

# The use of a geographical information system (GIS) to evaluate the distribution of tuberculosis in a high-incidence community

Nulda Beyers, R. P. Gie, H. L. Zietsman, M. Kunneke, J. Hauman, M. Tatley, P. R. Donald

**Objective.** To determine the geographical distribution of tuberculosis in the two Western Cape suburbs with the highest reported incidence of tuberculosis.

**Design.** Descriptive illustrative study.

**Setting.** Two adjacent Western Cape suburbs covering 2.42 km<sup>2</sup> with a population of 34 294 and a reported tuberculosis incidence of > 1 000/100 000.

**Subjects.** All patients notified as having tuberculosis over a 10-year period (1985 - 1994).

**Interventions.** None

**Outcome measure.** The geographical distribution of the cases was determined using a geographical information system (GIS) and the National Population Census (1991).

**Results.** One thousand eight hundred and thirty-five of the 5 345 dwelling units (34.3%) housed at least 1 case of tuberculosis during the past decade and in 483 houses 3 or more cases occurred. These cases were distributed unevenly through the community, with the tuberculosis incidence per enumerator subdistrict (ESD) varying from 78 to 3 150/100 000 population.

**Conclusion.** In a small area with a high incidence of tuberculosis, the cases are spread unevenly through the community and there are certain houses where tuberculosis occurs repeatedly. This information should be used to direct health services to concentrate on certain high-risk areas.

*S Afr Med J* 1996; **86**: 40-44.

Africa as a continent has the highest tuberculosis incidence in the world (272 new cases per 100 000 population per year).<sup>1</sup> The overall tuberculosis incidence for the whole of South Africa is 366 new cases per 100 000 population per

year, with the lowest incidence (59/100 000) in the Northern Province and the highest (718/100 000) in the Western Cape.<sup>2</sup>

The incidence of tuberculosis in the coloured population of the Western Cape has been rising steadily. In the areas served by the Western Cape Regional Services Council (WCRSC) (now the Cape Metropolitan Council) (CMC) the incidence was 390/100 000 population in 1986<sup>3</sup> and by 1993 had risen to 650/100 000.<sup>4</sup>

This rise in the incidence of tuberculosis, especially in the coloured population, has been documented repeatedly and cohort studies predict a further rise.<sup>5</sup> The increased incidence of tuberculosis in the Western Cape cannot be ascribed to HIV or AIDS, since the prevalence of HIV seropositivity in pregnant women in the Western Cape at present is only 1.16% (95% confidence interval 0.76 - 1.56).<sup>6</sup> The reasons for the persistently rising tuberculosis notification rates in the coloured population, when those in other population groups are falling or static, are uncertain.

Since 1986 incidences have been reported regularly for different suburbs in the Western Cape and it is clear that in a province with an already high tuberculosis incidence, certain suburbs have a much higher tuberculosis notification rate than others. In 1993 the highest reported incidences in the Western Cape were recorded in Uitsig (1 424/100 000) and in Ravensmead (1 297/100 000).<sup>4</sup> The overall notification rate for these two adjacent suburbs was 1 339/100 000 in 1993 and it has been rising steadily since 1986, when the notification rate was already 968/100 000.<sup>3</sup> However, no precise data are available on the distribution and spread of tuberculosis in these high-incidence communities. More accurate information on factors determining the spread of tuberculosis in the communities would be of considerable value in efforts to control the disease.

Relatively little is known of the spatial or geographical distribution and occurrence of disease, although the geography of health has recently received considerable attention. This is particularly true with respect to the mapping of the major transmission routes of AIDS<sup>7,8</sup> and the geography of AIDS in different countries and communities.<sup>9,10</sup> However, limited data are available describing the precise geographical distribution of tuberculosis. County-by-county variations in tuberculosis incidence and death rates have been mapped in Wales,<sup>11</sup> but no data have been published on the geography of tuberculosis in South Africa. World-wide 'the request for the systematic monitoring of health and health care within small geographic areas has largely been ignored'.<sup>12</sup>

The aim of this study was to determine the geographical distribution of tuberculosis in the two Western Cape suburbs with the highest incidence of the disease.

## Material and methods

The study was done in the suburbs of Ravensmead and Uitsig, which cover an area of 2.42 km<sup>2</sup>. The area is served by two local authority health clinics and a tertiary care referral hospital is adjacent to the suburbs. The local authority clinics and their staff are responsible for the management of tuberculosis. There is a small industrial area adjacent to the suburbs where people from other suburbs

Departments of Paediatrics and Child Health and Medical Biochemistry, and Institute for Geographical Analysis, Department of Geography, University of Stellenbosch, W. Cape

Nulda Beyers, M.B. CH.B., F.C.P., M.Sc., PH.D.

R. P. Gie, M.B. CH.B., M.MED., F.C.P.

H. L. Zietsman, M.A., D.PHIL.

M. Kunneke, B.A.

J. Hauman, PH.D.

P. R. Donald, D.C.H., F.C.P., M.R.C.P., D.T.M.&H., M.D.

Cape Metropolitan Council, 38 Wale Street, Cape Town

M. Tatley, B.BUS. SCI. HONS, M.B. CH.B., F.F.C.H.

are also employed. The official records of the WCRSC (now the CMC) provided the source of data on all notified cases of tuberculosis in the area. From these records the name, address, type of tuberculosis and age of each notified case from 1 January 1985 to 31 December 1994 were collected. If any patient was notified more than once during the 10-year period, only the initial notification was recorded, thereby assuring that no patient was included more than once.

Property boundaries were obtained in digital AUTOCAD DXF format from the WCRSC and Parow Municipality for Uitsig and Ravensmead respectively. These boundary files were imported into a computer-based (ARC/INFO) geographical information system (GIS) and integrated with clinical and notification data from the two residential areas for the 10-year period 1985-1994. For each patient the address and clinical data were computerised in the INFO relational database management system and linked to their property locations in the GIS. This was achieved by creating a relational join between property reference numbers and street addresses. The 1991 population census data for individuals was obtained in a digital format from the Central Statistical Services in Pretoria. To calculate the notification incidence of tuberculosis in different areas within the suburbs, the enumerator sub-district (ESD) boundaries used for the 1991 population census were superimposed on the property boundary coverage and the incidence for each ESD calculated after tabulating the number of people with tuberculosis in 1991 in each ESD and expressing the number as a ratio to the 1991 population for each ESD as recorded by the census.

The study was approved by the Ethics Committee, Faculty of Medicine, University of Stellenbosch. The local health committees of the two suburbs gave permission for the study to be done in the community.

## Results

The total population of the two suburbs was 34 294, of whom 34 150 (99.5%) belonged to the coloured population group. The age distribution of the population is illustrated in Fig. 1. There were 10 775 (31%) under the age of 15 years and 14 764 (43%) under the age of 20 years. Of the total population, 19 051 (55.5%) had Standard 5 education or

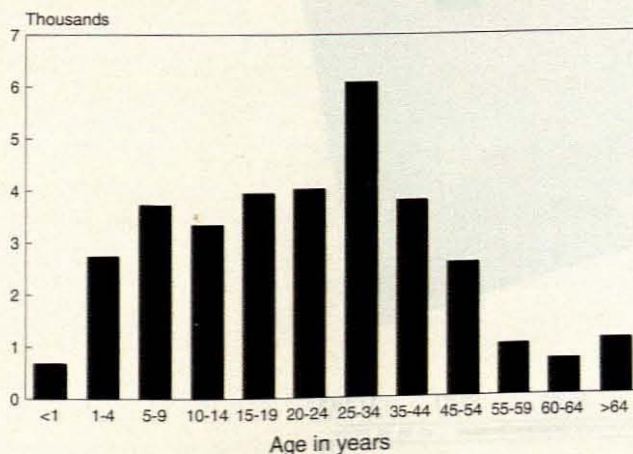


Fig. 1. Age distribution of population in Ravensmead and Uitsig as reported in the 1991 population census.

less, and we calculated that 34% of the adult population had Standard 5 education or less. Of the total population, 23 068 (67%) had a yearly income of less than R3 000, and 20 195 (59%) had no income at all. We calculated that 57% of adults had a yearly income of less than R3 000 and 40% had no income.

Over the 10-year period there were 4 490 cases of tuberculosis notified in the two suburbs. Of these 198 lived outside the suburbs but worked in the adjacent industrial area, and were therefore notified via the Ravensmead clinic. Of the 4 292 patients who resided in the suburbs, 281 (6%) could not be linked to a notified address, probably owing to incorrect addresses given or recorded. The analysis was done on the 4 011 remaining patients who could be linked to an address. There were 1 856 females (46.3%) and 2 155 males. The age distribution of the patients is illustrated in Fig. 2. There were 1 813 (45%) patients under the age of 15 years and 1 965 (49%) under the age of 20 years. The types of tuberculosis these patients had are listed in Table I. Of the 4 011 notified cases, 15 (0.37% or 1/270) had tuberculous meningitis or miliary tuberculosis. Of the 1 813 children under the age of 15 years, 9 (0.5%) had tuberculous meningitis.

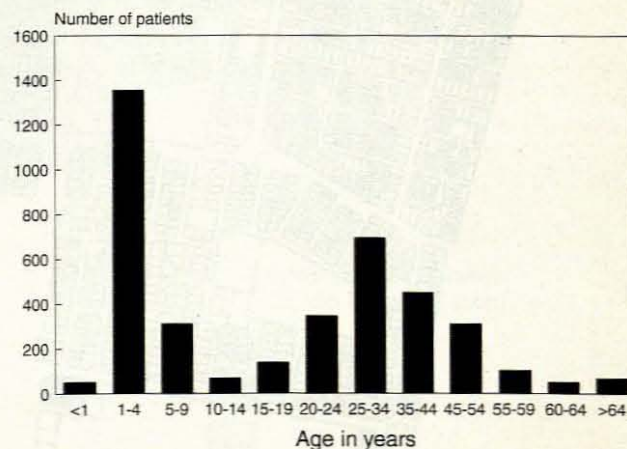


Fig. 2. Age distribution of patients in Ravensmead and Uitsig notified with tuberculosis between 1985 and 1994.

Table I. Types of tuberculosis in 4 011 patients notified from 1985 to 1994

	No.	%
Adult pulmonary tuberculosis	2 201	54.9
Primary tuberculosis*	1 705	42.5
TBM	10	0.25
Miliary tuberculosis	5	0.12
Other extrapulmonary tuberculosis	84	2.1
Unknown	3	

\*Includes hilar adenopathy, primary complex.  
TBM = tuberculous meningitis.

The cases occurred in 1 835 dwelling units. Over the 10-year period tuberculosis cases occurred in 33.6% of the single dwellings (houses) and 39% of the multiple dwelling units (flats) (Table II). Fig. 3 illustrates the distribution of dwelling units in the area with tuberculosis cases over the

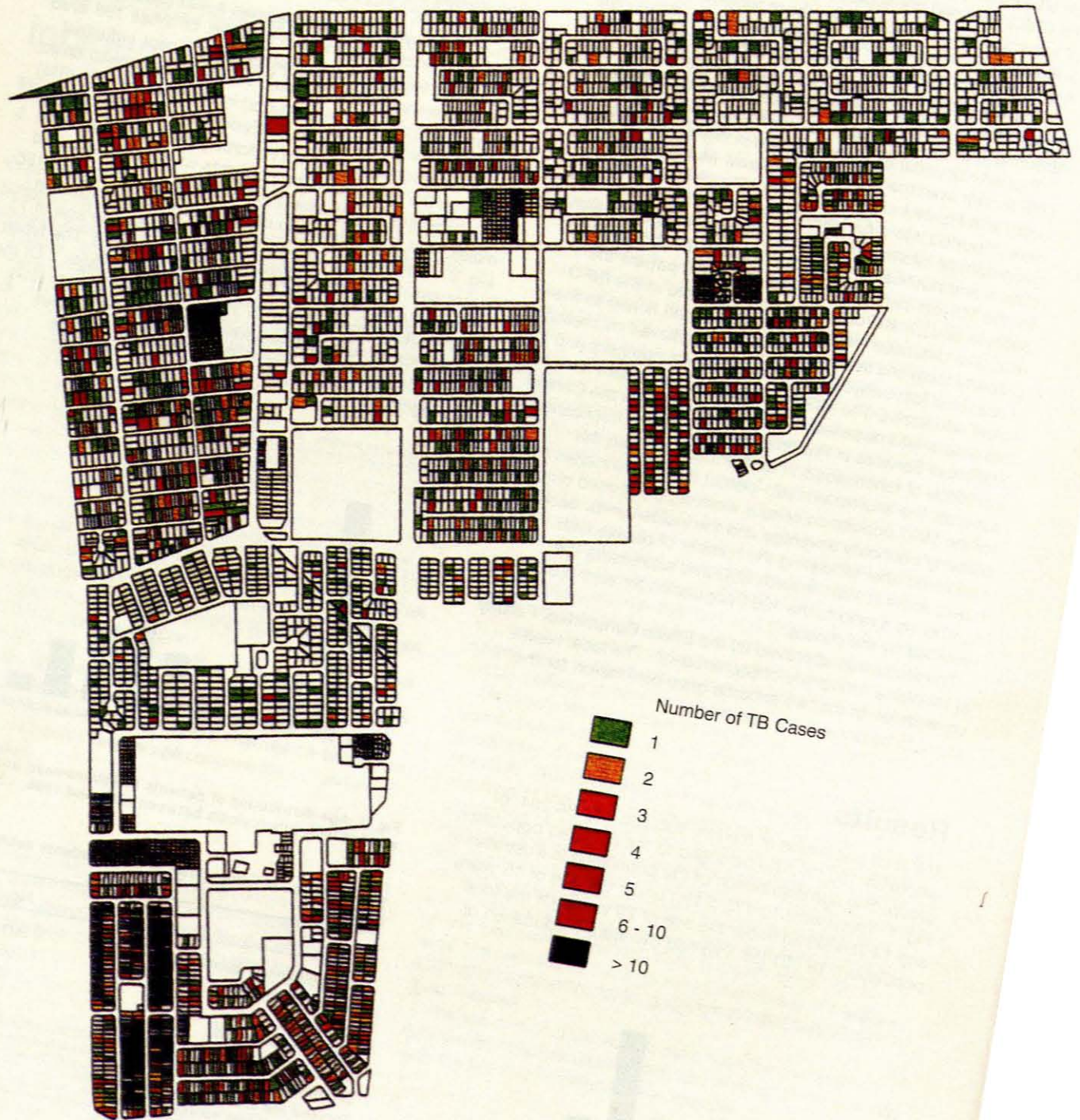
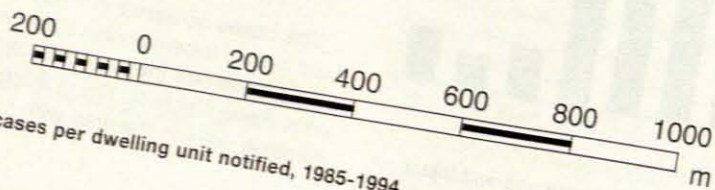


Fig. 3. Number of tuberculosis cases per dwelling unit notified, 1985-1994.



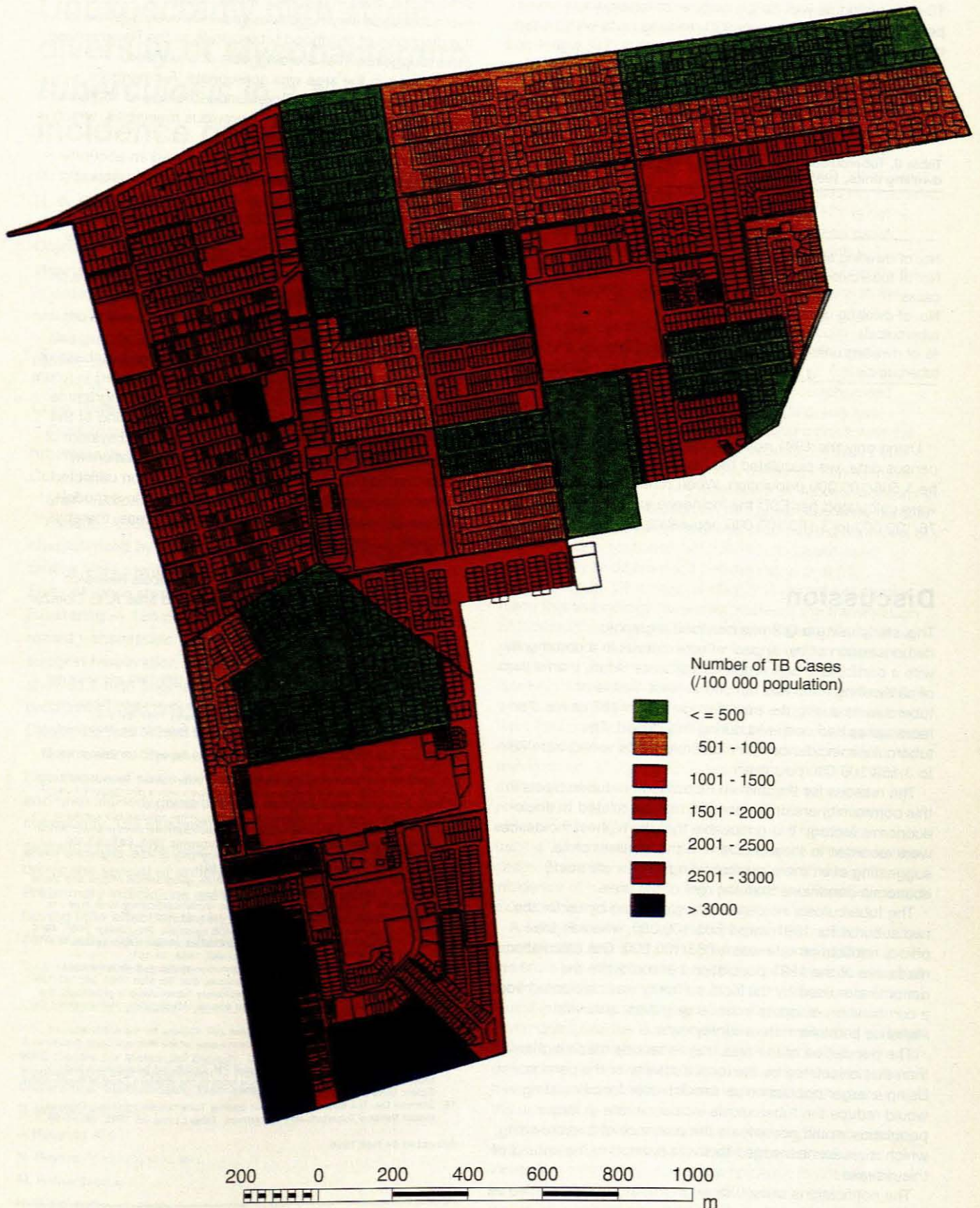


Fig. 4. Calculated incidence of tuberculosis per enumerator subdistrict in 1991.

10-year period as well as the number of tuberculosis cases per dwelling unit. There were 930 dwelling units with 1 case of tuberculosis, 409 with 2 cases, 190 with 3, 112 with 4 and 181 with 5 or more over the 10-year period. There were 21 dwelling units with more than 10 notified cases per house, and in one house 22 cases were notified over the 10-year period.

**Table II. Tuberculosis cases in single dwelling and multiple dwelling units, 1985 to 1994**

	Single dwelling units	Multiple dwelling units (flats)
No. of dwelling units	4 682	663
No. of tuberculosis cases	3 539	505
No. of dwelling units with tuberculosis	1 575	260
% of dwelling units with tuberculosis	33.6%	39%

Using only the 1991 notifications and the 1991 population census data, we calculated the incidence of tuberculosis to be 1 505/100 000 population. When tuberculosis incidences were calculated per ESD the incidence varied from 78/100 000 to 3 150/100 000 population (Fig. 4).

## Discussion

This study using a GIS has provided a graphic demonstration of the impact of tuberculosis in a community with a particularly high reported incidence. More than a third of all dwelling units had housed at least 1 case of tuberculosis during the past decade and in 483 cases 3 or more cases had occurred during this period. The tuberculosis incidence in the different ESDs varied from 78 to 3 150/100 000 population.

The reasons for the uneven distribution of tuberculosis in this community are uncertain, but may be related to socio-economic factors. It is noticeable that the highest incidences were recorded in those ESDs with the smallest plots, suggesting even more overcrowding and worse socio-economic conditions than the rest of the area.

The tuberculosis incidence rate calculated by us for the two suburbs for 1991 was 1 505/100 000, whereas the official notification rate was 1 083/100 000. Our calculation made use of the 1991 population census, while the denominator used by the local authority was calculated from a combination of inputs from census data, area vital statistics and intermittent survey data.

The population of the area may in fact be much higher than that calculated by the local authority or the census. Using a larger population as denominator for calculating would reduce the tuberculosis incidence rate. A larger population would accentuate the presence of overcrowding, which is an acknowledged factor in promoting the spread of this disease.

The notifications utilised by us in this study represented all forms of tuberculosis including childhood primary tuberculosis. As the diagnosis of tuberculosis in children is

difficult and often imprecise,<sup>13</sup> some degree of overnotification may have occurred. However, a review of the diagnosis of childhood tuberculosis at the Ravensmead clinic<sup>4</sup> suggested that the diagnosis of childhood tuberculosis in the area was appropriate. Furthermore, approximately 0.5% of children under the age of 15 years notified for tuberculosis had tuberculous meningitis, which is in keeping with published ratios.<sup>15</sup>

With the use of a GIS we have established an accurate database of the geographical and spatial distribution of tuberculosis in a high-incidence area. We have demonstrated that certain ESDs have much higher incidences than others and that there are certain houses where the disease occurs repeatedly. This information should be used to direct health services to concentrate on certain high-risk areas. Furthermore, the possibility of prophylactic therapy for certain high-incidence areas or houses at risk should be explored.

In addition, this area with its well-established database of patient clinical information and a GIS could be used in future to monitor the Tuberculosis Treatment Control Programme. 'The only means of ensuring the correct functioning of the programme is by means of regular, standardized system of recording and reporting which follows an internationally recognized format and definitions.'<sup>16</sup> Information collected from accurate monitoring and data collection in a model area could be used to extrapolate to other areas, thereby improving tuberculosis control.

The Glaxo-Wellcome International Tuberculosis Research Initiative is thanked for financial support, and Miss A. E. Coetzer for typing the manuscript.

## REFERENCES

1. World Health Organization first programme report, 1989-1990, and future plan 1991-1995. Geneva: WHO/TB/91.159.
2. The Department of National Health and Population Development Tuberculosis Control Programme 1992. *Epidemiological Comments* 1994; **21**: 2-8.
3. Western Cape Regional Services Council. Annual Report of the Department of Health Services, 1986.
4. Western Cape Regional Services Council. Annual Report of the Department of Health Services, 1993.
5. Department of National Health and Population Development, Republic of South Africa. Exploring some hypotheses on tuberculosis with a distinguished visitor from abroad. *Epidemiological Comments* 1993; **20**: 90-100.
6. Department of Health, Republic of South Africa. Fifth national HIV survey in women attending antenatal clinics of the public health services in South Africa: October/November 1994. *Epidemiological Comments* 1995; **22**(5): 90-100.
7. Shannon GW, Pyle GF, Bashshur RL. *The Geography of AIDS. Origins and Course of an Epidemic*. New York: Guilford Press, 1991.
8. Smallman-Raynor MR, Cliff AD. AIDS: literature, geographical origins and global patterns. *Prog Hum Geog* 1990; **14**: 157-213.
9. Löytönen M. The spatial diffusion of human immunodeficiency virus type 1 in Finland 1982-1997. *Ann Assoc Am Geogr* 1991; **81**: 127-151.
10. Gould P. Geographic dimensions of the AIDS epidemic. *Prog Geogr* 1989; **49**: 9.
11. Cliff AD, Haggett P. *Atlas of Disease Distributions. Analytical Approaches to Epidemiological Data*. Oxford: Basil Blackwell, 1988; 99-101.
12. Twigg L. Health based geographical information systems: their potential examined in the light of existing data sources. *Soc Sci Med* 1990; **30**: 143-155.
13. Schaaf HS, Beyers N, Gie RP, et al. Respiratory tuberculosis in childhood: the diagnostic value of clinical features and special investigation. *Pediatr Infect Dis J* 1995; **14**: 189-194.
14. Stoltz AP, Donald PR, Strebel PM, Talent JMT. Criteria for the notification of childhood tuberculosis in a high-incidence area of the Western Cape Province. *S Afr Med J* 1990; **77**: 385-386.
15. Berman S, Kibel MA, Fourie PB, Strebel PM. Childhood tuberculosis and tuberculous meningitis: high incidence rates in the Western Cape of South Africa. *Tuberc Lung Dis* 1992; **73**: 349-355.
16. Enarson DA. The International Union against Tuberculosis and Lung Disease model National Tuberculosis Programmes. *Tuberc Lung Dis* 1995; **76**: 95-99.

Accepted 24 Nov 1995.