

# **Spatial Variations in Under-Five Mortality in South Africa**

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## **Abstract**

Child mortality remains a huge challenge in South Africa. Although there have been numerous national level child mortality studies, few studies have focused on child mortality and its determinants at sub-national levels. This paper uses data collected from the 2007 Community Survey to investigate district level variations in under-five mortality rate (U5MR) in South Africa. Exploratory Spatial Data Analysis techniques are used to examine the spatial structure and distribution of U5MR, and spatial regression models employed to explore the relationships between U5MR and a set of predictors. Models are compared and the benefits of spatial data analysis in targeted child mortality reduction are discussed.

**Keywords:** Mortality, Exploratory Spatial Data Analysis, Spatial Regression.

## **1. Introduction**

Child mortality (CM) is an important indicator of child health and a measure of a population's socio-economic wellbeing (Masuy-Stroobant and Gourbin, 1995). According to the United Nations Inter-agency Group for Child Mortality Estimation (UN-IGME), almost 7 million children worldwide died in 2011 before reaching their fifth birthday mostly from preventable causes (UN-IGME, 2012). CM is usually monitored using two indicators: infant mortality rate (IMR) and under-five mortality rate (U5MR). IMR refers to the probability of dying between birth and first year of life per 1,000 live births, while U5MR refers to the probability of dying between birth and the fifth year of life per 1,000 live births. The United Nations (UN) established the Millennium Development Goals (MDG), and the fourth of these goals (MDG-4) seeks to reduce the U5MR by two-thirds between 1990 and 2015 (UN, 2000).

In spite of substantial worldwide reduction in U5MR experienced between 1990 and 2011, statistics reveal that the under-five deaths in the sub-Saharan Africa region constituted about 49% of the global annual incidence of child deaths in 2011 (UN-IGME, 2012). The decline in U5MR has also not been uniform within and between countries, and there are fears that the MDG-4 target may not be met in some countries (Rutstein, 2000; UN-IGME, 2012). Identifying geographical differences in U5MR across regions and its underlying correlates are important in channeling often limited resources for the effective reduction of under-five mortality (U5M).

There are major challenges involved in monitoring progress towards MDG-4 in developing countries such as South Africa (SA). Nannan, Dorrington, Laubscher, Zinyakatira, Prinsloo, Darikwa, Matzopoulos and Bradshaw (2012) state there is uncertainty around the true estimates of child mortality in SA owing to the historically fragmented data collection system, the incomplete vital registration system, the absence of a reliable household survey that collects comprehensive birth history and the bias in existing mortality estimates that do not take into account the high HIV prevalence in the country. The relative rarity of child deaths often result in unstable and unreliable U5MR estimates especially for small geographical areas. Nonetheless, statistics from [www.childinfo.org](http://www.childinfo.org), the UN's website reporting progress towards the MDG goals indicates that the U5MR in SA was 60 deaths per 1,000 live births in 1990

and 57 deaths per 1,000 live births in 2010. The estimate for U5MR in 2010 is far from the 20 deaths per 1,000 that is targeted for 2015 and it is feared that SA might not achieve the MDG target for U5MR reduction come 2015 (UN-IGME, 2012).

Previous analyses of CM variations based on survey data have shown that CM rates in SA vary substantially by province and urban-rural areas, and have shown the relationship between CM and biological factors as well as socio-economic factors such as education, employment and household environment (National Department of Health and Measure DHS, 2004). Sartorius, Sartorius, Chirwa and Fonn (2011) and Sartorius and Sartorius (2013) conducted national level studies for SA and explored the influence of covariates on mortality ratios within the spatial modeling context. Rajaratnam, Tran, Lopez and Murray (2010) recently developed a “low-cost” method of estimating U5MR from summary birth history data collected from surveys. The method offers ‘significant potential’ for deriving small-area U5MR (Jankowska, Benza and Weeks, 2013), and estimates of U5MR derived using this method can be mapped and modeled within the spatial analysis context. The results can then be used in the allocation of resources and interventions for more meaningful CM reduction.

This paper explores the use of a “low-cost” method of deriving U5MR at small area levels and utilizes spatial statistical techniques to understand the determinants of U5MR in SA using data from the 2007 Community Survey (CS) conducted by Statistics South Africa (Stats SA).

## **2. Study Area**

SA is the southernmost country on the African continent. The country has a population of 51.8 million according to the most recent census (Stats SA, 2012) and is administratively divided into 9 provinces which are further divided into 52 districts. Statistics from the recent census indicate that SA has a young population with about 29.6% aged between 0-14 years, and a further 28.9% aged between 15-34 years (Stats SA, 2012). SA had a gross domestic product of \$408.3 billion in 2011 and is considered the economic powerhouse of the African continent. In 2011, 8.8% of SA’s households did not have access to piped water, while about half of SA households did not have flush toilet (Stats SA, 2012).

## **3. Data and Methods**

The study utilizes data from the CS conducted by Stats SA in 2007. The CS is a nationally representative sample survey conducted to provide reliable estimates of key demography and socio-economic indicators at the district levels (Stats SA, 2008). The district level was chosen as the unit of analysis for this paper, and supplementary information, namely HIV prevalence for each district was obtained from the District Health Barometer for 2007/2008 ([www.hst.org.za](http://www.hst.org.za)).

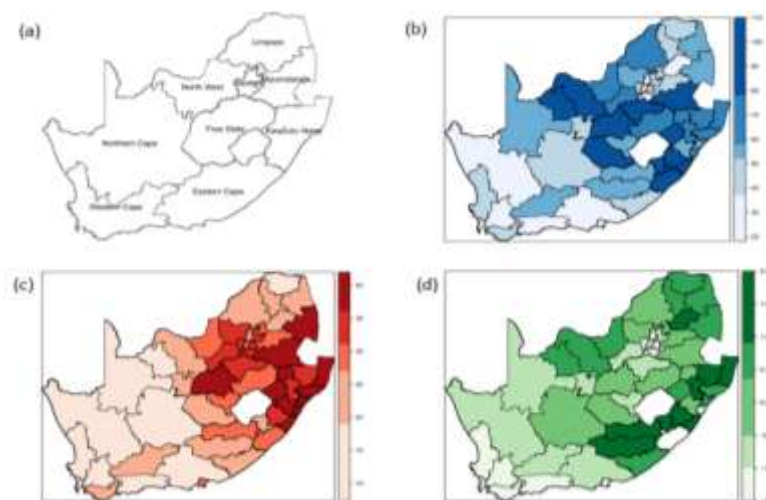
**Dependent Variable:** The CS did not collect detailed birth history. As such, the questions on children ever born (CEB) and children who died (CD) asked of every child bearing aged woman (ages 15-49) formed the basis for calculating U5MR using the maternal age cohort-derived (MAC) method described in Rajaratnam *et al.* (2010). Preliminary analysis revealed observations with inconsistent CEB and CS values which were deleted before estimates of U5MR was obtained for each of the 52 districts in SA.

**Explanatory Variables:** The selection of the variables included in this paper was guided by previous research on CM (Mosley and Chen 1984), and by the MDG country report which advocates ‘improving the socio-economic factors that impact on the health status of children’ (Stats SA, 2010). Principal component analysis (PCA) was used to derive a deprivation index (DI). The variables used in the PCA relate to the proportion of a district’s population: (1) living in households without a radio; (2) living in households without a Television; (3) living in households without a refrigerator; (4) living in households without piped water inside the yard ; (5) living in households not using “clean energy” (electricity, solar or gas) for either lighting, cooking or heating ; (6) living in households without flush toilet ; (7) living in households where refuse is not removed by local authority or private company; (8) living in female headed households; (9) receiving a social grant and (10) adults 18-65 years with no secondary schooling. The first principal component with 78% variance explained was chosen as representing the DI. HIV prevalence among antenatal clients for each area was also included in the study considering the reality that the MAC derived mortality estimates are biased downwards in populations heavily affected by HIV (Rajaratnam *et al.*, 2010).

**Analyses:** Spatial Autocorrelation (SAC) or the tendency of U5MR to cluster in space is assessed using the Exploratory Spatial Data Analysis (ESDA) techniques of Global and Local indicators of Spatial Autocorrelation (SAC): namely the Moran’s I and LISA. Moran’s I provides an indication of the overall strength of SAC, while LISA helps identify significant "hot spots" (Anselin, 1988). Ordinary least squares (OLS) regression is used to model the relationship between U5MR and the explanatory variables. Spatial regression techniques that account for SAC and help obtain more reliable estimates are also employed. Specifically, spatial lag (SL) and the spatial error (SE) models are fitted to the U5MR data.

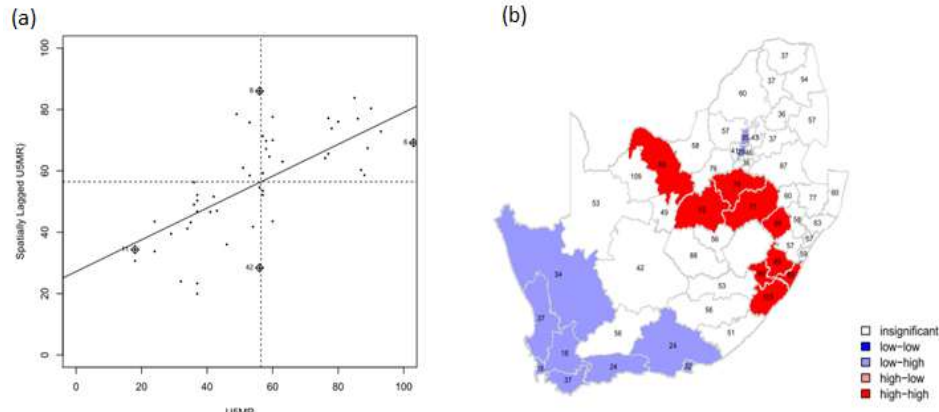
#### 4. Results

All variables described above were calculated for each of the 52 districts. Preliminary analyses were performed using the statistical package SAS® software and spatial analyses and mapping implemented in the spdep R package. *Figure 1* shows the study area and the quintile maps of the variables considered. As can be seen in *Figure 1b*, U5MR appear to cluster in parts of the Eastern Cape, Free State, North West and Mpumalanga provinces. A similar pattern of clustering can be observed for HIV prevalence and DI (*Figures 1c and 1d*).



**Figure 1:** (a) Map of South Africa showing the 9 provinces and Quintile Maps of (b) U5MR (c) DI and (d) HIV Prevalence

The queen's first-order contiguity criteria for defining spatial weights matrices is commonly used in spatial modeling for defining the spatial connectedness of areas and this specification was also selected for this study. The result of Moran's I calculation show statistically significance SAC in U5MR (Moran's I = 0.5185,  $p < 0.0001$ ). *Figure 2b* reveals that the richer provinces of Gauteng and Western Cape are significant "cold spots". These are the areas shaded in blue and are basically areas with low U5MR surrounded by areas of equally low mortality. Areas shaded in red in *Figure 2b* are significant mortality "hot spots" or areas with high U5MR surrounded by other areas of high U5MR. In summary, the results reveal clustering of U5MR at the district level and it is important that such clustering be taken into account in statistical modeling of the data.



**Figure 2:** (a) Moran's scatterplot of U5MR and (b) LISA cluster map of U5MR

OLS regression results in Table 1 show that both DI and HIV prevalence are significant predictors of U5MR with both variables explaining about 38% of the variance in U5MR. Moran's I for the OLS residual reveal significant SAC in the OLS residual (Moran's I = 0.34;  $p < 0.0001$ ). This is a clear violation the OLS model assumptions and to account for the SAC, the SE and SL models were fitted. The SE model incorporates SAC through the error term and captures the effect of omitted variables, while the SL model includes a spatially lagged dependent variable and is often interpreted as the lag effect (Anselin, 1988). Both DI and HIV prevalence are found to be significant predictors in both the SE and SL models. Results of diagnostics test (not shown) suggest the use of the SE model which is also the model with the lowest AIC value. Residuals for both the SE and SL models were normally distributed.

**Table 1:** Results for OLS, SE and SL models

	OLS Model	SE Model	SL Model
<b>Intercept</b>	34.5613	34.65727	18.6353
<b>DI</b>	10.6298***	10.93196***	7.24528**
<b>HIV Prevalence</b>	0.7984**	0.78862**	0.47478*
<b>Adj Rsq</b>	0.3784		
<b>AIC</b>	450.6395	441.56	444.23
<b>Moran's I</b>	0.34***		

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

## 5. Discussion and Conclusions

The analysis explored the use of a “low-cost” method for obtaining U5MR for SA districts, and examined the spatial distribution of the derived estimates and its association with DI and HIV prevalence. Results from Moran’s I which measures SAC show significant clustering of U5MR at the district level, while LISA cluster map reveal U5MR “hot spots” in SAs’ “rich” provinces of Gauteng and Western Cape. Results from spatial regression models are an improvement on the OLS model and reveal both DI and HIV prevalence as significant predictors of U5MR. The chosen model (SE model) suggests that additional variables could be included to obtain a better model fit. Mortality clusters could be studied more closely at sub-district levels using the spatial analysis and targeted interventions devised for more effective child mortality reduction.

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