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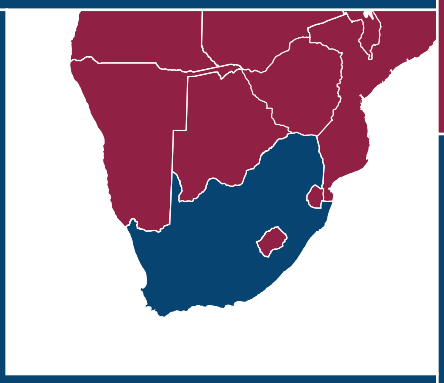
HPP GeoHealth MAPPING



Using Geospatial Analysis to Understand the Local HIV Epidemic in KwaZulu-Natal Province and eThekwini Municipality in South Africa

This publication was prepared by Ian Wanyeki, Benard Mitto, Lucy Nganga, Isabel Brodsky, Anita Datar, and Eurica Palmer of the Health Policy Project.

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HPP GeoHealth Mapping

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BACKGROUND

Donors and development partners are now emphasizing the importance of taking a geographic approach to funding requests. For example, the Global Fund's New Funding Model encouraged countries to support funding requests with mapping and spatial analysis as part of the evidence base for Concept Note submission (i.e., funding requests).

In support of the Global Fund's New Funding Model, the President's Emergency Plan for AIDS Relief (PEPFAR) worked in coordination with the United States Agency for International Development (USAID) through the Health Policy Project (HPP) to provide technical assistance to select high-impact countries. This work was intended to strengthen these countries' capacity to use mapping and spatial analysis to identify the location of epidemic 'hot spots' at subnational levels to more effectively target the HIV response. Technical assistance included the use of mapping and spatial analysis to strengthen the evidence base of Concept Note submissions.

Toward this end, HPP supported the South Africa National AIDS Council (SANAC) and provincial health authorities in KwaZulu-Natal (KZN) on a proposal to map estimated HIV prevalence using routinely collected facility-level data and other related data in KZN province and the metro municipality of eThekwini (formerly known as Durban). These efforts were intended to help inform the country's Concept Note submission, scheduled for June 2015. In addition to providing technical assistance in support of the analysis, HPP documented the methodology (Judice and Datar, 2014)—adapted from Dr. Frank Tanser's work in Mpumalanga Province—so that SANAC might include a request to replicate this analysis in multiple municipalities throughout the country as part of the funding application to the Global Fund.

This report documents the methodology, data sources, and statistical methods used to map and analyze routine data to examine HIV variation at subnational levels.

OBJECTIVES

The objective of this analysis is to use a geographic approach to examine spatial variations in HIV disease burden within KwaZulu-Natal Province, with a focus on eThekwini municipality. HIV burden is analyzed in three ways: 1) HIV positivity, 2) number of people living with HIV (PLHIV), and 3) antiretroviral therapy (ART) coverage gaps.

METHODOLOGY

Setting

The primary area of study was the province of KwaZulu-Natal and, specifically, eThekwini municipality.

Data Sources

Table 1: Indicators, Level of Aggregation and Data Source

Data	Key Indicators/Variables	Date	Level of Aggregation	Source
PMTCT	Annual HIV positivity among women*	2012–2014	Clinic	DHIS
ART	# Adults currently on ART*	December 2014	Clinic	DHIS
Administrative boundaries	Catchment areas	2012	Province, district, municipality	StatsSA
Gridded population	Population 15–49	2013	1 Km^2	LandScan
Master facility list	Latitude, longitude of health facilities	2014	Clinic	DHIS

* Indicators collected from the provincial monthly PMTCT and ART data collection form (Appendix A and B), which are then entered in the electronic DHIS database.

Catchment Areas

The boundary files from the Census 2012 were used. Estimates were aggregated to the district level, as this is where decision making occurs in KwaZulu-Natal; however, estimates can be aggregated up to any desired boundary level.

Inclusion and Exclusion Criteria

The following criteria (tables 2 and 3) were used to determine the final number of prevention of mother-to-child transmission (PMTCT) and ART clinics for analysis.

Table 2: Inclusion and Exclusion Criteria for PMTCT Clinics

	Criteria	KZN
Inclusions	PMTCT clinics that provided and reported on PMTCT services between 2012 and 2014	**840**
Exclusions	< 50 women tested for HIV in 2014	232
	Missing geo-coordinates	48
Total PMTCT clinics included for analysis		**560**

Table 3: Inclusion and Exclusion Criteria for ART Clinics

Criteria		KZN
Inclusions	ART clinics that provided and reported on ART services in 2014	**804**
Exclusions	Missing geo-coordinates	175
Total ART clinics included for analysis		**629**

Geocoding and Linking Programmatic Data to the Health Facilities

An attempt was made to obtain geocoded program data from the KwaZulu-Natal Department of Health; however, program data was provided without the geocodes of clinics. MEASURE Evaluation Strategic Information for South Africa (SIFSA) provided a geocoded master facility list (MFL) that contained a list of clinics in KwaZulu-Natal. Programmatic PMTCT and ART data were linked to this MFL and matched for facility name, district, and province. This enabled latitude and longitude coordinates of health facilities to be linked to program data. Facilities with missing geo-coordinates were excluded from the analysis.

560 (92%) of the 608 health facilities offering PMTCT services selected for analysis were geocoded, while 629 (78%) of the health facilities offering ART services were geocoded. The final dataset, after exclusions, resulted in 560 PMTCT sites and 629 ART sites.

Statistical Methods

HIV positivity

Annual trends in HIV positivity for the years 2012, 2013, and 2014 were graphed at both the provincial level and the eThekwini municipality level.

Annual HIV positivity at each PMTCT clinic was calculated as

*Antenatal client HIV 1st test HIV positive / Antenatal client HIV 1st test * 100*

Confidence intervals

The 95% confidence interval around this estimate was calculated as

*HIV positivity% ± 1.96 * std error*

HIV prevalence estimates

We calculated an estimation of HIV prevalence at each clinic (see below) through adjustment with HIV prevalence values from the 2012 national HIV population-based survey. In the 2012 National HIV Human Sciences Research Council (HSRC) survey, HIV prevalence among those ages 15–49 was 14.5 percent for men, 23.2 percent for women, and 18.8 percent overall. We created an adjustment factor (Gouws et al., 2008) by dividing overall prevalence by the female prevalence.

(HRSC 2012 overall HIV prevalence / HRSC 2012 female prevalence) = 18.8/23.2 = 0.81

We then used this adjustment factor to convert HIV positivity among pregnant women to an estimate of prevalence in the general population, as show below:

*% HIV-positive females from PMTCT * 0.81*

For example, if an HIV positivity of 13.8 percent was observed among pregnant women, this would result in an estimated prevalence of 11.2 percent in the general population.

*13.8 * 0.81 = 11.2%*

We used HIV prevalence for the 15–49 age group from the 2012 HRSC survey, as it is expected that women attending PMTCT clinics will be within this age range.

Interpolation

Interpolation can be defined as the estimation of attribute values at unsampled points from measurements made at surrounding sites (sampled points). In this example, the sample points are the PMTCT clinics and the attribute value is estimated HIV prevalence. Interpolation enables us to obtain estimates of HIV prevalence at a fine level of aggregation (1 km^2); with these estimates, we can then calculate estimates of PLHIV at the same resolution. This enables us to drill down or aggregate these estimates up to any desired level of aggregation and examine HIV burden.

Selection of an appropriate interpolation method and parameters

Multiple interpolation methods exist and different methods have been used to estimate HIV prevalence from point data (HIV Monitoring Consortium, 2014; Burgert, 2014). These methods vary in both complexity and prediction accuracy. Our aim was to select the most appropriate method that minimizes the prediction error and provides estimated errors of prediction. We formally evaluated several interpolation methods, along with various input parameters, prior to selecting an appropriate method for the KwaZulu-Natal dataset. Two validation processes were used, as described below.

- Partitioned holdback: This involves holding back 10 percent of data points and using the rest of the data to create an interpolated surface. The predicted estimates are compared with the actual values in the sample. We selected the model that resulted in the best prediction (the lowest root mean square error).
- Leave-one-out cross validation method: This involves holding back one data point and comparing this with the predicted estimate. This process is done iteratively for all data points. The predicted estimates are then compared with the actual values in the sample. We selected the model that resulted in the best prediction (the lowest root mean square error).

Universal Kriging was eventually selected to provide the best predicted HIV surface. Kriging utilizes a geostatistical technique in predicting values, and assumes that distance or direction between sample points reflects spatial correlation that can be used to explain variation in the surface.

Interpolation of HIV prevalence

All data was first projected to Cape_UTM_Zone_35S, which is a good projection for areas such as KwaZulu-Natal that are located within the UTM grid between 28°E to 30°E and has units in meters. Adjusted HIV prevalence rates for the PMTCT clinics in 2014 were then interpolated using Universal Kriging.

Calculation of people living with HIV

To obtain estimates of people living with HIV, we multiplied the projected 2013 surface of adult population ages 15–49 by the interpolated prevalence surfaces to obtain numbers of PLHIV per km^2. This information was then aggregated up to the desired level of aggregation.

ART coverage

To calculate estimated ART coverage gaps as of December 2014, we calculated the proportion of adults ages 15–49 on ART divided by the estimated number of PLHIV in the same age group. We multiplied this by 100 to obtain the percentage of patients on ART by district.

Hot spot analysis

Hot spot analysis can be used to identify the locations of statistically significant hot spots (locations where high values cluster together) and cold spots (locations where low values cluster together) in a dataset. For HIV burden analysis, hot spot analysis can be used to identify the locations of PMTCT clinics that have a cluster of HIV positivity values that are either statistically higher (hot spots) or lower (cold spots) than the average. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values. This information can be used for resource allocation. We used the spatial autocorrelation (Moran's I) statistic iteratively to determine if clustering existed, and then to determine the optimal distance scale for analysis. Using the optimal parameters, we used the Getis-Ord GI* static (Getis and Ord, 1992) to identify statistically significant hot and cold spots at the ≥ 90% confidence level.

LIMITATIONS, POTENTIAL SOURCES OF BIAS

HIV prevalence estimates

Using data from women attending ANC clinics to obtain estimates of HIV prevalence may be limited, as it only samples pregnant women attending health services and excludes women who are not pregnant or sexually active, as well as women who are pregnant but do not attend ANC. This data also excludes men (Burgert, 2014). The proportion of pregnant women attending ANC who were not tested for HIV likely impacts the ability to adequately estimate HIV prevalence in this methodology. Excluding PMTCT clinics with a low sample size (fewer than 50 women tested for HIV in 2014) may have limited the geographic representativeness of the study. The reporting rate of PMTCT service data in 2014 was also likely to impact the results.

Geographical representativeness

All PMTCT clinics in the district with geocodes were selected (excluding those with low sample size as outlined in table 2); in this way, issues around geographical representativeness were minimized.

Data quality

There may be data quality issues. These could occur at several stages in the process, from quality of HIV testing to transcription or transmission of results. We were unable to assess the quality of data, as this was beyond our scope of work.

Data of patients on ART

Programmatic data of people ages 15–49 currently on ART is likely to be overestimated. This could be a result of clinics lacking the ability to accurately keep track of patients on ART, or of patients who appear to be active on ART but who may have actually died or become lost to follow-up.

Assumptions on where patients get tested and where they receive treatment

This methodology assumes that patients receive HIV testing or ART services at the clinic closest to where they live; however, this may not necessary be true. For urban areas like eThekwini—in which many people work but do not reside—this assumption could be a limitation of the analysis.

TIMELINE AND STAFF TIME PER LOCATION OF INTEREST

Activity	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Proposal review and approval						
Identification and collection of data sources						
Data cleaning and geocoding (if necessary)						
Data analysis and mapping						
Dissemination and validation of analyses and maps						
Methodology write-up						

Staff time: 2.5 full-time equivalents (FTEs) for duration of analysis, per location of interest (i.e., municipality, district, etc.).

- 1 spatial epidemiologist
- ½ time spatial analyst
- ½ time epidemiologist
- ½ time manager/consultant

ILLUSTRATIVE EXAMPLES

(See Annex C for illustrative maps.)

RECOMMENDATIONS

Understanding geographic variation at the most granular level can help identify 'hot spots within hot spots' and target the HIV response, resulting in allocative efficiencies. The use of routinely available facility-level PMTCT data, which is both low-cost and timely, allows decisionmakers to monitor and manage key indicators, including HIV positivity, the estimated number of PLHIV, and ART coverage. Using maps to visualize these data allows decisionmakers to explore potential drivers of disease transmission, understand why some facilities experience a higher volume of HIV-positive patients than others, identify which sites are on track to meet targets, and identify where additional resources might be needed. The HPP team recommends replicating this analysis in multiple epidemic hot spots throughout South Africa so that SANAC and partners may identify where HIV disease burden is greatest and thereby effectively target new and existing resources.

ANNEX A. THE PROVINCIAL MONTHLY PMTCT DATA COLLECTION FORM

Provincial Data Management and GIS Services
Monthly PMTCT Data Collection Form

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

Health Facility: _____ Date: (dd/mm/yy) _____/_____/_____

ANTENATAL CARE CLINIC	Number	Comment
Antenatal client Pre - Test counselled for HIV		
Antenatal client HIV 1st test		
Antenatal client HIV 1st test positive		
Antenatal client HIV 1st test negative		

ANNEX B. THE PROVINCIAL MONTHLY ART DATA COLLECTION FORM

Provincial Data Management and GIS Services
Monthly ART Form

health
Department:
Health
PROVINCE OF KWAZULU-NATAL

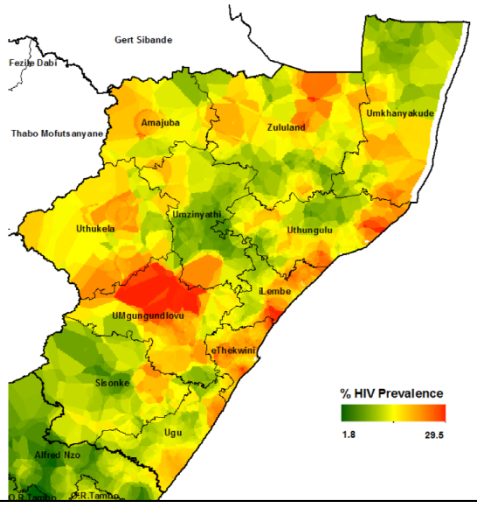
Health Facility: _____ Date: (dd/mm/yy) _____/_____/_____

Pre - ART	Number	Comment
Pre-art assessment first visit - Male		
Pre-art assessment first visit - Female		
Pre-art assessment first visit - Paediatrics		
HIV positive new patient screened for TB		
HIV positive new patient diagnosed with TB		
HIV positive client eligible for IPT		
HIV positive patients started on Co-trimoxazole prophylaxis		
TB/HIV co-infected client - total		
TB/HIV co-infected client initiated on CPT		
HIV positive client initiated on IPT		
Patients who develop active TB whilst taking INH Preventive Therapy (IPT)		
HIV Positive patients who completed 6 months of INH preventive therapy (IPT)		
Newly diagnosed HIV positive patient (excluding antenatal client) with Blood drawn for CD4		
Child under 1 year eligible for ART during this month		
Child 1- 5 years eligible for ART during this month		
HIV positive adult patient eligible for ART		
HIV positive child under 15 years eligible for ART		
HIV patients medically eligible for ART on waiting list		
ART	**Number**	**Comment**
Child under 1 year started on ART during this month - naïve		
Child 1 -5 years started on ART during this month - naïve		
Child under 15 years started on ART during this month - naive		
Adult started on ART during this month - naive		
Child <15 remaining on ART at the end of the month - Total		
Adult remaining on ART at the end of the month - Total		

ANNEX C. ILLUSTRATIVE MAPPING EXAMPLES

KwaZulu-Natal Analysis

Estimated HIV Prevalence

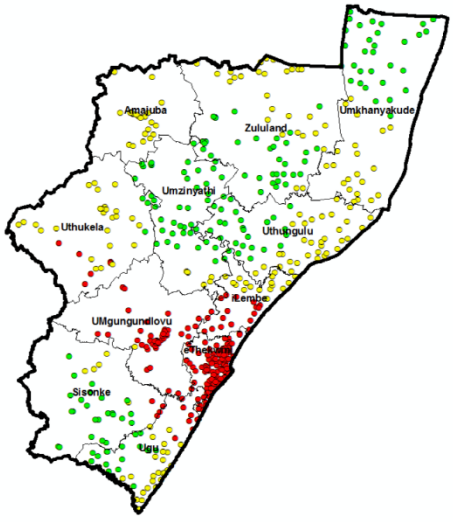


Using the same methodology of HIV prevalence estimation from HIV positivity at PMTCT sites and interpolation, HPP created a map of estimated HIV prevalence in KwaZulu-Natal.

The map shows major hotspot areas in uMgungundolvu, eThekwini, iLembe, uThungulu, and Zululand.

KwaZulu-Natal Analysis

HIV Positivity at Health Facilities



HPP conducted a hotspot analysis to identify the locations of statistically significant "hot" and "cold" spots in the province.

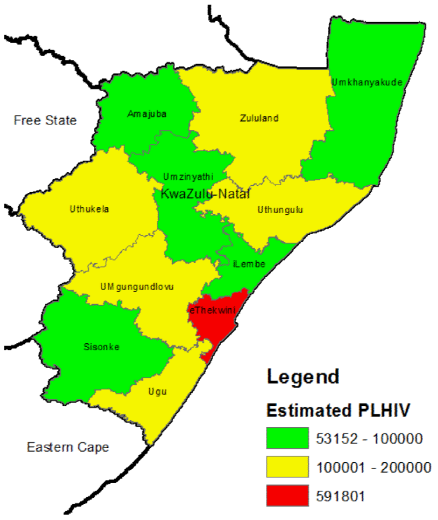
Hot spots have a high HIV positivity and surrounded by other facilities with high values. Cold spots have a low HIV positivity and are surrounded by other facilities with a low value.

For HIV burden analysis, this map can be used to identify the locations of PMTCT clinics that identify a significantly high number of HIV positive cases.

uMgungundlovu, eThekwini, and iLembe have almost all of the hot spots within the province. Note that these three districts also showed high HIV prevalence in the previous map.

KwaZulu-Natal Analysis

Estimated PLHIV by District



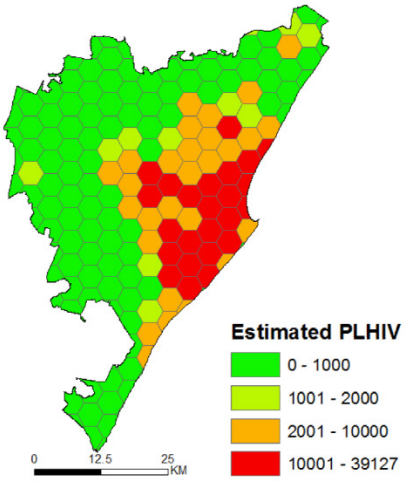
The second method HPP used to estimate disease burden was number of PLHIV by district. This is calculated by multiplying estimated HIV prevalence by the total population.

When examining disease burden through this measure, the only district that shows up as a "hot spot" is eThekwini. Note that uMgungundlovu is in yellow and iLembe is in green.

Examining PLHIV takes into account population density, so urban areas will have higher numbers than rural areas even if the prevalence is similar in both locations. This has important implications for resource allocation and access to services.

KwaZulu-Natal Analysis

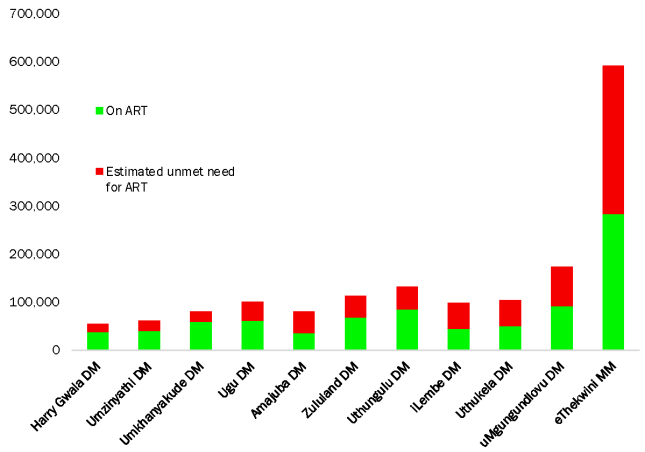
Estimated PLHIV in eThekwini



HPP drilled down to examine estimated PLHIV within eThekwini. 16 km^2 hexagons were created as artificial sub-district boundaries to further understand the spatial distribution of PLHIV living in a concentrated area with high disease burden.

KwaZulu-Natal Analysis

ART and Estimated Unmet Need by District, December 2014

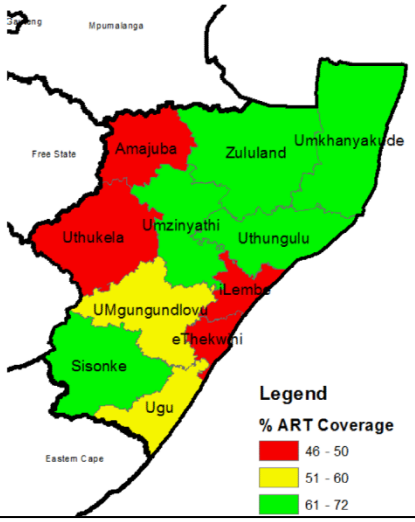


The number of people on ART can be compared to the total number of PLHIV in each district to calculate and estimated unmet need for ART. The limitation to this estimate is that it does not take into account South Africa's ART eligibility guidelines.

Understanding unmet need for ART can have implications on decisions with regards to resource allocation.

KwaZulu-Natal Analysis

Estimated ART Coverage



This same information can be portrayed in a map to further understand geographic variations in ART coverage. eThekwini and iLembe both have very low ART coverage, as do uThukela and Amajuba.

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