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Physical access to primary health care in Andean Bolivia

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Abstract

Limited physical access to primary health care is a major factor contributing to the poor health of populations in developing countries, particularly in mountain areas with rugged topography, harsh climates and extensive socioeconomic barriers. Assessing physical access to primary health care is an important exercise for health care planners and policy makers. The development of geographic information system (GIS) technology has greatly improved this assessment process in industrialized countries where digital cartographic data are widely available. In developing countries — particularly in mountain areas, however, detailed cartographic data, even in hardcopy form, are nonexistent, inaccurate or severely lacking. This paper uses GIS technology to assess physical access to primary health care in a remote and impoverished region of Andean Bolivia. In addition, it proposes an alternative model of health personnel distribution to maximize physical accessibility. Methods involved extensive fieldwork in the region, utilizing GPS (global positioning system) technology in the development of the GIS and gathering other pertinent health data for the study. Satellite imagery also contributed to the development of the GIS and in the modeling process. The results indicate significant variation in physical access to primary health care across the three study sites. More importantly, this paper highlights the use of GIS technology as a powerful tool in improving physical accessibility in mountain areas of developing countries. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Primary health care; Bolivia; GIS

Introduction

Primary health care has been officially recognized as the universal solution for improving world health since the Alma Ata Conference in 1978 (WHO/UNICEF, 1978). However, limited physical access to primary health care continues to be a major impediment to achieving the goal of health for all. Nowhere is this more starkly apparent than in the Bolivian Andes,

where rugged topography, variable climates and isolated populations — combined with scarce and poorly distributed health care resources and socioeconomic barriers — present health care planners with a unique challenge. This paper addresses the problem of physical accessibility in Andean Bolivia.

Studies that deal with such extreme barriers to access as the Bolivian situation presents are relatively rare. Although physical access to health care has been one of the primary concerns of medical geography (Shannon and Dever, 1974; Joseph and Phillips, 1984; Ricketts et al., 1994; Parker and Campbell, 1998), not surprisingly, the bulk of this work has been carried out in industrialized countries and in places where popu-

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lations are fairly dense. However, some attention has been paid to physical accessibility in developing countries (e.g. Annis, 1981; Stock, 1983; Gesler and Gage, 1987) and in rural areas where populations may be isolated (e.g. Basu, 1982; Joseph and Bantock, 1982; Rushton, 1984). This study contributes to this latter literature.

The basic procedure for measuring physical accessibility involves the calculation of some measure of distance (map, road, time, perceived) between consumers of care and health care resources such as hospitals, clinics and various types of health personnel. In the past, distances were often determined rather imprecisely and did not take such variables as topography into account. More recently, however, the availability of global positioning system (GPS) units and geographic information systems (GIS) software has greatly enhanced the accuracy and flexibility of distance measures, the ability to present visual displays of accessibility research and the capability to model many different scenarios rapidly (Albert et al., 1995). In countries such as the US, measuring physical accessibility is greatly facilitated because data files containing very detailed road networks and digital elevation models (DEMs) are available. Even with the availability of GPS and GIS, however, this task is often quite formidable in developing countries. Another unique contribution of this paper is the use of these techniques in the Bolivian Andes.

The following section briefly expands on the ideas introduced here. Then we provide some context for the study by summarizing health care resource availability and distribution in Bolivia. In the next section we focus our attention on three study sites, using maps and satellite imagery to show that they represent three very different geographies. Then we briefly describe the methods used to measure physical accessibility. Finally, we display and discuss physical access to health care resources in the three sites, both given the current situation and an alternative scenario where recommended changes have been made in the numbers and distributions of health personnel.

Background

A central problem in establishing health care systems is to provide resources in locations that are close enough to be reached with a reasonable amount of effort by populations being served. Therefore, ensuring physical accessibility or the potential for provider/consumer links to be formed is a key concern. Physical distance between provider and consumer has been recognized as an important barrier to care for several decades (e.g. see King, 1966) and studies have shown

that most people will not travel farther than 5 km to basic preventive and curative care (Stock, 1983). Linear or map distance is relatively easy to measure, but other measures, which are more difficult to obtain, may be more appropriate, including distance along roads, travel time (which may take road quality into account) and perceived road or time distance (Shannon et al., 1969; Joseph and Phillips, 1984; Gesler and Savitz, 1994). Very importantly, many non-geographic factors affect physical accessibility: means of transportation (foot, horse, bicycle, car, etc.) is crucial, as may be the ability to pay for transport or whether or not a health care resource is within one's daily activity space. The terrain over which people have to travel to care may also strongly influence physical accessibility: contrast a map which shows populations traveling for up to 1 h to a health facility in the flat plains of the mid-western US with a similar map drawn for the eastern cordillera of the Bolivian Andes. Climate is an important consideration because, for example, roads may be difficult or even impossible to traverse during a rainy season or in the depths of winter; and, of course, physical accessibility is not the only access consideration; one should also investigate political, economic, social and cultural access as well (Anderson, 1973; Curtis and Taket, 1996).

Map or road distance works fine in relatively flat places with trails or roads lying unobstructed by mountains or other natural barriers. However, travel time is a much more practical form of measurement in mountain areas with high mountains and deep gorges. Two points may represent a map distance of 5 km but lie on either side of a 1000-m high ridge, making the actual travel distance and travel time much greater. In addition, travel distance does not represent a valid form of measurement of physical accessibility in mountain areas because significant elevation gains and losses affect the walking pace. Utilized in the right context, travel time represents an important measure for determining the physical access to primary health care.

Studies of physical accessibility link consumers and providers, so these two groups must be considered as well as distance and other linking measures. On the consumer side, population distribution is a key factor; the most difficult problem being to serve dispersed or isolated settlements. The cultural, social and economic characteristics of consumers must also be taken into account. On the provider side, there are at least three key considerations: (1) the number of different types of health personnel and facilities, (2) the type of personnel and quality of care they provide and (3) their geographic distribution (Mejía et al., 1978). Severe problems may arise in situations where numbers and quality are low, training is not appropriate for job requirements and distributions do not match where

consumers reside. Perry (1997) and Perry and Schroeder (1998) further address health personnel imbalances in Andean Bolivia.

Geographers and others have carried out research that examines the factors related to physical accessibility noted above. Various types of distance, including linear, travel time and road distance have been reviewed by Joseph and Phillips (1984). It has been found that many consumers act on perceived rather than real distance (Winter, 1986) and that people in rural areas may be willing to travel farther to care than their urban counterparts (Basu, 1982). Distance decay functions have been calculated for various levels of service and types of problems (Mayer, 1983; Stock, 1983). Means of transport has been factored into some studies (e.g. Gesler and Gage, 1987). Some research has gone into the minimum recommended health services for areas of varying population size (Elison, 1986); of special concern has been dispersed population in “frontier” areas (Ricketts et al., 1994). Physical accessibility has also been looked at alongside other access factors. For example, Annis (1981) found that in western Guatemala government facilities were located to give good physical accessibility and yet were little used because they were understaffed and poorly equipped, staff was poorly trained and people felt that their treatment was inadequate.

As noted above, GIS technology is now being used to study health problems (Curtis, 1989; Verhasselt, 1993; Barnes and Peck, 1994; Rushton et al., 1995; McManners et al., 1996; Gobalet and Thomas, 1996; Wain, 1997; Vine et al., 1998), although it is still in its infancy. In a recent article, Albert et al. (1995) review the GIS in health literature in terms of four categories: potential, cautionary, preliminary and applications. The latter category includes GIS used to examine emergency response (Tyler, 1990; Van Creveld, 1991), an AIDS prevention program (Fost, 1990) and catchment areas for GPs and clinics (Twigg, 1990). Only two studies cited in the review were carried out in developing countries, one on measuring accessibility for blacks and whites in Natal/KwaZulu, South Africa (Zwarenstein et al., 1991) and one on measles surveillance in Southern Natal (Solarsh and Dammann, 1992). Caution should be used when employing GIS technology, as is the case with any technology; it may not be suitable for answering a research question, it often requires a large amount of data, the requisite data may be difficult to obtain for economic or political reasons and data sets may be inaccurate or incomplete (Albert et al., 1995). However, when utilized in the appropriate context with accurate data, geographic information systems can serve as powerful tools to the health researcher, health planner and program manager.

Health care resources and distribution

The Andean environment, historical and cultural realities, health personnel imbalances and curative (as opposed to preventive) health policies have hindered the development of rural primary health care programs, contributing to the poor access to primary health care in rural areas. The rugged topography and harsh climate — when combined with the limited infrastructure as a result of centuries of disinterest and neglect of the rural indigenous population — has made social development initiatives, including health care, quite challenging. In addition, health care resources are overwhelmingly concentrated in urban areas, as is the case in most countries.

Health care institutions can be grouped into four general categories: governmental health services, non-governmental organizations (NGOs), traditional health resources and private practice. Officially, human health resources are divided into four levels, although in reality many more levels exist. Physicians and physicians-*año de provincia*, or those serving their obligatory year of rural service, are the top of the hierarchy, whereas graduate nurses and auxiliary health nurses are located at progressively lower levels within this structure. Although not an official part of the hierarchy, community health workers and traditional health providers play varied, yet vital roles in much of Andean Bolivia. Bastien (1987) further expands on traditional health providers and their role in Andean culture.

Auxiliary health nurses represent the lowest yet most important component of the Bolivian human health resources hierarchy. On the *altiplano*, these health personnel almost exclusively have a rural background, speak an indigenous language, understand and relate to the local culture and have a strong appreciation for community involvement and preventive programs (Perry, 1988). Although their training is limited, auxiliary health nurses can effectively treat the majority of health problems encountered in rural areas.

Recently, auxiliary health nurses have become recognized as the most efficient and effective means to deliver primary health care services in rural areas of the developing world. Not only are these types of health personnel closer to the population culturally, but they also have similar socioeconomic characteristics and are often from the same region that they serve. Maglacas et al. (1987), Flahault (1978) and Taylor (1976) have demonstrated that upwards of 80% of all health conditions can be treated effectively by auxiliary health nurses and other middle-level health personnel. Therefore, the physician's role in primary health care in rural areas of developing countries is basically nonexistent. Taylor (1976) argues that physicians are too expensive, too many physicians exist and medical care by

physicians is not always the best health care. For example, auxiliary health nurses are trained to do specific jobs and can produce a very consistent quality of work. Physicians, on the other hand, quickly become “bored, dissatisfied and ineffectual” in routine primary health care activities (Taylor, 1976, p. 222).

This is not to say, however, that physicians are not needed in rural areas of the developing world; it is more appropriate to say that opportunities are limited. Taylor (1976, p. 219) explains: “[Physicians] cannot be effective in rural health centers until these peripheral units are upgraded and reorganized to provide opportunities for efficient and satisfying work”. In many areas of the developing world much emphasis is still centered on the output and training of physicians, when, in reality, a substitution of auxiliary health nurses can lead to great reductions of cost and increased effectiveness and efficiency (Maglacas et al., 1987).

Traditional health providers are an important category of human health resources in Andean Bolivia, as elsewhere. They belong both culturally and socially to the community and the local population supports their practice. In addition, their treatments can be very effective and practical remedies that take into account local culture and tradition. Often ignored or chastised by modern medicine, these vital health personnel represent important links in the achievement of health for all (Bastien, 1978, 1987; Taylor, 1978; Twumasi, 1987). Though not addressed in this paper, distributions of traditional health providers and the associated physical accessibility could also be modeled.

Human health resource imbalances occur in almost all countries, developed and developing and can generally be broken down into three dimensions. First, a mismatch between training and job requirements can lead to qualitative imbalances. Such imbalances occur when more highly trained health personnel are used to perform tasks that less highly trained health personnel could do or vice versa (Mejía et al., 1978). Many countries in the developing world experience these types of health personnel imbalances due to the exorbitant number of physicians produced by health systems (Taylor, 1976).

A second human health resource imbalance can develop as a result of an over- or undersupply of health personnel. This numerical imbalance is a result of rapidly growing populations, extremely high population densities, or a lack of resources in the health care system (Mejía et al., 1978). Numerical imbalances can be measured by a calculation of population per health personnel, as many countries or regions have standardized goals to ensure the proper number of health personnel based on the population.

Third, geographical, occupational, institutional and specialty distributions can lead to distributional imbal-

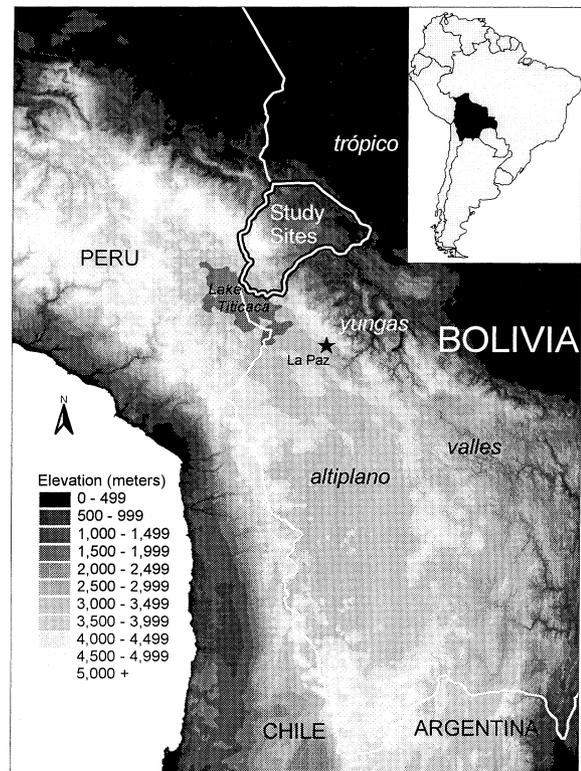


Fig. 1. Location of study sites in South America, Bolivian Andes. (Source: United States Geological Survey (USGS), 1997).

ances of health personnel (Mejía et al., 1978). These imbalances occur as a result of core/periphery relationships and the general spatial inequality evident in societies. It is important to note, however, that a certain degree of spatial inequality is rational since more highly specialized services depend on population densities and the majority of these services are located in cities. A useful analysis of distributional imbalances is through a measure of physical access to primary health care personnel and associated health centers.

The integration of the different analyses of health personnel imbalances leads to a comprehensive overview of the human health resource situation in a given region. In addition, it is possible to establish alternative models of health personnel distribution based on minimum standards of criteria for each of the three types of imbalances. This is particularly useful for health policy and planning efforts.

Study sites

The sites selected for this study are located in the

department of La Paz, just to the northeast of Lake Titicaca (Fig. 1). The physical geography of this area truly is spectacular. The eastern *cordilleras* (ranges) of the Andes dominate the landscape in the west, while eastern areas are largely uninhabited montane rainforest environments. The classic representation of agro-ecological altitudinal belts also can be found in the study sites, with elevations ranging from 200 to just under 6000 m. The Aymara and Quechua people comprise the majority of the population, which is concentrated in *altiplano* (high plain) and *valle* (valley) locations; *mestizo* (mixed) and other indigenous groups also form minority populations. Some communities in the study sites are accessible via a rough road requiring four-wheel drive, but the majority are accessible only by foot. Although communities with road accessibility may have a large truck, families (with only a few exceptions) do not have personal jeeps or trucks.

The three health areas selected as case studies (Carabuco, Ambaná and Charazani) represent the broad range of physical accessibility evident across Andean Bolivia. The Carabuco health area includes the strong

presence of an NGO, *Consejo de Salud Rural Andino* (CSRA) and is primarily located on the *altiplano*. The Ambaná and Charazani health areas, however, are much more marginalized in terms of human health resources and exhibit greater physiographic diversity and steep relief. Figure 2 identifies the health areas selected as case studies in a greyscale satellite image to highlight the ruggedness of the terrain.

The Carabuco health area is located on the shores of Lake Titicaca, in the northern *altiplano* region (Fig. 2). Data taken from the January 1997 CSRA annual census indicate a total population of 7512 persons (CSRA, 1997). The Ambaná health area lies just to the northeast of the Carabuco health area (Fig. 2), though substantial physical barriers of high, rugged mountains and deep river gorges inhibit much interaction between the two areas. The majority of the population in Ambaná is situated in the *valles* zone. Some communities, however, are located in the high *puna* (above 4000 m) and also near the bottoms of the deep river gorges. The total population of the two health sectors in this health area is 5128 (Saavedra, 1994). Located along the Peruvian border and extending to the east into the montane rainforests (Fig. 2), the Charazani health area is characterized by great physical and cultural diversity. The main population concentrations are located in the Charazani and Amarete river valleys, while another less significant concentration is in the region of the Camata River valley. The health area is divided into two health sectors with a total population of 10,858 (Bolivia, INE, 1993).

Another fundamental difference between the Carabuco health area and Ambaná and Charazani health areas is that CSRA staff in Carabuco has been using the census-based, impact-oriented (CBIO) approach to primary health care since 1986. This primary health care methodology, originally developed in the Carabuco health area and in other CSRA sites in Bolivia, strives to improve the health of populations through local health priorities and community participation, epidemiologic surveillance, home visitation and through home delivery of services to those at greatest risk (Perry et al., 1999). The CBIO approach to primary health care has not only improved the health of people living within the Carabuco health area, but also their physical access to primary health care (Perry et al., 1998). Therefore, the spatial implications of CSRA versus government administered health centers are enormous.

Methodology

Since much of the study area is not covered by maps of sufficient detail, it was necessary for the primary

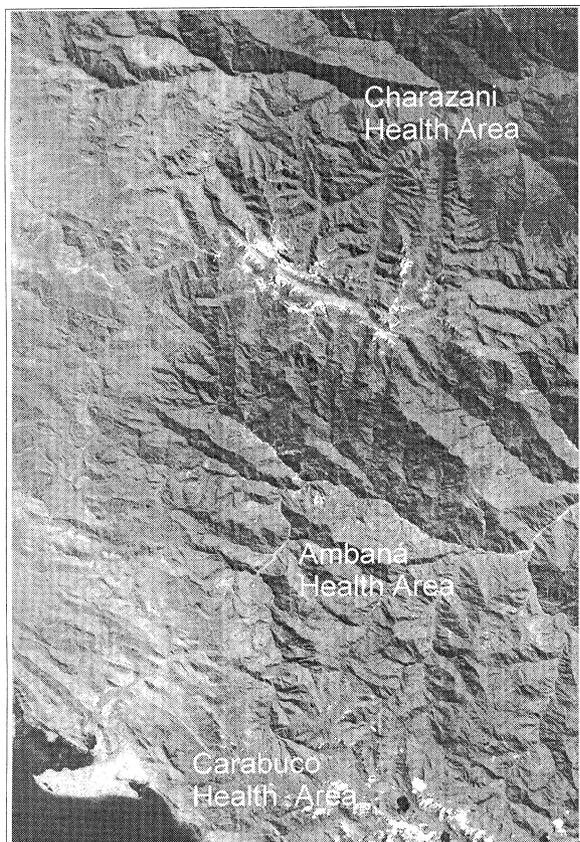


Fig. 2. Topography of study sites. (Source: Landsat Multi-spectral Scanner (MSS) Image).

author to travel to Bolivia in the summer of 1997 to georeference communities and gather ground control points (GCPs) for a digital Landsat Multispectral Scanner (MSS) Image to aid in the development of a GIS for the three study sites. This field research was in conjunction with the Bolivian NGO (non-governmental organization) CSRA (Consejo de Salud Rural Andino) and is of vital interest to their program operations.

In the study sites, it was possible to georeference communities with a global positioning system (GPS) unit. In each health area chosen as a case study, travel times from the communities to the health centers were verified to provide an accurate as possible representation of the actual situation.

Once all of the communities were accurately located, it was possible to develop polygons showing those areas within a 1-h walk of the health center. This was accomplished through the generation of a 5-km buffer, which approximately represents a 1-h walk on flat surface on a straight line, from the health center. This service area was subsequently adjusted manually to incorporate observed travel times and physiographic barriers. Although the adjusted 1-h service area correctly portrays travel times with respect to communities, it is a much more general approximation of travel times in the local area. At best, it is an attempt to take into account the presence of ridges, gorges or other physical obstacles that affect travel times.

Physical access to primary health care in the study sites

The current situation

Carabuco health area

Within the Carabuco health area exist 34 communities which are grouped into six health sectors based on physical accessibility and population densities. CSRA is the institution responsible for the administration of the health programs in the Carabuco health area. Program activities are overwhelmingly preventive

in nature, although limited curative services are provided at the health sectors and in the Carabuco Hospital. A total of nine health personnel practice within the Carabuco health area. Six are auxiliary health nurses, one is a physician-*año de provincia*, one is a dentist and the other is the District Director, who is also a physician. Table 1 summarizes data on the population per auxiliary health nurse in the six health sectors.

In terms of physical accessibility, the communities in the Carabuco health area are in relatively close proximity to auxiliary health nurses and associated health centers. Figure 3 shows the Carabuco health area and those communities within a 1-h walk of an auxiliary health nurse and health post; 25 communities, representing a population of 6645 (88% of the total), are within 1 h of primary health care services. In sum, the Carabuco health area is in comparatively good shape with regard to type of health personnel, number and spatial distribution.

Ambaná health area

The government is the institution responsible for the administration and financing of health programs in the Ambaná health area. Health programs are administered almost exclusively in the health centers and an emphasis is placed on curative services. The health area's size, steep relief and lack of both public transportation and roads present enormous obstacles to even the most dedicated health personnel. A total of three health personnel are present in Ambaná health area. One auxiliary health nurse and a physician-*año de provincia* are located in Ambaná, while another auxiliary health nurse is in Copusquía. Table 2 summarizes data on populations per auxiliary nurse.

In addition to limited resources, physical access to primary health care is much more difficult to achieve in the Ambaná health area due to the extreme topographic relief and sparsely settled communities. Figure 3 also shows those communities within a 1-h walk of auxiliary health nurses and associated health centers. In the Ambaná health sector, only 11 of the 37 communities or 1800 inhabitants (50.1%) are within 1 h of

Table 1
Population per auxiliary health nurse in the Carabuco health area

| Health sector | Population | Auxiliary health nurses | Population per auxiliary health nurse |
|-------------------|------------|-------------------------|---------------------------------------|
| Mollipongo | 494 | 1 | 494 |
| Yaricoa | 1625 | 1 | 1625 |
| Carabuco | 1169 | 1 | 1169 |
| Aguas Calientes | 988 | 1 | 988 |
| Chaguaya | 1758 | 1 | 1758 |
| Santiago de Okola | 1478 | 1 | 1478 |
| Totals | 7512 | 6 | 1252 |

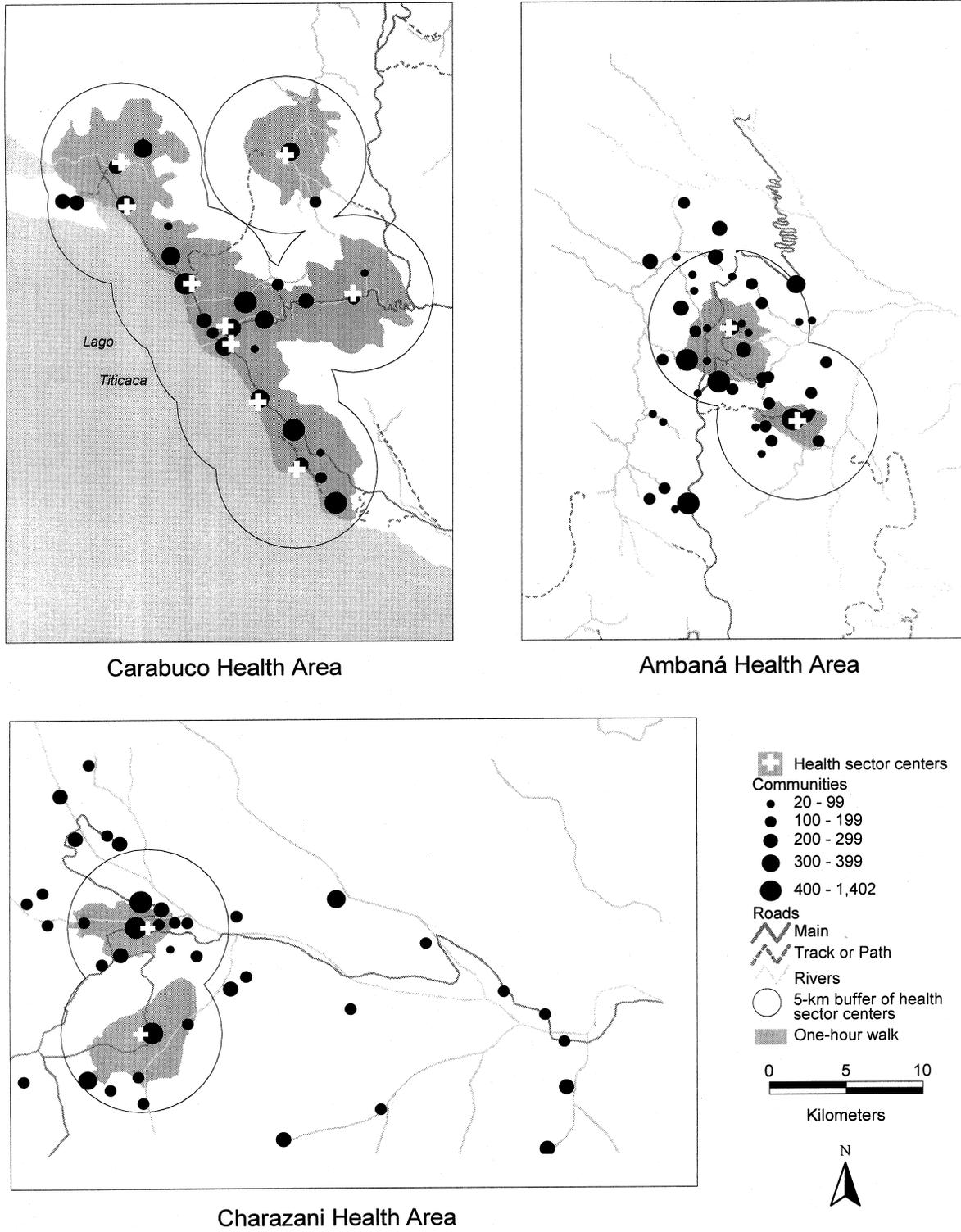


Fig. 3. Physical access to primary health care in study sites, current situation.

Table 2
Population per auxiliary health nurse in the Ambaná health area

| Health sector | Population | Auxiliary health nurses | Population per auxiliary health nurse |
|---------------|------------|-------------------------|---------------------------------------|
| Amбанá | 3592 | 1 | 3592 |
| Copusquía | 1536 | 1 | 1536 |
| Totals | 5128 | 2 | 2564 |

primary health care services. Four of the 10 communities in Copusquía health sector, or 744 inhabitants (48.4% of the total) lie within this 1-h zone.

Charazani health area

Aside from the strong traditional health resource base of the Kallawayas and others in the Charazani and Amarete regions, the sole provider of modern health care services is the government. These health services are extremely limited and suffer from poorly equipped health centers and unsupervised and poorly motivated health personnel. The sheer vastness and rugged mountains of the health area leave the health personnel with little chance to reach all segments of the population, let alone allow the population to access the health care system. A total of three health personnel are present within the Charazani health area. One auxiliary health nurse and a physician are located in Charazani, while another auxiliary health nurse is located in Amarete. Table 3 shows extremely high population per auxiliary nurse ratios.

Physical access to primary health care is extremely poor throughout the health area. Figure 3 shows those communities within a 1-h walk of auxiliary health nurses and associated health centers. In the Charazani health sector, only five of the 39 communities, or 1183 persons (16% of the total), are within 1 h of primary health care. Perhaps more striking is that 10 communities, representing a population of 1497 (21% of total), require travel times of one day or greater. In the Amarete health sector, four of the 14 communities, or 2028 persons (56%), are within 1 h of primary health care.

To summarize, Carabuco, Ambaná and Charazani health areas represent broad ranges of physical access to primary health care. The majority of the population of the Carabuco health area, with its generally flat

topography and institutional presence of CSRA and their CBIO approach to primary health care, has unsurpassed physical access to primary health care. However, the populations of Ambaná and Charazani health areas experience limited physical access to primary health care due to understaffed and poorly supervised health personnel and immense topographic barriers. Physical accessibility in Charazani health sector, in particular, is extremely poor.

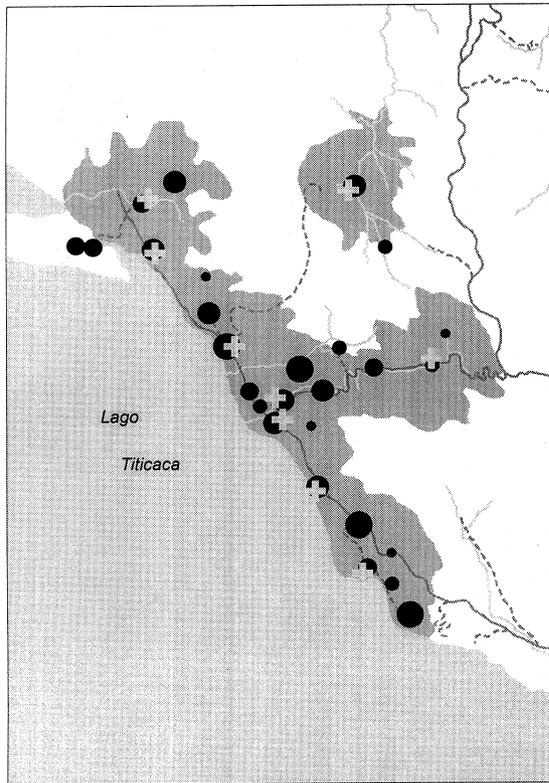
An alternative method of health personnel distribution

Based on the results of this study, it is plausible to propose an alternative model for health personnel distribution within the study area. Drawing on important components of qualitative, numerical and spatial imbalances of health personnel, this alternative model seeks to maximize both efficiency of resource use and effectiveness of health services provided. In terms of qualitative health personnel imbalances, this paper highlights the appropriateness of auxiliary health nurses and the inappropriateness of physicians-*año de provincia* in the rural setting. Therefore, auxiliary health nurses are the health personnel of choice for the provision of primary health care services, while physicians-*año de provincia* no longer hold a place in the alternative model. Physicians have a limited role in the alternative model due to the underdevelopment of hospitals and the much more efficient and effective nature of auxiliary health nurses in primary health care activities; consequently, they are not addressed within the focus of these case studies. There are several places, however, where physicians can be of use in conjunction with referral centers with existing hospital infrastructure.

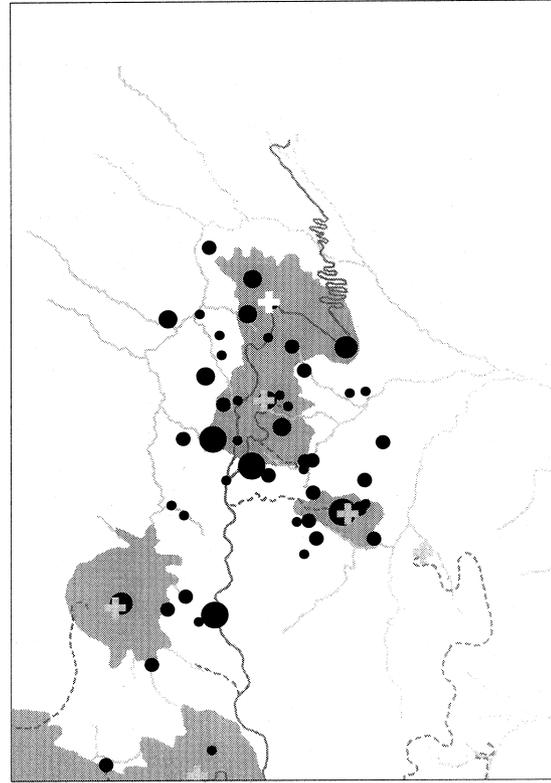
Certain minimum standards were developed to serve as a set of criteria for formulating the alternative

Table 3
Population per auxiliary health nurse in Charazani health area

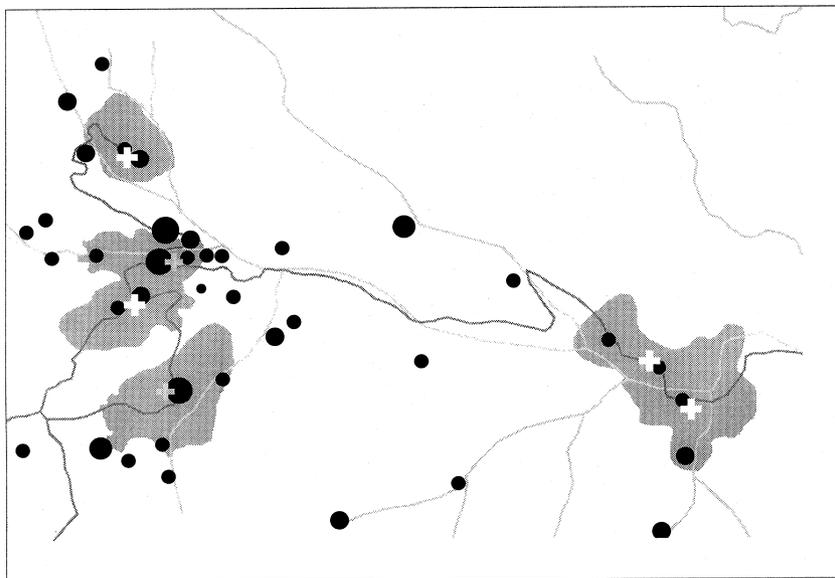
| Health sector | Population | Auxiliary health nurses | Population per auxiliary health nurse |
|---------------|------------|-------------------------|---------------------------------------|
| Charazani | 7236 | 1 | 7236 |
| Amarete | 3622 | 1 | 3622 |
| Totals | 10,858 | 2 | 5429 |



Carabuco Health Area



Ambaná Health Area



Charazani Health Area

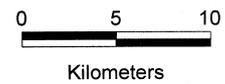
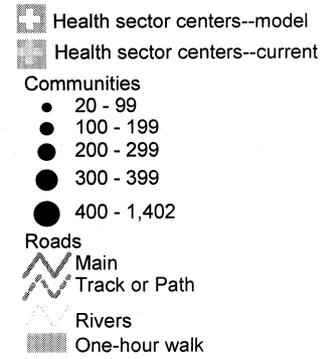


Fig. 4. Physical access to primary health care in study sites after implementation of alternative model.

model. The first is a numerical standard of 2000 persons per auxiliary health nurse. The first value serves as a realistic expectation of population per health personnel, as 2000 lies between the SRS standard of 2850 and *Consejo de Salud Rural Andino's* standard of 1500 (Ferrel, 1997). Based on relatively low population densities and sparsely settled populations, with the exception of a few areas along Lake Titicaca, the Suches River and sections of the *valles*, 2000 persons per auxiliary health nurse serves as a more acceptable standard than the high 2850 of the government.

The second minimum standard is a physical accessibility standard of having each *cantón* (county) seat within 5 km of an auxiliary health nurse and health center. Since *cantón* seats are generally the largest population centers in a given *cantón* and represent the most reliable population data available, these are used as part of the criteria for improving physical accessibility.

As a result of this alternative model of health personnel distribution, the physical access to primary health care increases overall in the three selected case study sites. Physical accessibility remains the same in the Carabuco health area, but it is in the Ambaná and particularly the Charazani health areas where physical access to primary health care is maximized. Figure 4 indicates the larger area and hence greater population, now within a 1-h walk of primary health care services with the addition of one auxiliary health nurse in Ambaná and four in Charazani. As a result of one additional auxiliary health nurse in an optimally-located site in the Ambaná health area, 71.0% of the population (as compared to 49.6%) is within a 1-h walk of primary health care. With the addition of four auxiliary health nurses in the Charazani health area, 43.7% of the population is within a 1-h walk of primary health care, as compared to only 29.6% with the current situation. Perhaps more importantly, however, is that the overwhelming majority of the population in the Charazani health area is now within a 2-h walk of primary health care, whereas a significant portion of those communities, or 21% of the total population of the health area, faced walking times in excess of one day in the previous analysis.

Summary and conclusions

Existing distributions of health personnel and access to primary health care services are clearly inadequate for the majority of the population in the study sites, with the exception of the Carabuco health area. Severe imbalances exist in the type, number and spatial distribution of health personnel, leading in turn to limited physical accessibility. The majority of the population

in Ambaná and Charazani health areas has limited access to primary health care, defined by travel times on foot of greater than 1 h. The proposed alternative model of health personnel distribution signifies a more efficient, equitable and effective distribution of human health resources to improve the physical access to primary health care services.

This paper presented a relatively simple application of some basic technologies to address the universal problem of physical access to primary health care. It was shown that GIS could be used to assess the current situation in three areas of Bolivia with very different physical geographies and health care resources, as well as demonstrate what the gains in physical accessibility would be with fairly modest changes in the types, numbers and distribution of health personnel.

The methods used in this study, we believe, are feasible, generalizable and appropriate. The first author, armed with some widely available technologies and assisted in the field by people with knowledge of local situations, completed the data collection within a fairly short period; thus the technology was shown to be *feasible*. We argue that what has been described here is especially useful because it shows how the access issue can be addressed even in a region of the world where physical, climatic and socio-economic barriers to health care are quite extreme. Therefore, the methods are *generalizable*; if they can be applied in this relatively extreme case, they can surely be applied elsewhere. GIS and image processing techniques are also, we feel, an *appropriate* use of technology in developing countries. Expertise and funds are required, of course, but the gains in improved physical accessibility due to this straightforward application could be enormous. Given the feasibility, generalizability and appropriateness of a method to improve physical accessibility, however, it still remains a question if governments have the political will to make use of the method to improve health care for their people.

The relatively simple GIS methods were appropriate and effective to fulfill the goals and objectives of this study. However, another potential use of GIS in this context is location/allocation modeling. Oppong and Hodgson (1994) further demonstrate the usefulness of this type of modeling of primary health care accessibility in Ghana. With additional digital cartographic data, particularly digital elevation models (DEMs), it would be possible to model not only a distance variable, but also elevation gain/loss.

This paper analyzed physical access to modern health resources in three study sites in Andean Bolivia. However, it is important to recognize that it was not possible to conduct an exhaustive analysis of all the spatial components of the health care system. Therefore, numerous opportunities are available for future research, including a more detailed study of the distri-

bution of traditional human health resources such as *parteras empíricas* (traditional birth attendants) and *curanderos* (healers) and physical access to these traditional health providers. In addition, other measures of accessibility such as utilization rates and patients' perspectives are other topics to consider for future research.

As discussed above, this paper analyzed a specific spatial component of the health system. Although physical accessibility is important to consider, it is only a part of the overall health context. The total social, cultural, economic and physical environments are all part of this overall health context. Therefore, International Health practitioners must improve existing methodologies of health care delivery and refine these to ensure processes of sustainability. The CBIO approach to primary health care is one such methodology that deserves wider application. In addition, the special considerations presented by mountain environments to the delivery of primary health care services require additional study and modeling, by geographers and public health researchers alike.

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