NEW APPROACHES TO SPATIALLY ANALYSE PRIMARY HEALTH CARE USAGE PATTERNS IN RURAL SOUTH AFRICA

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SUMMARY

Introduction Knowledge and understanding of health care usage and population distribution is vital for health resource allocation and planning. There is a need for indices that enable the large-scale spatial usage patterns of health facilities to be quantitatively assessed.

Methodology We map and interview in excess of 23,000 homesteads (approximately 200,000 people) in the Hlabisa district, South Africa and spatially analyse their modal primary health usage patterns using a geographical information system. We generate contour maps of health service usage. We quantify the relationship between actual clinic catchments and distance-defined catchments using inclusion and exclusion error. We propose the distance usage index (DUI) as an overall spatial measure of clinic usage. The index is the sum of the distances from clinic to all actual client homesteads divided by the sum of the distances from clinic to all homesteads within its distance-defined catchment. The index encompasses inclusion, exclusion, and strength of patient attraction for each clinic.

Results 87% of homesteads use the nearest clinic. Residents of homesteads travel an average Euclidean distance of 4.72 km to attend clinics. There is a significant logarithmic relationship between distance from clinic and usage by the homesteads (r^2= 0.774, p<0.0001). The DUI values range between 31 and 198% (mean = 110%, SD =43.7) for 12 clinics and successfully highlight clinic usage patterns across the district.

Conclusions The DUI proves to be a powerful and informative composite measure of clinic usage. The results of the study have important implications for health care provision in developing countries.

Keywords

Accessibility, global positioning system, GIS, primary health care, South Africa

INTRODUCTION

Proximity to primary health care has long been considered a major factor contributing to the health of populations (Perry & Gesler 2000). Knowledge and understanding of health service usage and population distribution are therefore vital for health resource allocation and planning (Joseph & Phillips 1984). Good health system management depends on informed decisions regarding resource allocation. Unfortunately, these decisions often occur in the absence of data that allow the pattern of resource allocation to be assessed.

Physical accessibility of health services is determined by the geographical location of client homesteads in relation to available facilities, by physical and topographical barriers and by the modes of transport that are available to reach these destinations. The effect of distance on patient travel to health care facilities and the estimation of critical distance thresholds for different levels of health care have been subjects of extensive study (Morrill & Earickson 1968, Morrill & Earickson 1970, Shannon & Dever 1974). There is ample evidence to suggest that physical accessibility of services is a major factor influencing patient choice of health care facility (Shannon et al. 1969) and that attendance rates at health facilities decline markedly with distance (Rahaman et al. 1982, Stock 1983, Kloos 1990, Müller et al. 1998). In developing countries where health facilities are relatively sparse and access often achieved on foot (Stock 1985) it has been assumed that patients will preferentially use nearest health facilities and that there is a finite limit to the distance that patients will travel for health care. These assumptions may not hold in countries like South Africa in which well resourced facilities of reasonable quality are available and where public transport may increase access to facilities some distance away from home.

Accessibility is also influenced by social and cultural factors such as knowledge and information, and by economic factors since the use of different forms of transport and access to channels of communication are usually associated with some monetary cost (Deichmann 1997). Various social factors affecting choice and usage of health services in developing countries have been studied (Egunjobi 1983, Habib & Vaughan 1986, Van der Stuyft et al. 1996). These factors include quality of care, perceived level of sickness, income, transport availability, religion, occupational status, relationships to health facility staff and proximity of relatives to health facility. Although social factors are important determinants of health service usage, these factors will vary from household to household and are difficult to measure. They are therefore less readily available to health planners than physical space, which has provided the traditional basis for macro planning of health services and for which there are increasingly sophisticated spatial analytical tools. It is also held that improvements in health care usage can be quickly realised by the simple expedient of relocating health centres or improving the road network (Airey 1992).

To the best of our knowledge, large-scale usage patterns of multiple primary health care services across an integrated health unit have never been spatially investigated. Health care systems in the developing world face increasingly diverse and complex health problems. There is a need for methods that enable the large-scale spatial usage patterns of health facilities to be quantitatively assessed (Joseph & Phillips 1984). These data are needed to inform resource allocation methodologies in developing countries. We interview in excess of 23,000 geo-referenced homesteads (approximately 200,000 people) and analyse their modal usage patterns using a geographical information system (GIS). We map facility usage across the district, analyse the effect of distance on facility usage and develop indices that quantify the relative patient attraction and repulsion by the different health facilities. We develop a new index as an overall spatial measure of facility usage in relation to the size of the facility's distance-defined catchment.

METHODS

Study area

Hlabisa district is located in northern KwaZulu-Natal, South Africa and is 1430 km^2 in size. The resident population of 210, 000 people is Zulu-speaking and predominantly rural (although there are pockets of urban and peri-urban populations in the southern part of the district near the market town of Mtubatuba). This population, with an annual per capita income of US$ 1730, relies mainly on migrant labour remittances, subsistence farming and pensions for its support and livelihood (Department of National Health 1996). The rural population is scattered throughout the district and is not concentrated into villages or compounds as in the case in many other parts of Africa.

The district is transected by a nature reserve and bounded by hard boundaries in the form of large perennial rivers, nature reserves, forestry areas and commercial farmland. This makes Hlabisa district a geographically discrete unit with minimal cross boundary population flow, and is therefore ideal for a study of this nature. KwaZulu-Natal has the highest HIV prevalence in South Africa (Department of National Health 1996). HIV infection has spread rapidly in Hlabisa, and HIV prevalence among pregnant women increased from 4.2% in 1992 to 14% in 1995 (Coleman & Wilkinson 1997) and to 41.2% in 1998 (Wilkinson et al. 1999).

Primary health care in Hlabisa district

A central community hospital and 11 satellite fixed clinics provide primary health care in the Hlabisa district. The hospital and one of the fixed clinics are 24 hour, the remainder only function during the day. This district with its health infrastructure is typical of many similar rural health systems in South Africa and functions as a semi-autonomous unit at the third tier of a national health system. In addition to providing emergency and curative care for the entire district, Hlabisa hospital also serves as a clinic for the surrounding population and is therefore equivalent, for the purposes of this study, to the other fixed clinics in the district. The clinics handle minor ailments, family planning, antenatal and postnatal care, deliveries, treatment of sexually transmitted diseases, child immunization, tuberculosis directly observed therapy (DOTs), chronic illnesses (such as diabetes and hypertension) and emergencies. The clinics are staffed by nurses, some of whom have advanced training in midwifery and primary health care, and are visited monthly by medical officers from the hospital. In comparison with the rest of Africa, clinics are well resourced; most have telephones, running water and are relatively accessible to the local population.

In addition to the fixed clinics, there are 31 mobile clinic points throughout the district, that are visited twice monthly. The mobile clinics offer family planning, child immunization, treatment of chronic illness and antenatal care. The district is also serviced by 131community health workers (CHW), each of whom is expected to regularly visit a group of assigned homesteads. The CHWs are responsible for health education, nutritional support, first aid and, in selected cases for HIV home-based care. They are also responsible for the dispensing of tuberculosis DOTs and for directing obviously ill patients to the clinics or district hospital. The CHWs work 16 days a month and on average should visit each of their allotted homesteads once a month but frequency varies between CHWs. In addition to the community health workers there are approximately 90 community volunteers disseminating tuberculosis DOTs. The spatial configuration of the tuberculosis DOTs programme has been described (Tanser & Wilkinson 1999).

Location of homesteads

All 24,236 homesteads in the study area were positioned by 12 fieldworkers carrying hand-held global positioning systems (GPS) (Trimble Geoexplorer II). The fieldworkers were divided into three teams of four and the movements of each team coordinated by a supervisor in a vehicle. The mapping took approximately one year to complete at an average of 8 homesteads per fieldworker per day. The GPS system, owned by the United States Department of Defence, introduces an intentional error to the system, typically around 50-100m*. This error is unacceptable in the study area where some homesteads are only 10m apart. We differentially corrected for this and other errors against a local base station. By plotting the errors over time, it is possible to subtract these errors from a roving GPS in the field. Differential correction occurred subsequent to positioning in the field. Comparison with trigonometric beacons in the district revealed all positions to be accurate to within 2m.

Quality Control

A number of quality control measures were instituted which ensured good quality of data collection as well as comprehensive coverage of the district. These measures are more fully described elsewhere (Tanser, 2000). Nevertheless, despite these measures a small number of homesteads were inadvertently not mapped. In a subsequent intensive questionnaire exercise covering approximately 11 000 homesteads in a contiguous geographic area, 1.7% of randomly distributed homesteads were found to have been not mapped. This small number is unlikely to affect any results in the research.

Creating the primary health care GIS

We obtained GPS coordinates for the hospital, fixed clinics, mobile clinic points and for all CHW homesteads. All homesteads in the district were uniquely numbered and a dataset collected about the usage of health and educational services. Our objective was to perform a geographical analysis of modal primary health care usage patterns across the entire district at a homestead level. At each homestead we therefore asked a single informant ‘which fixed clinic/mobile clinic most people in the homestead normally use’. Informants were also asked whether the homestead was visited by a CHW. The only criteria for selecting the informant was that they be senior enough to give the fieldworker permission to map the homestead and to answer questions. There were an average of 7.4 residents per homestead and this did not differ significantly across the clinic catchments. All data were collected in the field using the GPS data dictionary facility. We could not obtain information in some homesteads due to the residents being absent (3.9%) or refusing to answer questions (0.4%). These point locations were superimposed on a base map consisting of a series of geographical layers of the district (including magisterial and tribal areas, nature reserve boundaries, roads and rivers) digitised from 1:50 000 topographical maps using MapInfo 5.0 (MapInfo Corporation, New York).

Analysing clinic and community health worker usage across the district

We produced contour usage maps for fixed clinics, mobile clinics and CHWs. All homesteads were superimposed onto a 20m raster grid in Idrisi 32 (the Idrisi project, Clark University, Worcester, MA, USA). We then passed a moving 1km x 1km filter across the image which calculated the percentage of homesteads that made use of clinics and CHWs in the filter window. In the resulting images the value of each pixel is the percentage of homesteads that make use of primary health care facilities in the surrounding 1km x 1km neighbourhood. The images were then converted into vector format and exported to Mapinfo.

Spatial indices to quantify clinic usage

We plotted all homesteads occurring in the study area on the GIS and colour coded them by actual clinic used. We constructed distance (thiessen) polygons for each of the fixed clinics in Mapinfo and superimposed them onto the homesteads. Distance polygons divide space such that any particular home is allocated to its geographically nearest clinic. Cross-tabulations of predicted clinic usage (on the basis of distance) and actual clinic usage were used to generate an error matrix. We defined the terms exclusion error (the proportion of homesteads from a particular distance clinic catchment who use other clinics) and inclusion error (the proportion of homesteads from other distance clinic catchments who use a particular clinic) to assess discrepancies. In epidemiological terms (using distance as the predictor of actual clinic catchments) exclusion and inclusion error are equal to *1- the positive predictive value* and *1-sensitivity* respectively. A clinic with a strong attraction of patients from within other distance clinic catchments will have a high inclusion error, whilst those with a high proportion of homesteads within their distance catchments who use other clinics will have a high exclusion error. There is some interaction between the indices for neighbouring clinics. Patients not using their closest clinics will increase exclusion errors in their origin distance catchment and increase inclusion errors in their destination clinic. Heterogeneity in exclusion and inclusion errors does not necessarily indicate discrepancies in standard of service delivery. The differences may be a function of the relative accessibility (e.g. by public transport) of the health facilities.

We calculated the average Euclidean distance that patients will travel to use each clinic as another measure of the strength attraction of a clinic. However, clinics with large distance clinic catchments will be predisposed to having patients travel longer distances to seek primary health care and it is because of necessity and not relative attraction of a particular clinic that patients will travel longer distances. We therefore propose a new measure which we have termed the distance usage index (DUI) as an overall measure of inclusion, exclusion and the strength of patient attraction (using distance travelled). The denominator of the index is the sum of the distances between all homesteads within a distance clinic catchment and the clinic. The numerator of the DUI is the sum of the distances between all homesteads actually using a particular clinic and the clinic itself. The index is expressed as a percentage. Thus a clinic which attracts a large number of patients from great distances (from outside its own distance clinic catchment) and has a good attendance within its own distance catchment, will have a DUI of greater than 100%. Conversely a clinic which only attracts patients from short distances and has a poor attendance within its own distance clinic catchment will have a DUI value of less than 100%.The concepts are illustrated using a simple map (Figure 1). We also applied the above methodology to mobile clinic points and compared the values obtained with the fixed clinic results.

The effect of distance on clinic usage

We wanted to establish the effect of distance from clinics on usage. We therefore constructed 500m buffers around each of the fixed and mobile clinics and calculated usage within each of the buffers. We then plotted the relationship between distance from clinic and usage within each distance clinic catchment.

RESULTS

Contour usage maps for fixed clinics, mobile clinics and CHWs are shown (Figure 2). 93 % of homesteads use fixed clinics (64% use fixed clinics only); 34% use mobile clinics (5.0% use mobile clinics only); 29% use both fixed and mobile clinics and 1.7% used neither. From a spatial perspective, the proposed location by the Provincial Department of Health (Figure 2a) of a new clinic is optimal, given the low clinic usage of the surrounding area. It is striking that the mobile clinics service all of the areas of low fixed clinic usage. In addition, they service those areas with high homestead densities that are a significant distance from the fixed clinics (Figure 2b, d). 36% of homesteads reported regular visits by CHWs. The community health worker distribution reveals a large gap in service in the middle of the largest of the four tribal areas (Figure 2c).

There is a large amount of congruence between actual clinic usage and those predicted by distance (Figure 3). In some cases (e.g. Nkundusi) major public transport routes appear to have had a‘distorting’ effect on the shape of a clinic catchment providing greater accessibility to patients living in close proximity to these routes.

The error matrix and associated spatial indices of actual versus distance-predicted fixed clinic usage are given (Table 1). The horizontal axis shows actual clinic usage whilst the vertical axis shows the nearest clinic on the basis of Euclidean distance. For example, 261 of the 269 homesteads that actually used Esiyembeni clinic came from within its distance catchment and only 8 homesteads came from the neighbouring catchment of Machibini (inclusion error = 3%).

However, a large proportion of homesteads whose nearest clinic is Esiyembeni used other clinics/didn't use clinics (exclusion error = 51%). Inclusion error can be used as a measure of attraction whilst exclusion error can be used as a measure of repulsion. There is an overall inclusion error of 13% (i.e. 87% of homesteads making use of clinics used the nearest clinic) across the district. The results show that proximity to primary health care centre is a major factor influencing clinic choice.

Exclusion and inclusion error, average distance travelled and the DUI are displayed for all fixed clinic distance catchments in the form of thematic maps (Figure 4). There is substantial heterogeneity in these indices across the district. The largest proportion of homesteads not using the closest clinic/not using clinics, occur within Esiyembeni (exclusion error = 51%) and Machibini (exclusion error = 41%) distance catchments. Somkhele clinic (inclusion error =31%) attracted the largest proportion of patients from outside its own distance catchment. The clinics with the largest exclusion and inclusion errors are adjacent, as a large number of patients from the distance clinic catchment of Esiyembeni use Somkhele clinic. Inclusion errors are similar for both mobile and fixed clinics (although there was more variation in mobile clinics). Exclusion error, DUI and average distance travelled differ markedly as would be expected (Table 2).

Inhlwathi clinic (5.9 km) and Hlabisa hospital (5.7 km) recorded the largest average distance travelled by homesteads to attend clinics. The DUI indicated that the clinics with the strongest attraction, and least repulsion relative to catchment size are KwaMsane (198%) and Somkhele (170%). In other words, the sum of Euclidean distances between all client homesteads and KwaMsane clinic is approximately double that of all homesteads within its distance clinic catchment. KwaMsane (198%) and Nkundusi (113%) are characterised by similar inclusion and exclusion errors and therefore similar net influx of patients from other distance clinic catchments.

The DUI shows however, that KwaMsane has a greater magnitude of attraction (attracts patients from a greater distances) relative to the size of its distance catchment.

The graphs for the individual fixed clinics is given (Figure 5a). A large variation in decay curves is evident between the fixed clinics. For example, KwaMsane clinic shows almost no reduction in clinic usage 7 km from the clinic, whereas Esiyembeni clinic shows 0% usage 6 km from the clinic. Some clinics for example, Mpukunyoni show a decrease in usage until a point whereafter usage increases. This apparent paradox is explained by the fact that distance catchments are sometimes surrounded by clinics at differing distances and differing strengths of attraction. For example, Somkhele and KwaMsane (which are the closest clinics to Mpukunyoni) attract large numbers of patients from the West and South of Mpukunyoni's distance catchment respectively. However, almost all patients in other parts of the distance catchment use Mpukunyoni, irrespective of distance (Figure 3). The combined graphs for fixed and mobile clinics are given (Figure 5b). The results reveal that mobile clinic usage decreases to 0% at approximately 8 km from mobile point, whilst at the same distance fixed clinic usage is still approximately 58%. The relationship between distance from clinic and usage was logarithmic and highly significant ($p<0.0001$) in both fixed ($r = 0.880$) and mobile $r =0.934$) clinics. The relative increase in clinic usage after 8km from a fixed clinic (Figure 5b) is a function of the fact that only a small number of clinics have distance catchments exceeding 8km and within these clinic catchments, usage is good at these distances.

DISCUSSION

We have used GIS/GPS technology to map the modal primary health care patterns of approximately 23, 000 homesteads. Our study has shown that there is a significant relationship between actual and distance clinic catchments in a typical rural South African setting. We propose the DUI as a composite spatial measure of inclusion error, exclusion error and strength of attraction.

Disparities between actual and distance clinic catchments near the extremities of the distance polygons can probably be explained to a large degree by proximity to major public transport (in the form of minibus taxis) routes. Clinics sited on or at the intersection of major public transport routes attract large numbers of patients from other clinic catchments. For example, Somkhele clinic is sited at the intersection of two major public transport routes and attracts 30% of its patients (inclusion error) from the neighbouring clinics of Esiyembeni, Madwaleni and Machibini. A detailed analysis of the reasons behind clinic choice went beyond the primary objectives of this research. However, we identified contiguous groupings of homesteads whose actual and distance-predicted clinic usage differed (near the extremities of distance polygons) and conducted informal interviews with residents of 20 homesteads in these areas. In all cases respondents reported that availability of public transport had determined their choice of clinic. This suggests that public transport access is an important determinant of clinic choice at the margins of distance catchments. All clinics situated along major public transport routes had DUI values of >100%. The indices could be improved by the construction of polygons which incorporate public transport access into their boundaries (Deichmann, 1997). We were unable to do this because public transport in the area is non-regulated, highly variable and unreliable and incorporating its effects would constitute a major data collection exercise in its own right. KwaMsane is a 24 hour clinic and this may have contributed to its elevated DUI value. Somkhele clinic is the only clinic bordered on all sides by other clinic catchments. This centrality may have contributed to its increased DUI value. Some topographically complex areas (e.g. Macabuzela clinic) are characterised by large DUI values, whilst some areas with small variations in altitude (e.g. Esiyembeni, Machibini) are characterised by small DUI values, suggesting that topography is not an important or consistent barrier to usage in this topographical setting. Smaller clinic catchments appear to be associated with lower DUI values. This is probably because these clinics are situated in more remote, less accessible areas as well as being less well resourced due to the smaller populations they serve.

The DUI values indicate that Esiyembeni and Machibini clinic are not well used, for example. An analysis of health-seeking behaviour should be conducted within their respective distance catchments to determine the reasons for this. There is additional complexity in the interpretation of mobile clinic spatial indices from a primary health care perspective because mobile clinics are likely to rank lower in the primary health care preference hierarchy because of the limited services offered and lower frequency of availability. A high exclusion error and low DUI in a fixed clinic indicates that the clinic is underutilised relative to its distance catchment. The same values for a mobile clinic may simply indicate that the mobile clinic point is effectively servicing those homesteads within its distance clinic catchment that are unable to attend fixed clinics. The results are still useful however, as they reveal mobile clinics that are used by their entire respective distance catchments (and beyond) and are thus indispensable. For example, three mobile clinic points have DUI values of approximately 150% and exclusion errors of only 20 -30%. These mobile clinic points are further from the fixed clinics than their higher exclusion error/ lower DUI counterparts. Although the DUI is a single index expressing both inclusion error, exclusion error and strength of patient attraction, it cannot replace entirely its ‘constituent’ indices. This is because the spatial indices will need to be accessed independently to allow health planners to more fully understand the spatial dynamics of facility usage.

It was not possible to compare our distance decay data against previous studies in developing countries as these studies have incorporated a frequency component (i.e. number of clinic attendances per person per year) into their usage data. The results of these studies are worth mentioning however, as they were conducted in similar rural settings. The distance from health facility at which 50% of potential attendances are lost has been measured at 3.5km (Müller, et al. 1998), 3.2 km (Jolly & King 1966) and 3.4 km (Stock 1983) in Papua New Guinea, Uganda and Nigeria respectively.

Distances travelled to clinics and clinic choice will differ by age, sex and diagnosis (Stock 1983) and possibly season. We have examined modal usage patterns of homesteads and have therefore deliberately masked out deviant usage behaviour by individuals. This may take the form of different facility choice by an individual to that of the homestead or may be brought about by a change in an individual's health status. We did not obtain this information for this study because collection of this data for a population of 200,000 people would have been logistically impossible and fell outside the objectives of this research. We are currently conducting a study of 10, 000 homesteads (95,000 people) in five of the clinic catchments in the district and will use the indices to investigate health care usage patterns (including frequency and temporal variations) at an individual level. There is an argument that Euclidean distance is a sub-optimal measure of accessibility (Shannon et al. 1973, Deichmann 1997), since it ignores physical barriers such as hills, rivers, the transport system and social factors. Accessibility can be determined by a complex inter-linkage of both physical and human factors in addition to proximity to clinics (Fiedler 1981). The magnitude of the agreement between nearest clinic and actual clinic usage (87%) and the fact that a large number of people use walking as their primary mode of transport suggests that Euclidean distance is an adequate measure of accessibility for the purposes of this study and in this rural setting. Although the study area was selected on the strength of its geographic integrity, a limited amount of inter-district clinic usage will occur. This will increase attendances and average distance travelled to receive treatment. The spatial indices are unlikely to be affected significantly (as they are essentially ratios), as the external clinic's distance catchments do not impinge on our existing catchments. Patient referrals between clinics are unusual and would not affect the modal usage patterns.

How can these results contribute to health provision, resource allocation and evaluation of health centre efficacy in the developing world? Some may argue that the indices are of little use to district health services who are unlikely to have the resources to survey every homestead in a prescribed geographical area. However, geographically stratified sampling techniques of small populations can be successfully employed to facilitate calculation of the indices. Alternatively, patients using clinics over a specified time period could be geo-located. This method would ensure that the sample was weighted by frequency of clinic attendance as well as geographic distribution.

At a district level, health managers should strive towards low exclusion and inclusion errors and DUI values close to 100% at all health facilities. This indicates that the facilities are evenly distributed, patients are generally using their closest facility and attendance is good. Clinics exhibiting low DUI values should be further investigated to determine whether quality of service differs from other clinics or whether the differences are merely a function of physical accessibility. The fact that homesteads which commonly use a particular clinic can be predicted with a small margin of error in a rural South African setting is exceedingly useful for health care planning. There is more data required for successful health planning than the indices alone can provide. The indices need to be combined with demographic profiles and detailed health-seeking behaviour data to facilitate optimal positioning of the health services.

Research in a rural district approximately 200 km north of Hlabisa has shown that our results are not dissimilar to other rural populations in South Africa and that the percentage of people using the nearest clinic in our area may even be lower than the rural average. In a survey of 7,160 homesteads, it was found that 97.6% of homesteads attended the nearest clinic defined on the basis of Euclidean distance (J. Tsoka, South African Medical Research Council, *pers comm*). Both of these rural health districts make use of a similar integrated health system model.

It is not clear whether these results are transferable to other settings in the developing world outside Southern Africa. For example, in a study of 859 patients in Nigeria, it was found that although distance was the leading factor in determining hospital choice, it accounted for only 31.8% of the total responses (Egunjobi 1983). Social factors accounted for the remaining 68.2%. The above comparison may not be strictly valid however, because hospitals offer a comprehensive range of services and are therefore more likely to be influenced by social factors than are clinics. Though it is better resourced than similar models elsewhere in sub-Saharan Africa the elements of many African health systems are similar and many of these spatial principles could well be applicable to other district health systems in scattered rural populations in the sub-continent. Future research should focus on the calculation of the DUI in different settings and stratified at an individual level, by age, sex and diagnosis. The indices should be weighted by frequency of clinic attendances. There is likely to be an increase in the indices with the shift from a homestead to an individual level as more deviant usage behaviour is revealed.

The world health report of 2000 (WHO 2000) was dedicated to improving the performance of health systems. Health systems performance make a profound difference to the quality, as well as the length of the lives of the billions of people they serve. However, an important omission from the report was the spatial aspect of health systems research. The DUI provides a composite index of clinic usage and inter-clinic catchment interaction. Our study has shown how integrated health systems can be effectively spatially analysed and has highlighted the potential of GIS to play a key role in rational and more cost-effective health service planning and resource allocation in developing countries.

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Table 1: Error matrix of the relationship between actual fixed clinic usage and nearest clinic. Commission error , omission error, average distance travelled and the distance index are displayed for each clinic.

		ACTUAL CLINIC USAGE																
	NAME	None	Esiyembeni	Hlabisa	Inhlwathi	KwaMsane	Macabuzela	Machibini	Madwaleni	Makhowe	Mpukunyoni	Nkundusi	Ntondweni	Somkhele	**TOTAL**	**Unknown**	**Exclusion error (%)**	**Mean Distance (km)**	**DUI (%)**
NEAREST CLINIC	Esiyembeni	79	**261**	0	0	22	0	45	0	0	15	0	0	109	**531**	8	50.8	2.4	30.9
	Hlabisa	146	0	**2,818**	61	43	0	0	0	0	0	0	0	0	**3,068**	46	8.1	5.7	109.5
	Inhlwathi	111	0	255	**1,501**	3	67	0	1	4	0	0	0	0	**1,942**	113	22.7	5.9	84.9
	KwaMsane	167	0	0	0	**2,721**	0	0	0	0	7	1	0	7	**2,903**	217	6.3	3.9	198.0
	Macabuzela	20	0	0	25	0	**1,052**	0	0	76	0	0	3	0	**1,176**	134	10.5	4.8	121.7
	Machibini	283	8	0	0	8	1	**738**	0	0	48	0	0	163	**1,249**	29	40.9	3.0	44.9
	Madwaleni	61	0	0	0	75	0	2	**1,741**	0	49	406	31	125	**2,490**	95	30.1	4.0	60.1
	Makhowe	7	0	0	106	0	117	0	0	**573**	0	0	0	0	**803**	97	28.6	3.6	72.1
	Mpukunyoni	36	0	0	0	246	1	0	11	0	**1,669**	0	0	142	**2,105**	69	20.7	4.1	121.9
	Nkundusi	119	0	0	0	20	0	0	12	0	1	**3,032**	124	1	**3,309**	129	8.4	5.4	113.6
	Ntondweni	430	0	0	0	8	20	1	11	0	53	7	**1,180**	132	**1,842**	60	35.9	4.9	66.8
	Somkhele	98	0	0	0	54	0	11	1	0	87	0	4	**1,529**	**1,784**	37	14.3	5.0	170.4
	TOTAL	**1,557**	**269**	**3,073**	**1,693**	**3,200**	**1,258**	**797**	**1,777**	**653**	**1,929**	**3,446**	**1,342**	**2,208**	**23,202**	**1,034**	**18.9**	**4.7**	**110.3**
	Inclusion error (%)	-	3.0	8.3	11.3	15.0	16.4	7.4	2.0	12.3	13.5	12.0	12.1	30.8	**13.0**				

Table 2: Weighted average (min - max; standard deviation) spatial indices and average Euclidean distance travelled to clinic for fixed and mobile clinics in Hlabisa.

Variable	Fixed Clinics		Mobile Clinics	
Usage (%)	93.3	(77 - 99; 6.7)	34.3	(7 - 96; 24.6)
Inclusion error (%)	13.0	(3 - 31; 6.9)	14.6	(1 - 34; 11.9)
Exclusion error (%)	18.9	(8 - 51; 12.1)	71.5	(19 - 95; 19.8)
Mean distance travelled (km)	4.72	(2.4 - 5.9; 0.85)	2.42	(0.8 - 3.9; 1.06)
Distance usage index (%)	110.3	(31 - 198; 43.7)	26.8	(2 - 157; 41.6)