care by Costa Ricans and the impact on it by the ongoing reform of the health sector. It uses traditional measurements of access based on the distance to the closest facility and proposes a more comprehensive index of accessibility that results from the aggregation of all facilities weighted by their size, proximity, and characteristics of both the population and the facility. The weighting factors of this index were determined with an econometric analysis of clinic choice in a national household sample. Half Costa Ricans reside less than 1 km away from an outpatient care outlet and 5 km away from a hospital. In equity terms, 12–14% of population are underserved according to three indicators: having an outpatient outlet within 4 km, a hospital within 25 km, and less than 0.2 MD yearly hours per person. The data show substantial improvements in access (and equity) to outpatient care between 1994 and 2000. These improvements are linked to the health sector reform implemented since 1995. The share of the population whose access to outpatient health care (density indicator) was inequitable declined from 30% to 22% in pioneering areas where reform began in 1995–96. By contrast, in areas where reform has not occurred by 2001, the proportion underserved has slightly increased from 7% to 9%. Similar results come from a simpler index based on the distance to the nearest facility. Access to hospital care has held steady in this period. The reform achieved this result by targeting the least privileged population first, and by including such measures as new community medical offices and Basic Teams for Integrated Health Care (EBAIS) to work with these populations. The GIS platform developed for this study allows pinpointing communities with inadequate access to health care, where interventions to improve access would have the greatest impact.

Keywords: Access; Health services; GIS; Costa Rica; Health reform; Equity

Introduction

This article is about the access of Costa Ricans to public health care. It is based on an inventory of health facilities, the 2000 population census, and the use of geographic information systems (GIS). It also assesses the changes in accessibility attributable to the program of reform of the health sector and the corresponding impact on equity of access to health care. The study focuses in physical accessibility, i.e. that derived from the place of residence and facility's location. It does not address the access barriers of economic, social and cultural nature. Two focal points of the study are (1) the development of a methodology to measure access to health care and its equity; and (2) building a GIS of the demand and supply of health facilities in Costa Rica as a platform for data visualization and spatial analyses. This study illustrates the use of GIS technology in public health (Scholten and de Lepper, 1991; Longley & Clarke, 1995).

Costa Rica has achieved superlative health standards. Life expectancy is 78 years, second in the Americas only to Canada and higher than the United States and Cuba (Population Reference Bureau, 2000). Costa Rican health achievements, and its care system, have been

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doi:10.1016/S0277-9536(03)00322-8

subject to extensive scrutiny (PAHO, 2002; Rosero-Bixby, 1991; Mesa-Lago, 1985). A decade old reform in the health sector put all provision of health care in the hands of the Costa Rican Social Security Fund (CCSS), leaving the Ministry of Health with supervising and stewardship functions. According to the 2000 census, 82% of the population in Costa Rica is directly covered by health insurance of the CCSS, including 9% of low-income individuals whose insurance is paid by the central government. Practically, the entire population has access to the health services of the CCSS. For example, 96% of all births in 1999 took place in CCSS hospitals (plus 2% in private clinics and 2% home deliveries). Health care provided by the CCSS is essentially free of charge for the great majority of the population. Prices are thus not a barrier to health care in this country. The barriers are others. Among them: long waiting lists, red tape, perception of low quality of care, and the costs for users of traveling to clinics or getting information about the services. Location of facilities relative to population is an important determinant of these costs.

Costa Rica, like most countries in Latin America, is going through a process of reform of the health sector (PAHO, 2002). The reform was triggered by conditions such as limited resources to meet demand, poor quality of care, dissatisfaction among users, inequities in the allocation of resources, changes in the country's demographic and epidemiological profile, restructuring of the economy, and a shifting role of the State (MIDEPLAN & MS, 1993). The objectives of the reform enounced in official documents are ambitious and diverse. In practice, however, it seems that the dominant objectives in the process were of economic nature: improvement of efficiency and introduction of economic rationale in resource allocation decisions (see, for instance, World Bank, 2001). This is not a surprise given that the process was driven by World Bank loans and, consequently, with a proactive involvement of economists. Very few studies have evaluated the reform impact and these are mostly focussed on the managerial, institutional, and regulatory achievements (Sáenz, 2002; Proyecto Estado de la Nación, 2002). This article aims at evaluating the impact of the Costa Rican reform upon access to health care and its equity. In contrast with private sector and economic analyses that base its evaluations on such criteria as efficiency and profit, in public health, criteria of effectiveness and equity are paramount. Within these criteria, location of services and access by target populations deserve top consideration. The concept of accessibility is crucial for evaluating whether medical services are reaching the population and for estimating the need for new services. Accessibility is also useful for evaluating and guiding administrative decisions on assignment of populations, location allocation, and segmentation of territory.

The health sector reform might be the single most important public health intervention in the country's last decade. A recent study suggests that the reform is related to the improvements in Costa Rican health indicators in the late 1990s, after the stagnation, or even deterioration, observed in the early 1990s (Rosero-Bixby, 2002). Life expectancy, for example, which dropped from 76.9 to 76.2 years between 1990 and 1995, rose to 77.7 years in 2000, coinciding with the implementation of the reform.

Most changes in the provision of health services introduced by the reform occurred at primary and secondary levels of health care (changes at hospital-care level were mostly in managerial aspects). The transference of all health provision functions from the Ministry of Health to the CCSS changed substantially the service supply environment. Redundant health posts and centers were closed. Many new primary care facilities opened. Service provision in clinics was reorganized. In particular, the "EBAIS" (teams of health professionals and assistants in charge of a geographic sector of about 1000 households) were established in the facilities under the reform for the provision of primary health care. Given that the reforms were not introduced at the same time everywhere, there is a kind of natural quasi-experiment that allows this study to assess the effect of the reform on access to health care.

The concept of accessibility to health care has at least two dimensions: geographic and social (Donabedian, 1973). This study will focus on physical or geographic accessibility, the measuring of which poses several challenges (Chayovan, Hermalin, & Knodel, 1984; Hermalin, Riley, & Rosero Bixby, 1988), some of which are best addressed with the use of a GIS. One of the difficulties of measuring physical accessibility is the question of internal validity of subjective data about distance (or travel time) to clinics, as reported by interview respondents or by "expert" informants. A comparative study on the availability of family planning services identified several limitations attributed to the subjective nature of this type of data (Wilkinson, Njogu, & Abderrahim, 1993). Here the use of a GIS, with indicators based on objective cartographic measurements, may bring improvement in internal validity over subjective assessments. Indicators based on cartography can also be useful to validate reports on travel time to clinics. They can shed light on the advantages or disadvantages of using real indicators of access instead of perceived indicators, and on the dilemma over whether to use individual measurements instead of aggregate measurements (Entwisle, Hermalin, Kamnuansilpa, & Chamratrithirong, 1984).

Access has been traditionally measured by the distance (or travel time) to the nearest facility or by the presence of facilities in the community. These measures, however, do not handle properly such peculiarities as the use of services in other communities, the failure to use the nearest facility, overlapping coverages, redundant services in a community, the size of the population served (and the potential for overcrowded facilities), and variability in quality of care. The definition of "community" is also problematic, especially when making cross-national and temporal comparisons. A GIS platform helps to address most of these problems. For example, density of services that meet a standard quality can be calculated within a standard radius. While density indicators are not new (Davanzo, Peterson, Peterson, Reboussin, & Starbird, 1988), the novelty lies in the system's flexibility, which allows one to define density indicators for standard areas of any shape and size, handling the "problem of modifiable unit of area" (Wrigley, 1995). It also allows one to introduce the effects of friction of distance and attractiveness of service (Rosero-Bixby, 1993). With the use of GIS, the analyst is free of restrictions inherent to arbitrary geographic units defined for political and administrative purposes (Makuk, Haglund, Ingram, Kleinman and Feldman, 1991).

A common problem in measuring accessibility is the discrepancy between administrative data about the supply of services and reality. Administrative reports sometimes include facilities that are no longer in operation; or they give an overly optimistic picture of the quality and quantity of service supply. In response, ad hoc studies have been conducted to determine real availability of services. Two fashionable methods are: (1) the service availability module of the Demographic and Health Survey (DHS) project (Wilkinson et al., 1993) and (2) "situational analysis" (Fisher et al., 1992). Both methods have some limitations (Bertrand, 1994) and are neither simple nor economical enough to be used on a regular basis. Typically, these two methodologies collect a large quantity of information for a sample (not always representative) of facilities. Thus, one of the first problems with them is to reduce the enormous mass of data to manageable dimensions. Another problem is that having information about a *sample* of facilities may be not enough for determining accessibility in a given community. This study uses very few indicators of supply for the entire gamut of facilities, in contrast with the aforementioned methods that collect many indicators for few facilities. This study also uses GIS to link the data on supply to population (demand) on the basis of their geographic location.

In Costa Rica there is a good record of studies about the demand for health services, including several demographic and health studies, surveys of outpatient services, and studies of the demand and use of health services. Knowledge of supply, however, is somehow limited. Although official documents usually include a chapter on available services, the data tend to be highly aggregated and, consequently, of little use for local decision-making. Existing information of this kind may be useful, for example, to determine density of hospital beds or physicians for the entire country or for a large region, but it tells nothing about appropriate access to services in a given community.

The following are earlier Costa Rican studies that shaped the research reported here: (1) A supplementary study to the 1981 Contraceptive Prevalence Survey, measuring availability of services based on methods similar to those adopted later by the DHS project (Hermalin et al., 1988). (2) A community module completed as part of the 1984 census, which made it possible to measure travel time to health services throughout Costa Rica (Rosero-Bixby, 1987); this information later proved useful for mapping poverty and identifying priority areas for the Ministry of Planning. (3) A study prepared for a scientific meeting to demonstrate the potential of GIS for measuring accessibility of health services based on district-level data (Rosero-Bixby, 1993). (4) A study of access to family planning services based on GIS methods and data from a reproductive health survey taken in 1993 (Rosero-Bixby, 1997).

This article reports a GIS-based analysis of access to health care by the Costa Rican Population. Data came from a geocoded inventory of health facilities and the geocoded 2000 census. The study includes an econometric analysis of patterns of use of medical services on a national household sample. The study examines the magnitude and location of demand for services, placed in the context of the health sector reform process. One of its findings is that reform occurred first among disperse populations at the lower socioeconomic rungs. The data show that reform seems to have narrowed inequities in access to health services, as the situation for the most disadvantaged population has improved.

Data and methods

The study combines data on the supply of health services with demand for services according to the 2000 census. The confluence of supply and demand results in the concept of accessibility.

To depict the service *supply* environment, this study took an inventory or census of all public health facilities in the country by 1998, updated in 2000. The first step was to compile an exhaustive list of all facilities mentioned in statistical and administrative reports of the Ministry of Health and the CCSS. The collected information was mostly about the range of services offered (surgery, general medicine, primary care, laboratory, and so on) and facility's size (hours of consultation, number of beds, number of personnel, building area). Each facility was then marked on maps from the National Geographic Bureau, which provided a means to: (1) eliminate duplications from the list of facilities; and (2) "geocode" them. Each facility was geocoded by recording its coordinates on the map. The maps were at scales 1:10,000 in the Great Metropolitan Area of San Jose and 1:50,000 in the rest of the country (one millimeter on these maps represents 10–50 m on the ground, respectively, which gives an idea of the potential for error in this task). These maps are result of the collaborations of the National Geographic Bureau with the United States Defense Mapping Agency (DMA) and the Japanese International Cooperation Agency (JICA). The maps' standards of accuracy are specified in the documents: DMA, 1995 and JICA, 1991. These maps use the northern Lambert Conformal projection of Costa Rica ("Inter-American Geodetic Survey" 1950). The geographic coordinates were recorded in meters in the Lambert projection.

In a second step, a telephone survey to health officers in central and regional offices allowed to clean up the inventory and to gather missing information. The study focused on producing complete, accurate data on a small number of key variables:

- geographic coordinates;
- year the facility was created;
- type of facility (hospital, clinic, post, center, community health office);
- building area;
- MD hours hired for outpatient care;
- annual number of outpatient visits, 1992–97;
- year it entered the reform process;
- number of EBAIS in the facility.

In a third step, this study made field visits to a sample of 40 randomly selected facilities with the purpose of validating the inventory. This validity survey showed that figures in the inventory are reasonably valid, although they are not error free. The coefficient of correlation between data in the inventory and figures taken on the field (which is an indicator of reliability) ranged from a lowest of 0.75 for area of construction to a highest of 0.90 for year of creation. Possibly the most important variable in the study, MD hours, gave a coefficient of 0.86. The median difference between coordinates on the map and those taken on the ground with a global positioning system (GPS) device was 500 m. Since this is a considerable discrepancy, new GPS measurements were taken with a different receiver in a second visit. Results were similar to the first visit and showed that the main sources of error were problematic addresses (Costa Rica does not have an accurate address system based on streets and dwelling's numbers) as well as small facilities that are hard to distinguish from each other.

The study used the number of MD hours of outpatient consultation in 1994 (the year prior to reform) and by 2000 as key indicators of the size of the clinic. Official statistics yielded the information for Social Security clinics and most health centers. For hospitals and a few clinics where information was lacking, these figures were estimated using regression on the number of yearly visits and physical size of the building ($R^2 = 0.96$ in 200 clinics having complete information). The data for health posts and community medical offices came from information on office hours and the number of weekdays each facility opens, the presence of an EBAIS, and the volume of outpatient consultations handled.

Several health centers and posts reported being closed for outpatient consultations, prompting a follow-up telephone survey of all these facilities. The calls proved that, indeed, many were not offering medical services, being engaged instead in such tasks as epidemiological surveillance or malaria control; others had been closed.

Information on hospitals and clinics was complete and readily available in the central offices of the CCSS. Information was more difficult to obtain for other facilities, including health centers and posts, community health offices, and EBAIS newly created as independent facilities. This study classified these other facilities as providing or not MD services, according to the criteria that outpatient consultation is regularly offered at least 2 days per week.

The EBAIS, which are a central piece of the reform, were originally created as teams under the leadership of a physician, each serving to about 4000 population and based in an existing health facility. In recent years, however, the concept of EBAIS evolved and in some cases is considered a new type of health facility with its own premises.

To supplement data on supply, the CCSS office in charge of the health reform provided information on area boundaries and specific sectors covered by reform over time. With this information, areas were classified into three groups according to the year they joined the reform:

- pioneers (joined in 1995–96);
- intermediate (joined between 1997 and 2000);
- laggards (had not yet joined the reform by December 2000).

The concept of *demand* for health services comprises the need for services, which for the purposes of this study is considered proportional to the size of the population combined with certain characteristics such as a rural setting and proximity. Certain other population characteristics are also considered in developing a profile of demand, including precise location, density, growth, economic conditions, standards of health, and patterns of use of health services.

Data on demand came primarily from the 2000 census, which was geocoded for the purposes of this study. The ideal situation would be to have the geographic coordinates of each of the 800,000 dwellings in the census. As a compromise this study geocoded the centroids of the 17,000 enumeration units defined by the Census Office (INEC) for fieldwork purposes. Each unit consists of a cluster of approximately 50 dwellings, usually covering one to two city blocks or 1–10 km^2 of rural land. (In actuality, the census counted an average of 54 inhabited dwellings per enumeration unit, with a standard deviation of 19.) Trained assistants defined on census maps (provided by the INEC) the approximate demographic centroid of each unit and took its Cartesian coordinates, following a procedure that was used and validated to geocode the 1973 and 1984 censuses (Rosero-Bixby, 1997, pp. 267–268). This procedure assumes that all dwellings are located in the centroid of the enumeration unit, and it thus assigns the centroid coordinates to the corresponding households and individuals in the census database.

In order to facilitate spatial analyses and comparisons among censuses, the geocoded information on enumeration units was rasterized into cells of 750 m side (56.25 ha). Costa Rican territory holds approximately 100,000 of these cells. Population and housing numbers were rasterized, using the Bracken (1989) procedure of spatial interpolation-disaggregation and the FORTRAN algorithm developed by this author. Cells' population in 1994 was estimated by interpolation between the 1984 and 2000 census data. The error of assuming that all dwellings are in the centroid of the raster cell is close to 300 m on the average. This error adds to the estimated median error of 500 m in the location of health facilities.

The geocoded data on population and health facilities were integrated to a GIS that also included digital maps on the administrative division of Costa Rica at three levels (provinces, cantons and districts), the health areas in the reform of the health sector, highways and other characteristics. This GIS was processed using the software IDRISI and MapInfo.

An observer could visualize *accessibility* of services by overlaying the supply and demand layers in the GIS. Operationalizing the concept of accessibility into quantifiable indicators is not, however, a trivial task (Handy and Niemeier, 1997). Traditional indicators of access include distance to the nearest facility, presence of services in the community, and density of services in a given administrative area such as a municipality. This study uses a more general definition of accessibility a of an individual i to a facility j as a function f of: (1) distance d between i and j; and (2) the latent satisfaction or utility S that the individual derives from the service j (which is estimated using a vector of characteristics of the facility, including size, range of services, crowdness, office hours, and the like). The accessibility to each facility is then aggregated into a summary index A of accessibility to all facilities. In symbols:

$$a_{ji} = f(S_j, d_{ji}), \quad A_i = \underset{j}{\theta}\, a_{ji},$$

where θ is a generic operator of aggregation, including the summation operator Σ and the MIN operator of minimum distance.

With the criteria of minimum distance, this study determined two simple indicators of access to: (1) outpatient care and (2) hospital care.

The study also computed a third, more complex index of accessibility using the summation operator in the above formulae. The function f in the formulae was calibrated using information from a nationally representative sample survey in 2000 households that used outpatient services in the first half of 1997. The survey, which was taken for the purposes of this study, consisted of an eight-question module appended to the questionnaire of the Multi-Purpose Household Survey conducted by INEC in July 1997. This module, applied to one-third of the households in the INEC survey, identifies the precise health facility used by each household. The database for the analysis consisted of 130,400 observations, resulting from combining information from each of 2000 households with an average of 65 eligible health facilities, such that each observation is a household-facility pair. The facilities considered for each household were those that offer outpatient care in a radius of 10 km in the case of health posts or community medical offices, a radius of 20 km for clinics or health centers, and 200 km for hospitals. These radius values were the maximum figures reported in the survey on use of services. Of all possible pairs for each household, there is just one that corresponds to the clinic chosen by the household for outpatient consultation in the previous 6 months.

Conditional logistical regression (Breslow & Day, 1980; Greene, 1990) modeled the probability of selection of a health facility in this database. This type of model is known in econometrics as a discrete choice model and is analogous to a paired case–control epidemiological model (the case is the household/chosen facility pair; paired controls are all facilities not chosen by that household). The model assumes that households choose a facility after comparing the satisfaction or utility they can obtain from all possible choices. It then identifies variables that explain the choice of facility. These variables are then used as components for the index of accessibility a_{ji}. The regression coefficients in the model are the weights of each index component. In other words, such variables as distance, size and type of clinic get a particular weight for estimating accessibility; one assumes that this weight is proportional to the weight that individuals implicitly give to these variables when they choose a clinic, as reflected in the regression coefficients of the econometric model.

Table 1
Conditional logistic regression on the choice of health facility, 1997 household survey

Explanatory variable	Elasticity	Odds ratio	z-value	$P > \|z\|$
MD hours (*MD*)	0.93	—	21.37	0.00
Distance in km (d)	−1.56	—	−37.05	0.00
Interaction with rural	−0.47	—	−8.84	0.00
Interaction with residence at 2+km of a highway	−0.50	—	−6.08	0.00
Created in the 1990s (*new*)	—	0.44	−6.41	0.00
There is a EBAIS (*eba*)	—	1.28	3.02	0.00
Facility type				
Clinic	Reference	1.00	—	—
Hospital	—	1.30	2.92	0.00
Other	—	0.69	−2.81	0.01

$N = 130.375$ pairs; pseudo-$R^2 = 0.56$.
Design: matched case–controls (64 controls per case on the average).
Equation for clinics of urban dwellers at less than 2 km of a highway:

$$a_{ji} = \frac{MD_j^{0.93}}{d_{ji}^{1.56}}(0.44)^{new_j}(1.28)^{eba_j}.$$

The conditional logistical regression model was estimated with the STATA computer package (Stata-Corp, 1997). The selection of explanatory variables in the model was constrained by the availability of the information in the GIS platform (The survey has several other important variables, such as income, which were not modeled since these are not nationally available in the GIS.) Distance and MD hours were included in the model as natural logarithms; their logistic regression coefficients thus represent elasticities of the odds of choosing a specific clinic.

Table 1 shows the results of the econometric model of clinic choice. The size of the facility, measured in terms of MD office hours, is an important factor: a 1% increase in size raises the odds of choice by 0.9%. Distance is also very important, and its impact is conditioned by the rural vs. urban location of the home and proximity of a highway. For those living in cities and less than 2 km from a highway, a 1% increase in distance reduces the odds of choosing a given facility by 1.6%. By contrast, a similar increase in distance reduces the odds of choice by 2.5% for those living in rural areas far from a national highway. Geographers know this effect as "friction of distance," which resulted greater among more disperse populations. The effects of size of facility and distance comprise a typical Newtonian gravity model (the attraction between two bodies—apple and earth—depends on their mass and the distance between them). Nevertheless, these are not the only factors that have a significant impact on a clinic's force of attraction. Taking clinics as the reference, hospitals have 30% greater odds of being chosen, while health centers, health posts and community medical offices have 31% less chance. New facilities (those opened in the 1990s) have slightly less than half the likelihood of being chosen, by comparison with older facilities. Those having an EBAIS are 28% more attractive (Table 1).

The results of the regression model served for weighting the components in the formula for the index of accessibility. As an example, the footnote to Table 1 gives the formula for calculating the index of access to a clinic j from a home i located in an urban setting and less than 2 km from a highway. This household's access to all health services would be the sum of the amounts calculated with the formula for all j's. In actuality, the study computed an access index for each 750-m cell centroid as the weighted sum of access to all facilities j within a radius of 25 km. Because the most densely populated areas also tend to have many facilities nearby, the index was transformed into "density of access" as the ratio between the index and the population potential (total population in a radius of 25 km, weighted by the inverse of the distance to the index location). The measure unit of this complex index of density of services is approximately the MD hours available yearly to an individual in the location (cell) i.

Because a purpose of the study is to determine the impact of reform on *equity of access* to services, it became necessary to adopt a definition of equity (Rawls, 1971). The study adopted the criteria of "underserved" population or "unmet needs" to measure inequity (Mead & Erickson, 2000, p. 345). It set somewhat arbitrary cutoff points as threshold of access beyond which one can assume that individuals are not meeting their needs for health care. The proportion of individuals falling short of this threshold becomes the indicator of inequity or unmet need. The threshold values were 4 km for a facility offering outpatient services, 25 km to a hospital, and 0,2 yearly MD hours per capita.

Results

The supply of health services

The inventory identified 820 public health facilities in Costa Rica by 2000. This figure, however, drops to the 692 facilities showed in Table 2, after excluding those that do not offer outpatient consultations (42 health centers and 83 health posts). The figure drops again to 476 facilities after excluding those that do not offer at least 2 days of MD consultation per week. The final inventory includes 23 hospitals and 153 clinics or "Integrated centers." It includes also 268 "minor" facilities (centers, posts, community office or EBAIS) that have at least an EBAIS and 243 minor facilities with no EBAIS. Information in the latter group is not that reliable. The total number of EBAIS was 664.

The size of health facilities varies considerably by type, as shown by the average number of MD hours in Table 2. Hospitals have on the average 670 MD hours per week for outpatient consultation, which are about 20 physicians. In contrast, minor facilities with no EBAIS have only 11 MD hours, which is little more than one weekly day of outpatient consultation. The presence of an EBAIS in a facility, especially if it is a small one, means a substantial improvement in both quantity and quality of health care offered. The population had realized this, as shown by the econometric model presented in the previous section (Table 1). The odds of choosing a facility increase 28% if it has an EBAIS, after controlling other characteristics like distance or facility's size.

Of the 646 facilities open for outpatient visits, 77% are located in areas that have undertaken reform (Table 1). Little more than half of these facilities joined the reform process in the first wave (1995–96). Most hospitals are located in areas where reform has not yet begun.

Table 2
Health facilities in Costa Rica 2000

Type of facility	Number of facilities		Number of EBAIS	MD hours weekly
	Total	MD care[a]		
Hospitals	28	28	32	670
Clinics	153	150	291	141
Other with EBAIS	268	268	341	24
Other with no EBAIS	243	30	0	11
Total	692	476	664	72

[a] Offering outpatient consultation at least 2 days per week.

The reform and the supply and demand of health services

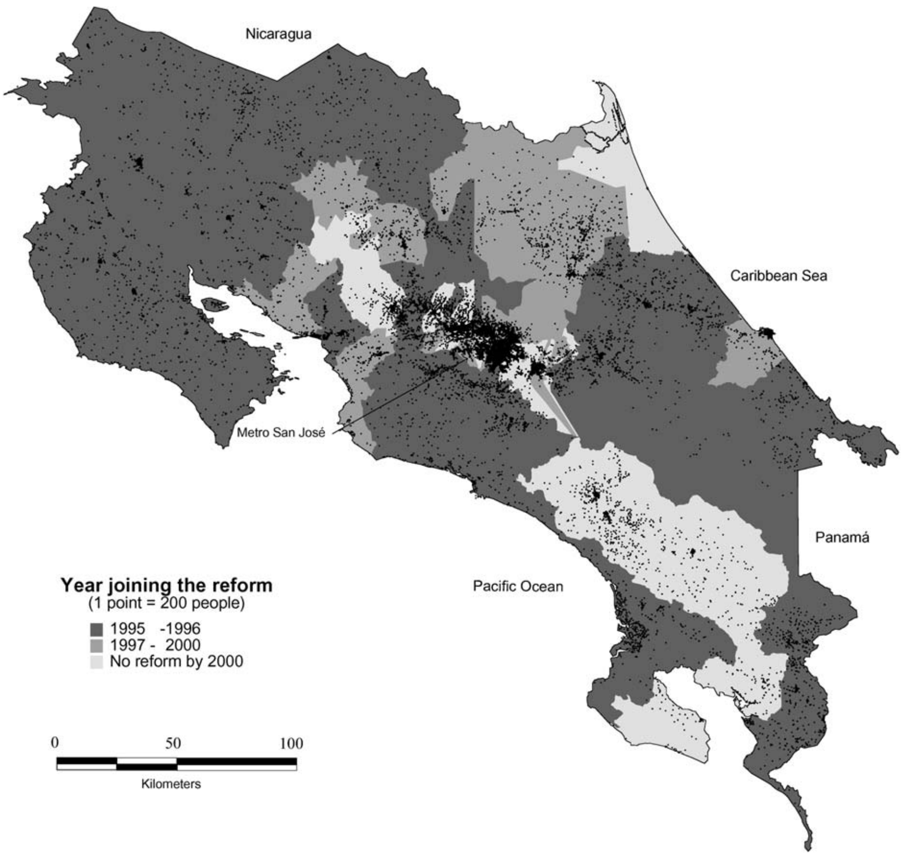
The 3.8 million population counted in the 2000 census are similarly divided in the three groups of the health reform (Table 3): pioneers (reformed in 1995–1996), intermediate (1997–2000) and laggards (not reformed by 2001). Spacewise, Map 1 shows that the reform begun mostly in the periphery and in low population density areas, i.e. in rural settings. The regions with higher population density at the center of the territory (including Metropolitan San Jose) joined the reform latter. Pioneer regions also characterize for being less developed, as shown by education attainment: 34% of adults have high school, compared to 49% and 55% in the other two regions (Table 3). Infant mortality before the reform was also higher in the pioneers areas. The data thus suggest that adoption of reform by areas was not random, but it happened by targeting first disperse, less developed populations.

Regarding the service supply environment, Table 3 shows that the first wave of reform (1995–1996) covered a larger number of facilities, although these were the

Table 3
Characteristics of the population and the services by reform timing

Indicators	Total	Reform 1995–96	Reform 1997–2000	No reform by 2000
2000 population (millions)	3.81	1.27	1.31	1.23
With high school education	46%	34%	49%	55%
Nicaraguan immigrants[a]	13%	12%	15%	14%
Infant mortality rate (per 1000) 1993–95	13.4	14.5	12.5	13.2
N. facilities	692	397	162	134
N. MD facilities	476	269	140	67
N. EBAIS	665	343	264	58
Weekly MD hours	72	41	85	151

[a] Mothers born in Nicaragua. *Source*: Vital statistics on births, 1999–2001.



Map 1. Population and the waves of health sector reform Costa Rica 2000.

smallest in size. In pioneer areas, most facilities are health posts, community offices and tiny clinics. Hospitals and big clinics usually locate in regions that were slow adopting the reform.

Populations access to health care

Access to services is given by the convergence of supply and demand. A simple way to characterize accessibility is with indicators of closeness of facilities to a given residential place. Fig. 1 plots the cumulative distribution of the 2000 census population according to the distance to public MD care and hospitals. About 50% of the Costa Rican population reside less than 1 km away from a primary health care facility. In contrast, only 8% have a hospital in that distance range. The median distance to a hospital is slightly higher than 5 km. The threshold of 4 km identifies 13% of population with unmet need of outpatient care. The threshold of 25 km for hospital care sets apart 12% of population with deficient access to this service. In turn, the more complex density index of accessibility to MD care shows a median of 0.34 MD hours per capita yearly. It also identifies 14% of population with inequitable access to health services; i.e. below the previously defined threshold of 0.2 yearly MD hours (Table 4).

The cartographic distances to health facilities in this study are measured ‘‘as the crow flies’’ or straight-lines. Real, travel distances are certainly longer. Moreover, a more realistic assessment of the cost involved in reaching a facility is given by ‘‘travel time’’. To what extent do distances in this study measure access costs? The survey of use of services described in the section of methods allows comparing reported travel times and cartographic distances to clinics visited by the population. The correlation between cartographic distances and reported travel times is high ($R = 0.77$ in logarithms), but not perfect. A Poisson regression (McCullagh and Nedler, 1989) estimates the following relationship between distance and reported travel time in minutes:

$$\text{Minutes} = 14.2(\text{km})^{0.59}.$$

According to this equation, while the first kilometer of travel takes 14 min to cover, a 100% increase in distance requires 59% more travel time (elasticity 0.59). This ratio is strikingly similar to the one found in an independent database on use of family planning services in Costa Rica (Rosero-Bixby, 1997, p. 275).

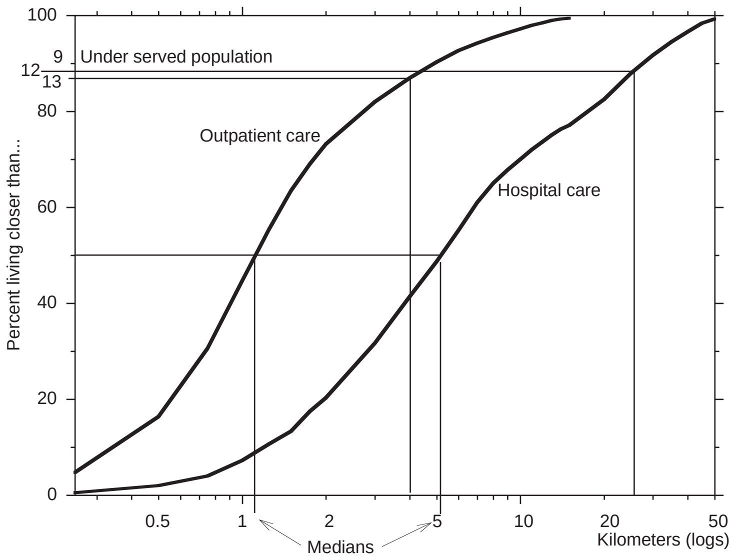


Fig. 1. Cumulative population proportion by distance to the closest outpatient and hospital care facility (Costa Rica 2000).

Table 4
Three national indicators of access (Costa Rica 2000)

Access indicator	Median	Threshold	% underserved
Closest outpatient care	1.14	4 km	13
Closed hospital care	5.22	25 km	12
Density of health care facilities	0.34	0.2 MD h.	14

Access and health sector reform

How does equity in access to health care have changed in recent years and in connection to the sector reform? Table 5 shows a clear improvement in access to outpatient care from 1994 to 2000. The proportion with inadequate access dropped from 22% in 1994 to 13% in the year 2000. There is also an improvement in the index of access density, which translates in a reduction of the unmet need from 18% to 14%. The main reason for these improvements is the establishment of EBAIS. In contrast, the data show a slight deterioration in access to hospitals. As a matter of fact, no new hospitals opened in the study period, while population increased by 20%. Underserved populations with hospital care increased from 11% to 12% between 1994 and 2000 (Table 5).

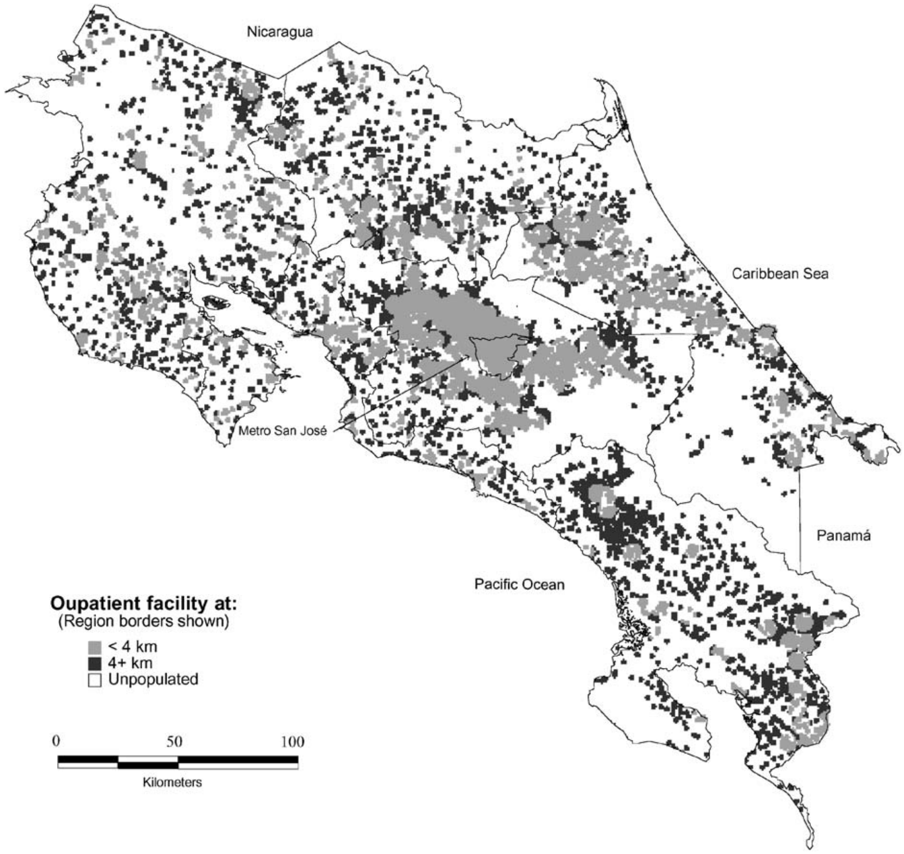
The aforementioned improvements in access to outpatient care coincide with the period of heath sector reform. The quasi-experimental fashion in which country areas joined the reform handily allows this study to look at the association between access improvement and reform. Table 6 shows that the 1994–2000 drop in access inequity to outpatient services was larger in pioneer

Table 5
Population with deficient access to health care

Access indicator	1994 (%)	2000 (%)	Change (%)
Closest outpatient care	21.7	13.0	−8.7
Closed hospital care	11.3	12.1	0.8
Density of health care facilities	17.5	13.6	−4.0

Table 6
Change in the population with deficient access to health care by reform group

Year	Reform 1995–96 (%)	Reform 1997–2000 (%)	No reform by 2000 (%)
Outpatient care			
1994	36	14	14
2000	21	6	11
Change	−15	−7	−3
Density of facilities			
1994	30	14	7
2000	22	10	9
Change	−8	−4	1



Map 2. Distance to the closest outpatient facility (Costa Rica 2000).

areas, which reduced it in 15% and 8% points depending whether the indicator is the distance to the closest or the density of facilities (Table 6). Among the reform laggards, the equity improvement is only three points in distance to the closest facility, while there is a deterioration of two points in density.

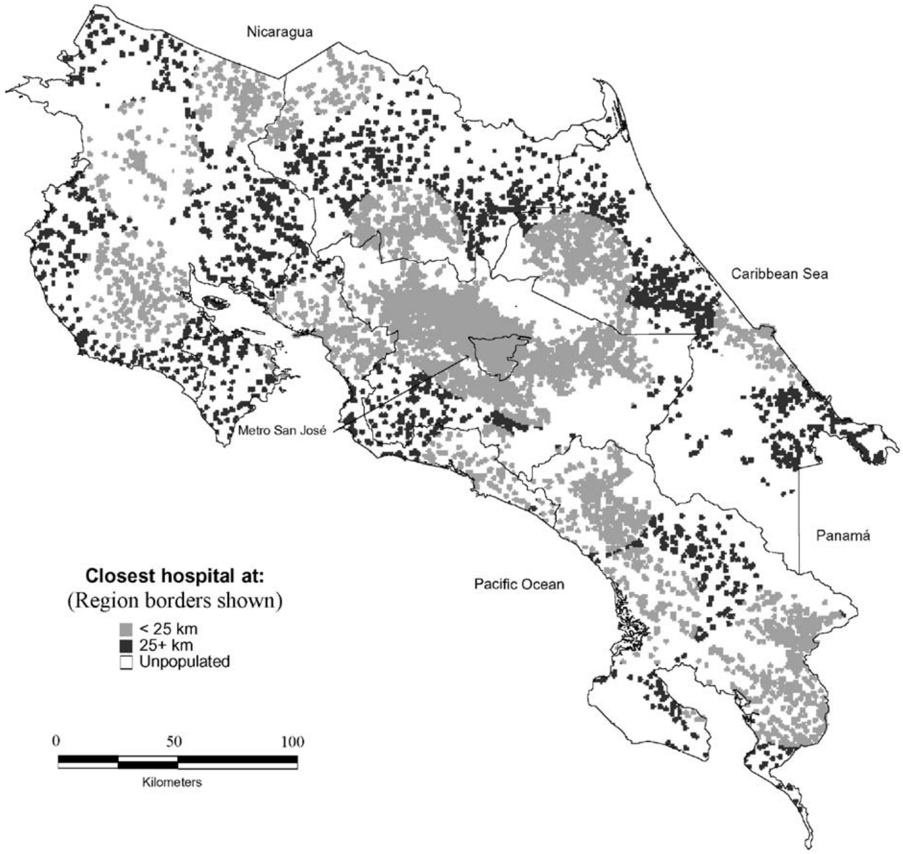
A naive observer looking at the 2000 data only would wrongly conclude that the reform has a negative effect on access equity. In a cross-sectional comparison, areas pioneering the reform have substantially less equitable access to health care than the laggards (Table 6). For example, in places that undertook reform in 1995–96, 22% of the population has inadequate access as measured by service density, compared with 9% in areas that have not yet begun reform in 2000. This association does not show causality, but reflects the selective nature of reform, which began in areas with less access to services, as the 1994 cross section clearly shows. The reform impact can be assessed only by looking at changes over time. The greatest improvements in access clearly took place in areas of the first wave of reform, while access has remained almost constant in areas still untouched by reform.

Geography of access equity

Given that this study estimated the access indexes in every point of Costa Rican territory, it is possible to have detailed maps showing the spatial inequities in access to health care. More importantly, it is possible to pinpoint the specific places with a concentration of underserved populations, which should serve for correcting the situation. Maps 2 and 3 show, with darker shades, the places with higher deficiencies in access to outpatient and hospital car, respectively, measured by the distance to the closest outlet. Map 3 on hospitals is of easier interpretation since places with deficient access cluster together in larger groups. It is self-evident the northern arc of deficient accesses that goes from the Pacific Ocean to the Caribbean Sea.

The places with deficient access to outpatient care are more disperse on Map 2, being thus harder to summarize. The central southern region of Buenos Aires and vicinity strikes as one with a large cluster of deficient access.

Map 4 shows the more comprehensive index summarizing density of services. The region of Buenos Aires



Map 3. Distance to the closest hospital (Costa Rica 2000).

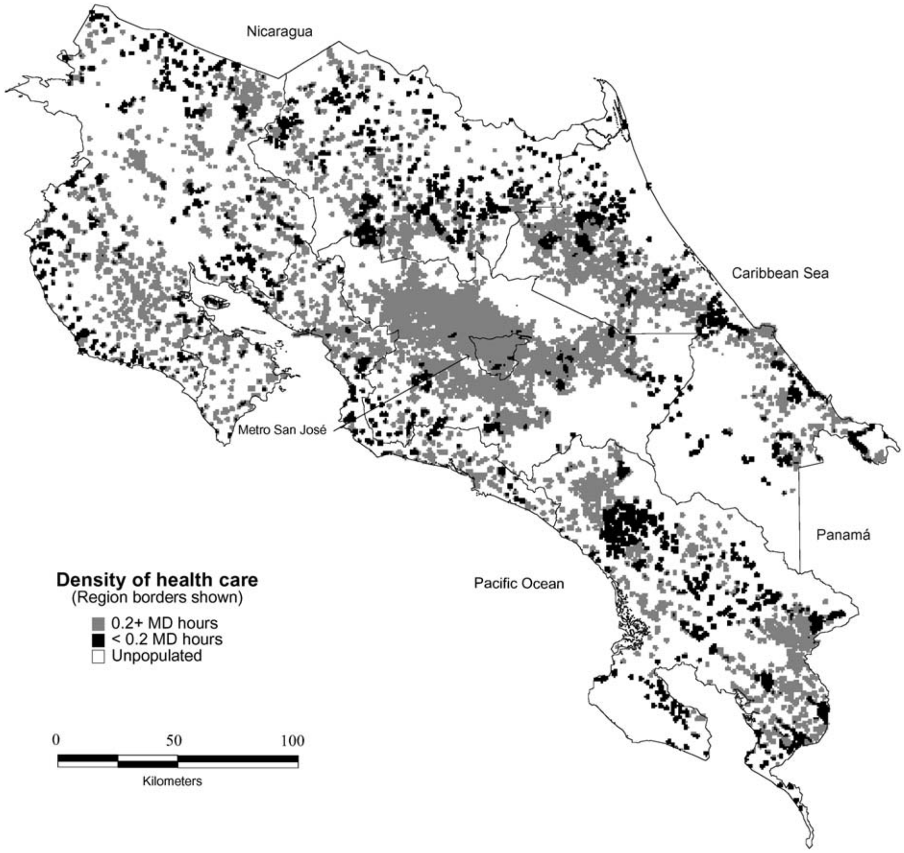
stands out again with underserved populations. An asset of these maps is that allows pinpointing isolated localities with deficient access in spite of being in well-served larger regions. Examples are the two black points at the south and southeast of Metro San Jose, which correspond to the localities of Salitral and Rio Azul.

Discussion

It is critically important to know the supply and demand of health services and to understand how these two factors converge in accessibility of health services for the population, in order to monitor and evaluate the impact of current reforms in the health sector. More equitable access to services is a central objective of reform; monitoring and evaluation of this factor requires rigorous measurement and analysis. This study uses GIS techniques to perform these measurements, evaluate the impact of reform on equity of access, and provide guidelines for focused interventions.

This study's data collection effort demonstrated that information about the service supply environment is deficient and difficult to obtain. In fairness, information for large clinics and hospitals is quite complete and of good quality, although not easily accessible. This is important because 85% of outpatient visits in the country take place in these facilities, according to the 1997 survey of use of health services. Information on smaller facilities (health centers, health posts and community medical offices), by contrast, is in a chaotic state. There are no centrally available up-to-date lists of such facilities, nor knowledge of which ones are actually functioning, and even less, any details on physical and human resources available in each one. Even though these units handle only a small fraction (15%) of all outpatient visits in the country, they hold tremendous importance in certain areas, including places that were touched by the first wave of reform, where they serve 25% of all medical visits. The inventory of health facilities, compiled for this study following a long process of consultations and double checking, showed that 32% of health centers and 20% of health posts were not providing direct medical services to the population.

The information on the service supply environment assembled for this study is not error free, especially



Map 4. Density index of health care facilities (Costa Rica 2000).

regarding small facilities. Moreover, the information about the location of both the populations demanding health services and the facilities supplying them has average errors of several hundred meters. The integration of demand and supply data in a GIS platform proved to be a powerful measuring and analytic tool. GIS, however, does not solve all the problems to study accessibility. It is also a tool with high demands on data availability. Although the location errors in a GIS may cancel out when computing indicators for large regions, they can result in potentially serious biases in highly disaggregated analyses.

The data showed that half Costa Ricans reside less than 1 km away from an outpatient care outlet and 5 km away from a hospital. In equity terms, 12–14% of population are underserved, according to several indicators of access. The spatial variation in these percentages allows pinpointing spatial inequities.

The reform of the health sector in Costa Rica began in outlying areas characterized by low socioeconomic levels, disperse populations, and poor access to health services. Because of, precisely, this targeting in underserved populations, the reform narrowed the gap of inequitable access. The opening of the EBAIS was key for this improvement. The share of the population whose access to outpatient health care (density indicator) was inequitable declined from 30% to 22% in pioneering areas where reform began in 1995–96. By contrast, in areas where reform has not yet occurred, the proportion with inadequate access slightly increased from 7% to 9%. Similar results come from a simpler index based on the distance to the nearest facility. Access to hospital care has held steady over time (the reform at this level of care consisted mostly in managerial changes to improve efficiency and quality of care).

An econometric analysis of data on the use of health services, collected in a nationally representative sample, provides the parameters for a refined index of access to services in which each facility is weighted by proximity, size, and other readily available characteristics. The effect of "friction of distance" is larger in rural areas. Additionally, hospitals receive higher weighting than clinics. The index also gives greater weight to facilities that have an EBAIS and less to those that opened recently. These weighting values reflect factual preferences of the population in the choice of a health facility and stand for the latent satisfaction derived from different facilities. Although this index marks progress over more traditional measurements of access such as distance the nearest outlet, results were not substantially different.

The mapping of access to health services allowed to identify geographic inequities and to pinpoint specific communities in need. Decision making to correct inequities in access should make every effort to optimize the use of scarce resources. One way to do this is focussing interventions in areas identified by these maps, where impact would be greatest. However, it is not enough merely to identify needed locations, as consideration should also be given to the size of the population that would benefit. This can be done easily by using a GIS to juxtapose the population layer (Map 1) with the access layers (Maps 2–4). A combined view of these maps suggests that the greatest impact could be achieved by improving access for populations on the outskirts of the Central Valley, especially toward south, where the largest concentrations of population with inadequate access can be found. Improvements of access in areas with little population density would have a lesser impact and would call for other strategies such as mobile units, small facilities, and perhaps the participation of volunteers in the community. In any case, the availability of data in a GIS platform, as the one developed in this study, makes possible to respond queries about the impact of alternative measures to alter the service supply environment and, in consequence, to optimize resource allocation.

This study has shown Costa Rica's need to centrally organize a complete, but simple, information system on the supply of health services that will easily tell, among other things, which facilities are operating. Decentralization, which is an important aspect of the reform, has hampered the availability of data at the central level. This study has also showed the feasibility of using GIS technology for monitoring and evaluating the reform process and the degree of equitable access to services. With the use of a GIS platform as the one developed in this study, different scenarios could be evaluated for changing supply and, consequently, setting guidelines to optimize decisions on location allocation to make access more equitable.

Acknowledgements

This study was in part conducted in the Health Research Institute (INISA) of the University of Costa Rica, with a grant from the Pan American Health Organization (PAHO) and with the assistance of geographer Douglas Güell. Two anonymous reviewers of *Social Science and Medicine* made useful suggestions.

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