Spatial trends and factors affecting tuberculosis in South Africa (2004-2014):

Evidence from the vital registration systems

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Mini-thesis presented in partial fulfilment of the requirements for the degree Master of Philosophy in Urban and Regional Science in the Faculty of Arts and Social Sciences at Stellenbosch University

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March 2017

AUTHOR'S DECLARATION

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ABSTRACT

Background: Worldwide, South Africa is one of the countries which has consistently witnessed no significant reduction in the number of TB deaths. TB in South Africa remains the leading cause of death responsible for almost half of deaths due to communicable disease yearly. Most studies have looked at incidence and prevalence of TB and very few studies have looked at TB mortality at local municipality level in South Africa.

Objective: This study examined patterns of TB deaths in South Africa for the period 2004 to 2014 and reviewed possible reasons for such patterns

Methods: Data analysis was performed in two levels namely: descriptive analysis and multivariate analysis. Multivariate analysis was subdivided into binary logistic regression with TB death as the outcome variable. The model predicts whether one dies from TB or other causes based on selected demographic and socio economic variables. Spatial statistics (Getis-Ord Gi* and Global Moran's statistics) identified hotspots.

Results: In multivariate analysis, age, occupation group, smoking status, were all significant predictors of TB deaths while marital status was found to be insignificant. Spatial patterns indicate clustering of high values. The results also show that positive values were nearby each other and in the North West Province, City of Matlosana, Naledi and Ventersdorp municipalities had H-H. EThekwini metro recorded significant reduction in the number of TB deaths and desktop reviews show that proximity of clinics to households, TB programs by USAID and implementation of DOTS strategy was responsible for this reduction. Municipalities in the North West province had highest number of standardized TB death rates compared to other municipalities.

Conclusion: These results show that there is no single solution in addressing TB deaths but programs aimed at reducing TB deaths should be local municipality based as challenges in delivering TB control programs differ from one municipality to another.

Keywords and phrases: tuberculosis, spatial distribution, hotspot analysis, communicable diseases.

OPSOMMING

Agtergrond: Wêreldwyd, Suid-Afrika is een van die lande wat konsekwent geen noemenswaardige afname in die aantal TB sterftes het getuig. TB in Suid-Afrika bly die grootste oorsaak van dood verantwoordelik vir byna die helfte van die sterftes as gevolg van aansteeklike siektes jaarliks. Die meeste studies het gekyk na die voorkoms en die voorkoms van TB en baie min studies het gekyk na TB sterftesyfer op plaaslike munisipaliteit vlak in Suid-Afrika.

Objektief: Hierdie studie ondersoek patrone van TB sterftes in Suid-Afrika vir die tydperk van 2004 tot 2014 en hersien moontlike redes vir sodanige patrone

Metodes: Data-ontleding is uitgevoer in twee vlakke, naamlik: beskrywende analise en meerveranderlike analise. Meerveranderlike analise is onderverdeel in binêre logistieke regressie met TB dood as die uitkoms veranderlike. Die model voorspel of 'n mens sterf aan TB of ander oorsake wat gebaseer is op geselekteerde demografiese en sosio-ekonomiese veranderlikes. Ruimtelike statistieke (Getis-Ord Gi * en Global Moran se statistiek) geïdentifiseer hotspots.

Resultate: In meerveranderlike analise, ouderdom, beroep groep, rook status, was almal beduidende voorspellers van TB dood terwyl huwelikstatus gevind onbelangrik te wees. Ruimtelike patrone dui groepering van hoë waardes. Die resultate toon ook dat positiewe waardes was nabygeleë mekaar en in die Noordwes-provinsie, Stadsraad van Matlosana, Naledi en Ventersdorp munisipaliteite het H-H. EThekwini metro aangeteken beduidende afname in die aantal TB sterftes en lessenaar resensies wys dat nabyheid van klinieke aan huishoudings, TB programme deur USAID en implementering van DOTS-strategie was verantwoordelik vir hierdie afname. Munisipaliteite in die Noordwes-provinsie het die hoogste aantal gestandaardiseerde TB sterftesyfers in vergelyking met ander munisipaliteite.

Gevolgtrekking: Hierdie resultate dui daarop dat daar geen enkele oplossing in die aanspreek van TB dood, maar wat gemik is op die vermindering van TB sterftes moet plaaslike munisipaliteit gebaseer as uitdagings in die lewering van TB programme verskil van munisipaliteit om 'n ander te wees.

Trefwoorde en frases: tuberkulose, ruimtelike verspreiding, hotspot ontleding, oordraagbare siektes.

ACKNOWLEDGEMENTS

I would like to thank God for granting me the wisdom and knowledge which made it possible for me to write up this work. Secondly I would like to thank Statistics South Africa for the opportunity it afforded me to further my studies.

I would also like to extend my appreciation to Ms Amanda van Eeden for supervising this work and also my colleagues from Statistics South Africa who provided technical and emotional support. Lastly I would like to thank my fiancée Ms Ayanda Ntshangase for emotional and spiritual support, she has been the pillar of my strength.

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ABBREVIATIONS AND ACRONYMS

ARV…………………………………………………………………………………Antiretrovirals
ARASA……………………………………………....AIDS and Rights Alliance for Southern Africa
DoH…………………………………………………….………………....Department of Health
DHA…………………………………………………….…………Department of Home Affairs
DOTS…………………………………………………....Directly Observed Treatment Strategy
ETA……………………………………………………………………Tuberculosis Adherence
HIV…………………………………………………………………......Human Immune Virus
MDG……………………………………………………………...Millennium Development Goals
NDP…………………………………………………………………....National Development Plan
NGO…………………………………………………….……Non-Government Organization
Stats SA……………………………………………………..………………Statistics South Africa
WHO…………………………………………………………...…World Health Organisation
TB…………………………………………………………..………………………Tuberculosis
TBDR…………………………………………………………..Age Standardized TB death rate
SDG……………………………………………………………….Sustainable Development Goals

SECTION 1: Introduction

Tuberculosis, commonly known as TB, is a bacterial infection that can spread through the lymph nodes and bloodstream to any organ in your body. It is most often found in the lungs and is an airborne disease which gets spread through inhaling tiny droplets from the coughs or sneezes of an infected person. Most people who are exposed to TB never develop symptoms because the bacteria can live in an inactive form in the body. Most importantly, it is a treatable and a preventable disease.

In South Africa, from 1996 to 2014 statistics on mortality and causes of death indicate that on average between 90 000 and 100 000 people die of certain infectious and parasitic diseases each year (Stats SA, 2014). In each year, almost half of these deaths are attributed to tuberculosis. Reports on mortality and causes of death in South Africa by Statistics South Africa indicate that tuberculosis has remained the number one leading cause of death in the country since 1994. It is useful to rank the underlying causes of death to show the relative burden of cause-specific mortality.

For most of the developing countries in the Sub-Sahara region, reducing deaths due to infectious diseases is a key developmental goal since as it goes a long way in increasing life expectancy (Masiye et al., 2008). Infectious diseases are diseases caused by pathogenic microorganisms, such as bacteria, viruses, parasites or fungi and can be spread, directly or indirectly, from one person to another.

According to World Health Organization, funding of TB research has increased globally as governments intensify fight against TB (Raviglione, 2006). Health is one of the corner stones of the 2030 National Development Plan (NDP) as well as the 2030 Sustainable Development Goals (SDGs). The NDP aims to increase life expectancy at birth from 57 in 2014 to 72 years in 2030 while the SDGs seek to reduce the number of communicable diseases to zero. Due to TB's high contribution to over all deaths from infectious diseases, the reduction of these deaths will play a significant role in the overall reduction of deaths. Deaths due to TB decreased from 50 872 in 2001 to 37 878 deaths in 2014. In 2016, the government of South Africa has invested R740 million to strengthen TB programmes to encourage early detection and treatment (Treasury 2016).

For a country to achieve positive health outcomes, there are a combination of factors that come to play, for instance food consumption, health seeking behaviours, status of health care centres and also health care practices (Harling et all, 2008). The study indicates that an increased risk of tuberculosis is commonly linked with increased poverty. The study by (Harling et all, 2008) also found that the average number of years of schooling and the mean earnings in an area plays a significant role, with those with higher education outcomes as well as those with higher earnings per area having better health seeking behaviours. Health seeking behaviour is defined as a state in which a person in stable health is actively seeking ways to alter his or her personal habits or environment in order to move toward a higher level of health.

The level of public health services provided by the state and the distribution of wealth in an area plays a significant role in the fight against TB. Malnutrition is one of the underlying social determinants of TB which means that malnutrition increases vulnerability to TB (Lönnroth, 2009). Some of the precautionary interventions may target then factors directly or via their underlying social determinants. Identifying groups at risk helps map strategies for early detection of people in need of TB treatment. South Africa remains one of the countries fighting against widespread poverty and also food insecurity and these have a substantial impact on health (World Bank, 2012). For both industrialised and developing countries, Tuberculosis (TB) is usually associated with poverty and various socio-economic factors.

The challenges of TB in South Africa remains great amidst many different strategies employed by government, NGO’s and other institutions however TB deaths remain amongst the highest in the world. This study looks at the municipalities which have recorded successes in the fight against TB and which programs were implemented in those municipalities. This will assist other municipalities, however the main question poised in the study is whether programs should be local municipality specific or should government rollout the same program for all municipalities.

SECTION 2. Study background

2.1 The Statement of the Problem

Tuberculosis contributes significantly to the burden of disease faced by South Africans. This is particularly true for poor and vulnerable groups. It is for this reason that the government has decided to put a huge effort into addressing TB in an integrated manner. This is predominantly true for underprivileged and vulnerable groups.

Worldwide, there currently are 22 high burden countries (HBCs) known and these are ranked according to their TB burden. These high burden countries account for more than 81% of all estimated cases worldwide. South Africa (4,6%) is ranked second in the top five countries in the world with the largest number of TB incident cases in 2015 with Indonesia ranked the first with 10,3% TB incident rate (WHO, 2015b). Tuberculosis in South Africa remains one of the biggest challenges in terms of health of the society (Churchyard et al., 2014). Even though in the 20 year period (1994 – 2014) South Africa has registered improvements in the health sector and trends in deaths due to TB indicate that it is declining, it still remains very high compared to other developing countries. TB accounts for more than 50% of all deaths due to communicable diseases in South Africa and about 10% of all deaths (Stats SA, 2014). A study by (Dye. et al, 2009) indicated that the rate of TB deaths was declining more quickly in countries that had a higher human development index, lower child mortality and access to improved sanitation. The study also found that TB incidence rate fell more swiftly in countries with better health-care expenditure.

In South Africa since 1994, TB remains the leading cause of death for all the municipalities except for the City of Cape Town. Some municipalities have recorded significant improvements in addressing the problem while others have not.

The study aims to investigate and analyse data to determine whether interventions aimed at reducing deaths due to TB such as early detection and treatment, intensification of case-finding for smear-positive tuberculosis, preventive therapy for adults as well as childhood immunization are municipality oriented (Borgdorff et al, 2002). In doing so the study will focus on municipalities with a successful reduction rate in TB cases and report on their interventions as well as a look at municipalities that were less successful.

Historical studies have established links between TB and public health interventions which includes housing policies, education, investments in infrastructures developments, and sanitation, leading to behavioural changes had an impact on the falling rates of mortality from TB (McFarlane, 1989; Hardy, 1993; Delfino et al., 2005)

Goal 3 of the Sustainable Development goals strongly target ending deaths due to TB by 2030, the END TB Strategy developed by WHO (Lonroth and Ravilgione, 2016) targets death rates and TB incidence to be reduced by 90% and 80 % respectively by 2030. Chapter 10 of the South African National Development Plan 2030 targets increasing life expectancy to at least 72 years which includes progressively improving TB prevention and cure.

TB and delivering TB programs is mainly challenged by poverty and the high rates of unemployment and compounded by very limited access to or delivery of basic municipal services such as electricity, water and sanitation as well as a absence of quality social services such as education, health and ambulances and transport services in terms of roads and reliable public transport.

2.2 Research Questions

1. What is the spatial distribution of TB deaths between the different municipalities?
2. Identify which interventions were implemented in municipalities with success in the reduction of TB deaths?
3. Which TB programs render better health outcomes for people: comparison between municipalities between 2004 - 2014?
4. Were similar or different interventions implemented in municipalities that recorded higher TB deaths?
5. Is there any observable spatial pattern of TB specific death rates?

2.3 Research Objectives

1. To examine differences in spatial patterns and determinants of TB in South Africa by municipality. Comparing mortality rates between different geographical areas is imperative in order to evaluate community health status. Mortality rates in this study will be calculated using cause-specific death rates which will be age standardized. (refer to methods section for more details).

2. The study will look at the municipalities which still have very high TB deaths with a view to establish which interventions have been implemented and how efficient are those interventions. The study will further look at municipalities spatially to determine the geographic distribution of municipalities which have recorded higher TB deaths as well as those which recorded improvements in the fight against TB. This will be done to establish which lessons can be learnt from both cases in order to improve and better the efforts against TB.
3. Identify interventions that were implemented in the municipalities with a successful reduction in their TB deaths over the past 10 years (2004 – 2014), it will profile municipalities which have recorded successes in the fight against TB with a view to establish which of the interventions mentioned were put in place.
4. Lastly the study aims to establish whether there is any pattern of clustering of TB deaths.

2.4 Hypothesis

Based on literature reviewed the hypotheses to be tested in this study are as follows:

1. Tuberculosis mortality is higher in municipalities with poor infrastructure than in municipalities with good infrastructure.

2. Municipalities with higher TB death rates cluster together

3. Municipalities clustered together will exhibit similar values of TB specific death rates

4. Approaches/strategies to the fight against TB should be different depending on municipality dynamics (i.e. budget, topology, population size).

Null Hypothesis: Factors affecting TB are the same for all municipalities meaning TB death rates are the same irrespective of the municipality of residence. There are no differences in terms of factors or correlates of TB death rates. Spatially, there is no difference in TB death rates between local municipalities.

SECTION 3: Literature review and background information

Tuberculosis is the world's leading curable cause of infectious disease mortality, with a disproportionate burden of disease falling on low- and middle-income countries and caused by bacteria called mycobacterium which mostly affect the lungs. TB is curable and preventable (Wilson, 2005). TB is airborne and is mostly spread from person to person. When someone with lung TB coughs, sneezes or spits, they propel the TB germs into the air. It only takes a person to inhale only a few of these TB germs to develop an infection. According to (WHO, 2014) about one-third of the world's population has latent TB. Latent TB means someone who has been infected by the TB bacteria but they are not yet ill from it though cannot transmit the disease. Someone with a compromised immune systems, such especially those living with HIV, malnutrition or diabetes, or people who smoke, are at a much higher risk of getting ill from TB (Stevenson et al., 2007). Delays in seeking health care often results in the spread of the bacteria to others. People ill with TB can infect up to 10−15 other people through close contact over the course of a year (Hargreaves et al., 2011). If untreated then up to a third of people ill with TB die.

Globally, tuberculosis is among the top ten leading causes of death and it greatly affects low-income countries particularly. In 2014, TB was the leading cause of death in the world responsible for over 1,5 million deaths that comprised of 890 thousand males, 480 thousand females and 140 thousand children (WHO, 2015). The MDG target called for a 50% reduction of TB in 2015 relative to the baseline levels in 1990. This target in terms of TB prevalence, incidence and mortality were met by nine of the 22 high burden TB countries, namely, Uganda, Brazil, India, China, Combodia, Myanmar, the Phillipines and Viet Nam (WHO, 2015). The 22 high burden countries which South Africa is part of represented more than 80% of the TB incidence in 2014 (WHO, 2015).

In 2014, Africa accounted for 28% of the 9,6 million new tuberculosis cases. Africa comprised the most severe burden relative to population with 281 cases per 100 000 population, more than two times the global average of 133 cases per 100 000 population (WHO, 2015). Out of the 9,6 million cases reported in 2014; 1,5 million died and over 95% of deaths due to tuberculosis occurred in low and middle income countries. In 2014, the top ten countries with high estimated tuberculosis incidence rates featured Lesotho as the number one country, followed by South Africa and Swaziland (WHO, 2015).

In the list of countries with the burden of disease problem, South Africa ranked as the third highest country in the world, this is after India and China with South Africa having an estimated prevalence of roughly 400 000 cases of TB in 2013, which represents an increase of 400% since the dawn of democracy (WHO, 2014). In 2011, South Africa accounted for about a quarter of the global burden of TB/HIV co-infection (Chihota, 2012). Addressing the missed TB cases was one of the priorities mentioned by WHO, based on their estimation that about three million TB cases were not notified in 2012 (WHO, 2012). Approximately 75% of the missed cases were in 12 countries, including India, South Africa, Mozambique and Nigeria.

In spite of effective treatment regimes, TB remains a worldwide health concern with 22 high burden countries bearing the brunt of it (Kipruto et al., 2015). Kenya is amongst these 22 countries estimated to account for over 80% of the global burden of TB (WHO, 2015). The TB disease is distributed disproportionately in Kenya with some regions bearing the most of TB notifications. However, Kipruto et al. (2015) note that research on the spatial distribution of the infectious disease has been limited in Kenya.

The researchers pinpoint that for effective treatment of TB high risk areas have to be known as well as the risk factors in those areas. In their study, Kipruto et al. (2015) used anonymized data from the Kenya National TB program for the years 2012 to 2014. The study identified the hotspots for TB in Kenya which were Nairobi, Mombasa, Isioli, Homa bay, Kisumi and Siaya). These areas had high populations, high TB notification rates and high likelihood of detecting smear positive TB cases that is TB cases that are highly infectious and easily transmittable from one person to another. The study further documented that these regions have been high risk areas throughout the observation period which is indicative of the failure to address the risk factors for TB in the regions.

The situation is further worsened by that most of the identified regions are high HIV prevalent areas, which brings to the fore issues around dealing with HIV/TB cormobidity. Nigeria also on of the 22 high TB countries, has a poor health care system with inadequate health care facilities, high numbers of out-patients, high mortality and poor knowledge of both prevalence and spatial distribution of TB (Ibrahim et al., 2015). Ibrahim and colleagues (2015) used TB cases for the Kebbi state, North West Nigeria from the Nigeria National Control Program 2008–2011. Most of the hotspot areas in the Kebbi state were urbanized areas. However, this finding was explained by lack of geo-coded location for some areas and that the rural dwellers in Kebbi state’s limited access to hospitals may serve as a barrier to TB case detection in the rural areas of the state.

In 2011, a total of 1,8 million people lived in informal settlements in South Africa, the highest proportion of which lived in Western Cape, followed by Gauteng and Free State, respectively (Classens et al., 2014). These informal settlements are characterised by overcrowding, poverty, unsanitary living conditions, high alcohol consumption and high unemployment rate, resulting in them being ripe for TB. Most informal settlements are characterised by shacks that are very small, close to each other, poorly ventilated, have no running water, sanitation and electricity. Classens et al. (2014) report that South Africa does not have a TB program that has been specifically standardized for informal settlement dwellers.

At the global level estimates from the Global Burden of Disease Study 2013 indicate that the number of deaths was 47,5 million in 1990, increasing by 15.6% to 54,6 million in 2013 (Global Burden of Disease [GBD] 2013 Mortality and Causes of Death Collaborators, 2015). In terms of the actual disease burden the proportion of deaths due to communicable causes decreased from 34,0% in 1990 to 21,5% in 2010 while non-communicable diseases increased from 56,9% in 1990 to 69,7% in 2013 (GBD 2013 Mortality and Causes of Death Collaborators, 2015). This global context indicating declining deaths due to communicable and increases in non-communicable deaths is comparable to the South African context. Stats SA (2015b) reports that based on the South African civil registration data a decrease was observed in the proportion of deaths attributed to communicable diseases from 48,2% in 2005 to 36,8% in 2014. Non-communicable diseases comprised 43,0% of the disease burden in 2005, after which they increased to 52,7% in 2014. Although non-communicable diseases are on the rise in South Africa, the impact of communicable diseases such as TB, influenza and pneumonia and intestinal infectious diseases also continue South Africa's health profile. This is seen in that these diseases have continued to be on the top ten leading causes of death in South Africa, for over a decade with TB enduring as the number one killer (Stats SA, 2015b). While the MDGs called for a TB incidence rate of less than 253 per 100 000 population by 2015, in South Africa the incidence rate increased from 253 per 100 000 population in 2004 to 860 per 100 000 population in 2013 (Stats SA, 2015a). More so the prevalence rate of the TB epidemic increased by 75% over the years 1990 to 2010.

Tuberculosis deaths have increased drastically over the past two decades in Africa due to HIV/AIDS epidemic, and the prevalence of multidrug resistant TB worsens the situation. In poor or underdeveloped and developing countries deterioration of the health infrastructure is one of the forces driving high death rates due to tuberculosis (WHO, 2001). TB has been called, 'a disease of the past' mainly because experts assumed that since it can be treated if the DOTS strategy was properly adopted then the disease can be eliminated. However, this has not been case especially in developing countries where the disease has continued to kill thousands of people and has re-emerged with drug resistant strains of TB as well as an opportunistic disease fuelled by high HIV prevalence. According to Corbett et al. (2006) although Africa accounted for 11% of the global population in 2003, it comprised 31% of the 1,7 million annual TB deaths that were estimated. Over the past two decades treatment of TB in most countries has been based on the Direct Observation Therapy, Short-course (DOTS) recommended by WHO. DOTS was introduced to improve success rate in treating TB through increasing timely diagnosis of patients and adherence to treatment.

The directly observed treatment (DOT) means that the patient is observed by the treatment supporter as he or she swallows the TB tablets (Department of Health [DoH], 2014). The treatment supporter trained to administer DOT may be a health care worker, community health care worker, family member or anyone the patient chooses. Patients living close to the clinic may take their medication by the clinic if it is convenient to them (DoH, 2014). This close monitoring strategy was recommended as a way of optimising treatment success and reducing re-infection (DoH, 2014). The DOT treatment facilitates patient control and community participation in treatment. In 2006, the TB treatment success rate was in South Africa was approximately 74%. This was compared to 90% success rate within six months of starting the antiretroviral (ART) programme which focuses on self-supervision and does not require patient control (Atkins et al., 2012). Against this background the DOT treatment has been contested such that, in 2005, the Tuberculosis Adherence (ETA) programme was developed and adopted in Cape Town. The DOT international strategy was contested in Western Cape due to failure to implement it at the local level. It is argued that it led to long patient waiting time, overburdened healthcare systems, was not convenient for patients who had to go to the clinic or hospital to get their medication every day and no home visits were done. The ETA programme only calls for direct observation at the clinic for the first two weeks, after which the patients take medication on their own, with the treatment supporter only involved in the pill count. Patients eligible for self-supervision are given a one month supply of TB medication. In addition home visits are done to assess the living conditions of patients and family members are also screened for TB and vaccinated. Boon et al. (2007) conducted a TB prevalence survey amongst adults aged 15 years and above in two communities with similar socioeconomic characteristics Ravensmead and Uitsig in Cape Town. The results showed that 9,7% of the 3 483 adults survey had previously been treated for TB. However, higher prevalence of TB was found amongst those that had been previously treated as compared to new infections (Boon et al., 2007). The researchers illuminate that these undetected re-infections contribute to continued high prevalence rate of TB in the two communities and are also risk factors for transmission of drug resistant strains of TB.

In the 2015, MDGs targets assessment South Africa did not manage to reduce tuberculosis by 50% between 1990 and 2015. South Africa is not only classified as high tuberculosis burden country but also a high multi-drug resistant tuberculosis country (Stats SA, 2015). AIDS and Rights Alliance for Southern Africa [ARASA] (2008) reports that TB rates in South Africa are up to ten times more in mining areas than in the general population as a result of exposure to silicosis dust and prolonged stay in poor ventilated mine shafts. Likewise, Dharmadhikari et al. (2013) also elucidate that TB rates in mines exceed the national rates for the general population and adds that they are also in excess relative to mortality due to mining accidents. Mathema et al. (2015) also reports high rates of TB mortality in 15 mine shafts across three South African provinces: Gauteng, North West and Free State. The study initially found 5 513 TB cases but reduced the study population 1 602 patients who tested positive for TB. Of the latter, 14,7% had previously had TB and 5,2% had the drug resistant strain of the infectious disease. Geographic variations showed a higher likelihood of the TB patients to be from North West and to be residing in hostels. Rees (2006) suggests that the elimination of silica dust through dust measurement in the mines and strong efforts to maintain low silica dust concentrations will reduce the risk of TB among mine workers in South Africa. The paper argues that while South Africa calls for mines to have silica dust concentrations below 0.1mg/m3, only a few mines actually measure the dust and amongst those that do the measurements only a few have reached this reference level.

Dheda and Migliori (2011) suggest that effectiveness of TB treatment especially in the case of drug resistant TB in South Africa is undermined by capacity of health institutions to deliver adequate and quality service in contexts of high burden of TB. The study argues that most provinces have neither isolated areas to keep TB patients nor capacity for inpatient treatments as such leading to higher transmission rates of the infectious disease within communities. According to Churchyard et al. (2014) TB among children accounted for 13% of South Africa's new TB cases in 2012. Although treatment outcomes for children are good, the study reports challenges such as lack of child friendly drug formulations, lack of capacity of health care systems to manage childhood TB and poor integration of TB control activities with other primary health care services.

Engelbrecht and Rensburg (2015) in a study on TB infection control in 127 primary health care facilities in three districts argues that failure of TB control programmes in public health facilities is partly attributed to poor control strategies. The three districts were Alfred Nzo and O.R Tambo both in Eastern Cape and John Taolo Gaetsewe in Northern Cape. Success rates in TB cure were 58% in Alfred Nzo, 71% in O.R Tambo and 72% in John Taolo Gaetsewe. The study found that 95% of the clinics had no TB screening tools, less than half of the 127 primary health care facilities had reliable water supply sources and two out 10 efficiently employed the open window strategy to facilitate ventilation. Moreover, about a third of the professional nurses and 7% of the community health care workers had received training on TB infection training. The study also highlights that 43% of the clinics had no infection control committee and 49% did not isolate coughing and non-coughing patients as a prevention strategy. The researchers suggest that involvement of national and provincial departments of health in provision training of health care workers and screening equipment as well as implementation of the inexpensive infection control strategies such as ventilation, screening, and isolation of coughing patients from non-coughing patients will go a long way towards reducing TB in primary health care settings.

Other studies have also established links between TB deaths and community socio-economic structures and these include limited social support, low levels of education, high unemployment rates, income inequality and poverty [(Boccia et al.,2009); (Glynn etal., 2000)]. A study by Mabunda et al. (2014) examined factors associated with TB in Limpopo; one of the poverty stricken, poor infrastructure and inadequate public health services provinces in South Africa. Out of the 18 074 new TB patients in 2008, the study found that 12,4% died by the end of the year. Over 50% (52%) of the TB deaths were to males, majority of them were in the economically active age groups (25−54 years) and the study also observed higher mortality rates among patients that were on retreatment. The study also reports that 32% of the TB patients had initially tested negative for pulmonary TB due to inaccessibility of diagnostic tools in setting with limited resources.

There are a wide variety of economic, social, demographic and physical determinants of TB infections. These also places of residence which may directly or indirectly affect the health status of a particular community (Diez Roux et al., 2001). There are several studies which were conducted in Zambia asserting that populations residing in informal settlements which are crowded and categorized by poor health living conditions are more susceptible to numerous communicable diseases including TB [(Mwaba et al., 2009) ;(Kapata et al., 2012); (Zumla et al., 2012)]. These studies indicate that the vulnerable and marginalized populations in a given district bear an unjustifiable share of health problems and more often TB which is referred to as a disease of poverty. A different study by (Dye and Floyd, 2006) also found that TB is often linked with behavioural and demographic factors and these include employment status, age, occupation type, poor nutrition as well as alcohol and tobacco consumption.

TB is highly prevalent among South Asian countries. Its prevalence has been further enhanced by the emergence of drug resistant TB. Bishwajit et al. (2014) argue that South Asian countries are not only failing to properly adopt and implement the DOTS treatment strategy recommended by WHO but the socioeconomic conditions are not conducive for TB treatment. For instance, they cite that Bangladesh ranked sixth highest worldwide in 2007 for TB incidence whereas the country adopted DOTS in 1993 and by 2006 the program had 100% coverage.

India on the other hand has had a TB treatment program since 1960. However, TB remains a huge problem in India with the country being the most high burden country globally alongside China. Bishwajit et al. (2014) contend that TB patients in South Asian countries are concentrated in high density areas with poor living conditions in terms of housing and sanitation. Food insecurity, impoverishment and poor housing in South Asia make the context endemic for heightened risk of TB. Similar to South Asia, Chaisson and Martinson (2008) report that Africa has one of the worst TB epidemics facilitated by poor and unsanitary living conditions. However, they highlight that unlike in South Asia, the situation in Africa is further compounded by the high prevalence of HIV and high susceptibility of HIV infected people to TB.

According to Jassal and Bishai (2010) TB incidence and transmission in Africa is enhanced by high levels of poverty which bring overcrowding and poor nutrition as well as that in high HIV prevalence countries HIV infected individuals are about 20 times more prone to TB infection as compared to HIV uninfected counterparts. In their study Meressa et al. (2015) report on a Non-Governmental Organization (NGO) that conducted a community and hospital programme in Ethiopia among 1 044 patients between the years 2009 and 2014. The researchers cite that WHO reports that in most African countries treatment of multi-drug resistant TB is less than 50% which is lower than the 75% recommended success rate. However the NGO programme in Ethiopia found managed to achieve a success rate of 81%; higher than most African countries and the recommended success rate. The high success rate was reported to be due to scaling-up of adherence strategies such as monthly patiently visits, food baskets to enhance patient nutrition , training on adverse effects of treatment and constant laboratory monitoring of patient (Meressa et al.,2015).

What is derived from the literature is that while TB continues to be a global health threat, South Africa remains one of the world’s hotspots for TB. Although South Africa has adopted WHO standard for TB treatment, variations may exist by municipality or health care facility in the ability to adopt the guidelines and potentially domestication of the guidelines to suit the local context. Several factors also threaten to stagnant efforts to control TB in the country from availability of bed space in hospitals, convenience of treatment method, appropriateness of treatment dosage amongst children, integration of treatment with other hospital services, availability of diagnostic tools, public health infrastructure to training on TB infection control.

While most research that exists in South Africa is with regards to subsets of the country like province, district or mining shafts; much less is known about the TB scourge when considering districts or at the municipalities. Information on the geographic variations becomes important in the fight against TB as it will illuminate the areas that are doing well and those that are not doing well in order for the poor performance areas to be able to employ infection control strategies that are based on internationally recognised best practices.

Section 4: Methodology

4.1 Study design and area of research

This study will follow a quantitative approach. It is an empirical study of secondary data analysis from administrative data sources. Desktop review approach will be used to complement results of the quantitative data analysis. For example, when the quantitative data analysis indicate that deaths due to TB in a particular municipality has declined over time, desktop reviews will be used to establish what might be the reasons for the recorded declines.

The study will focus in all local municipalities of South Africa and then the main focus will be on municipalities which have recorded improvements in TB deaths. Municipalities in South Africa are divided into four different categories based on the municipality budget and services it renders. The study will also look into these categories with an aim to establish trends within these categories.

4.2 Data and Data Sources

Four data sources will be used in the study namely:

Mortality and causes of death register 2004-2014 provided by Statistics South Africa will be used for this study as the main source of information. The data on mortality and causes of death in South Africa is collected through the civil registration system housed at the department of Home Affairs (DHA). It provides a snapshot of the current health problems in South Africa. The registration of deaths in South Africa is governed by the Act states that “in the case of a death due to natural causes, any person who was present at the time of death, or who became aware thereof, or who has custody of the burial concerned, shall give, as soon as practicable, notice of death” (Republic of South Africa, 1992). The information collected through the death notification form includes personal characteristics of the deceased (i.e. age at death, place of birth, occupation and others) as well as the details on causes of death.

After the death is registered, a death certificate is issued to the informant then the death notification form is kept by the DHA. All death notification forms are collected by Statistics South Africa for data processing and publication of statistical releases and data sets on mortality and causes of death. The data on causes of death is compiled in accordance with the World Health Organization principles which require that member nations such as South Africa classify and code cause of death in accordance with the ICD-10 (WHO, 1992).

The ICD-10 coding manual provides the simple regulations used in all countries of the world to code and classify causes of death data. It provides information on coding in terms of disease, injury and poisoning categories. Completeness of death registration of adults aged 15 years and above for the period 2004–2014 was 94% (Stats SA, 2014).

The mortality and causes of death data has variables on economic participation of the deceased however the study will use business register data to profile main economic activities of the different municipalities.

One of the explanatory variables in the causes of death dataset is the industry where the deceased worked for most part of his/her life. This establishes whether deaths due to TB varies by industry type. A study by (Bruce et all., 2000) concluded that exposure to pollution probably caused by certain industries to individuals causes less probability of their bodies to fight off mycobacterium tuberculosis infections or to suppress a reactivation of a latent infection by these bacteria.

Mid-year population estimates data from Statistics South Africa will be used to project population at local municipality level by making use of the ratio method. Mid-year population estimates used in the study are for the years 2004-2010 then 2012 – 2014. Ratio method is useful for projecting the population at lower geographic levels within a country for which all inputs required by the component method are not readily available (Jarabi, 2012). For example age specific birth rates as well as migration rate.

Census data was used to perform population projection. Projecting population over the years where there was no census but only the mid-year population estimates in order to derive mid-year population estimates for local municipalities.

Lastly, data provided by the department of health (DoH) will be used to establish the number of health care facilities within a given municipality.

4.3 Study population and sample size

For this study the targeted population are South Africans aged 15 years and older who died of TB in the period 2004 to 2014 and whose deaths were registered with the department of home affairs. TB deaths have been and remain the leading cause of death in South Africa amongst adults hence the study focuses on adult mortality. The study population size was 5 288 192. The proportion of deaths due to other causes was included in the final sample to calculate the odds of dying from TB compared to dying of other disease based on the deceased profile.

4.4 Limitations to the study

The ratio method used in this study to estimate population size assumes that the smaller geographic areas will grow at the same rate as per parent area.

Reduction of TB deaths may be due to other un-observed phenomena other than the functioning or non-functioning of the TB campaigns/programs.

4.5 Ethical Consideration

This study only uses secondary data. Permission to use the data will be requested from Statistics South Africa especially for variables not accessible on the public domain.

Section 5: Methodology

The statistical software SAS enterprise guide version 6.0 was used for all the management and analysis of data. SuperCROSS application was used to extract census data and Microsoft excel was used to perform age standardization as well as TB specific death rates. ArcGIS Version 10.1 of ArcGIS was used for spatial analysis and preparation of maps.

Data Analysis was carried out at two levels of analysis namely; univariate which provides description of the data and the second the multivariate analysis.

The univariate analysis will give a give a general trend on TB deaths in South Africa as a whole as well as the pattern of overall deaths in South Africa. Results will be presented in the form of a graph.

The second part is the multivariate analysis part. This will show comparisons between different municipalities and spatial distribution of Tb death rates between different municipalities. Multivariate analysis is divided into two sections, the spatial statistics and logistic regression section. However it is important to calculate TB specific death rate for all these municipalities and map the differences spatially using the TB specific death rate. It then becomes important to standardize the municipality data as health information is also affected by age structure of the population.

The cause of death was derived from death notification forms as previously mentioned, and the cause specific mortality rates were compared with the population of the same area for the same time period. Cause specific death rates were calculated as the number of deaths due to TB during a given time interval divided by person years lived multiply by 100 000. Age adjusted cause-specific death rates are a most useful measure as they allow comparisons with other populations given that population sizes are different as is the case with the South African municipalities (Roper. et all, 2002). The study made use of direct standardization method since age specific mortality rates for all the populations were known. Age standardization was important to perform since comparison was across different geographic areas in order to control for the effect that different population age distributions may take on health events. The mid-year population estimates were used project populations for each year while adjusting for age. For example, when adjusting ages for 2004 then mid-year population estimates for 2004 were used and the same applies for other years.

In calculating age standardized cause-specific mortality rates, the population for 2001 census was used as a standard population. In order to compare age adjusted results between municipalities, age standardization was age adjusted to the same standard population i.e. census 2001. The cause specific rate which was age-adjusted is hypothetical and only useful for comparing populations.

The size of the population living in each local municipality was estimated using the ratio method (Jarabi, 2002). The method assumes that small areas exist in a perfect hierarchical structure which means that geographic units at each level are mutually exclusive and can be aggregated to higher levels of which this is the case with South African geography. The ratio method uses the national census as a control while adjusting proportionally the projections of the lower level areas. It starts by obtaining the ratio of local municipalities to the district population and then assumptions are made on the future values of these ratios. The population of the local municipalities were obtained by subjecting those ratios to the projected district population in respective years. In order to establish trends, census 2001 required alignment of data with census 2011 municipal boundaries. This was done to correctly project population for non-censal years since the country's demarcations went through changes in district and local municipality boundaries. In 2001, there were 262 local municipalities which were reduced to 234 local municipalities in 2011. A total of 107 local municipalities reduced in geographic area while other 155 local municipalities had an increase in geographic size. For full explanation on municipality boundary changes between 2001 and 2011 refer to (Stats SA, 2012).

In South Africa local municipalities can be subdivided into five subcategories for analysis and these are: A which are metros, B1 which are secondary cities, B2 are large towns, B3 are small towns and B4 are predominantly rural towns (DEA, 2011). For this study, the focus will be on all the above municipal categories. B1 local municipalities are secondary cities. B2 local municipalities have an urban core. These municipalities have big variation in population sizes amongst them and they have a large urban dwelling population. B3 local municipalities are normally characterised by the fact that there is no large town as a core urban settlement. Typically, these local municipalities have a comparatively small population. In this category, rural areas are characterised by the existence of profitable farms and local economies are mainly agriculturally based. They are also characterised by the presence of shared land tenure and villages or dispersed groups of houses and usually located in former homelands. Due to their similar nature B3 and B4 municipalities were combined into B3 municipalities.

Public health services providing TB treatments within municipalities were identified and then mapped to spatially show the distribution of health care facilities within each municipality. The list of health care facilities supplied by the department of health provided latitude and longitude GPS coordinates and thus became easier to map points. However only mapping of eThekwini municipality was shown in the results as it's the municipality which recorded great improvements in reducing TB deaths. Spatial distribution of other municipalities were ran but not included in the results.

Calculations of densities of health care services encompasses adding up the total number of health care facilities then dividing each by the population of each municipality and then multiplying that by 100 000 for healthcare facilities except that only health care facilities which provide TB treatments were selected. This measure provides the number of public healthcare facilities per 100 000 of the population for each municipality (Tuoane-Nkhasi, 2016).

Binary logistic regression analysis was applied to estimate odds ratios with 95% confidence intervals based on the function:

$$\pi = \Pr(Y_i = 1 | X_i = x_i) = \frac{\exp(\beta_0 + \beta_1 x_i)}{1 + \exp(\beta_0 + \beta_1 x_i)} \tag{1}$$

$$\text{logit}(\pi_i) = \log\left(\frac{\pi_i}{1 - \pi_i}\right) = \beta_0 + \beta_1 x_i \tag{2}$$

where: Y represents the binary response variable (such that Y_i=1 denotes death due to TB, and Y_i= 0 death due to other diseases. The explanatory variables were X_1 = Age in completed years, X_2 = Sex of deceased, X_3 = Marital status of deceased, X_4 = Education level, X_5 = Occupation of the deceased, X_6 = Smoking status of deceased, and X_7 = Population group; for which x_i was the observed value of the covariate for observation i.

To determine the proportion of overall variation in TB-related deaths that was accounted for by the given covariates, the Cox & Snell Pseudo R-square, and the Nagelkerke R-square were computed. The respective tests statistics were performed based on the functions:

$$\text{Cox \& Snell Pseudo } R^2 = 1 - \left(\frac{-2LL_{null}}{-2LL_k}\right)^{\frac{2}{n}} \tag{3}$$

$$\text{Nagelkerke } R^2 \text{ (which divides Cox \& Snell } R^2 \text{ by its maximum)} = 1 - \frac{\left(\frac{-2LL_{null}}{-2LL_k}\right)^{\frac{2}{n}}}{1 - \left(-2LL_{null}\right)^{\frac{2}{n}}} \tag{4}$$

where: $-2LL_{null}$ symbolises the likelihood for the model with only an intercept; and $-2LL_k$ represents the model with the predictor.

To examine the predictive power of the model, the area under the nonparametric Receiver Operating Characteristic (ROC) curve was computed. The respective curve; which is a graph of sensivity versus 1 minus specificity, was derived at c=0.5 probability cut off. Sensivity is the fraction of observed positive outcome cases that are correctly classified; and specificity is the fraction of observed negative outcome cases that are correctly classified.

ANOVA technique was applied to establish whether TB deaths affect municipalities the same way irrespective of the population size and budget of the municipalities or TB deaths differ from one municipalities to the other.

The universal law which governs geography as coined by Waldo Tobler which states that “In the universe, everything is related to everything else, but immediate things are more related than distant things” (Goodchild, 2004). It further states that there is a relationship between phenomena and space. This therefore implies that one can establish how similar a data point is in relation to other data points around it.

Therefore, for spatial analysis, the study will first compute Global Moran’s Index (Moran’s I) which computes spatial autocorrelation based on attribute values and feature locations (Stieve, 2012). Moran’s I index returns three possible outcomes. It is whether the pattern is random, clustered or dispersed. If the index is closest to +1 then it means the points are clustering. Very close to +1 values indicate perfect clustering which means like data points group very closely to like points. A strong -1 index indicates that the data points are dispersed. Points with an index very close to -1 would look like a chessboard where every point is completely surrounded by those unlike it but this phenomena is very rare. An index of 0 indicates that locations data points are not related in space which means the location is random. This will indicate which municipalities have clustering of high values. Basically results from this technique will provide an answer whether pattern of TB deaths observed are clustered dispersed or random. Establishing the pattern is important as it will help in identifying which municipalities show clustering of high values therefore need immediate attention.

The first part of the spatial analysis looks at Moran’s I which will point out whether the data points are random, dispersed or clustered. If the data points are random then the cluster and outlier Analysis (Anselin Local Moran’s I) which is used to identify statistically significant hot spots, cold spots, and spatial outliers will not be computed as it would mean there is no pattern, however if there data points are either dispersed or clustered then hot spots, cold spots, and spatial outliers using the Anselin Local Moran's I statistic will be computed starting with hot spots, cold spots then lastly outlier analysis (Anselin). This will give an indication which areas are hotspot and require urgent interventions.

For Anselin Local Moran's I, given a set of weighted features, identifies statistically significant hot spots, cold spots, and spatial outliers using the Anselin Local Moran's I statistic. Locations of positive spatial association means the municipalities are similar with their neighbors. Outcome from cluster and outlier analysis has four quadrants of Moran Scatterplot which are:

- Positive values nearby positive [H-H],
- Negative values nearby negative values [L-L],
- Negative values nearby positive values [L-H] and
- Positive values nearby negative values [H-L]

The hot spot analysis works in a way that given a set of weighted features, it identifies statistically significant hot spots and cold spots using the Getis-Ord Gi* statistic. The null hypothesis for the High/Low Clustering (General G) statistic states that there is no spatial clustering of feature values. This analysis answers the question "which local municipality has unexpectedly high numbers of TB deaths, given the population size?"

Finally, desktop reviews was carried out to establish which programs were implemented in which municipalities to establish reasons for the observed patterns and trends. For example, if results show that Hibiscus Coast municipality has recorded significant improvements in the fight against TB, desktop review study provides a qualitative explanation of the observed trends. It is possible that different programmes were implemented which were responsible for the drop in TB deaths or it was only one program which was scaled up.

Section 6: Discussion of Analysis and Results

This section focuses on the discussion of the results from the analysis. It first looks at the overall trend of all deaths and TB deaths in South Africa for the period 2004–2014. Secondly the results of the spatial distribution of TB deaths between municipalities will be discussed. The results will be discussed based on the different categories of municipalities. Thirdly binary logistic regression will be applied to establish which selected socio demographic and socio economic factors are predictors of TB deaths, ANOVA results shows whether TB deaths differ by local municipality. Lastly studies and policy documents will be reviewed with the view to find out reasons for the trends observed in the data analysis and results. These reviews will help map out reasons for the observed trends in TB deaths for the selected local municipalities.

6.1 Descriptive statistics

6.1.1 Distribution of adult deaths (1997–2014)

The distribution of deaths in South Africa for adult population aged 15 years and older for the period 1997 to 2014 are indicated in Figure 6.1 although the focus of the study will be from 2004 – 2014.. It can be seen from the graph that since 2004 the total number of deaths in South Africa has been decreasing as well as the number of TB deaths. The number of TB deaths reduced from 71 017 in 2004 to 38 878 in 2014, however, it still remains the third highest number of deaths in the world after India and China (WHO, 2015c).

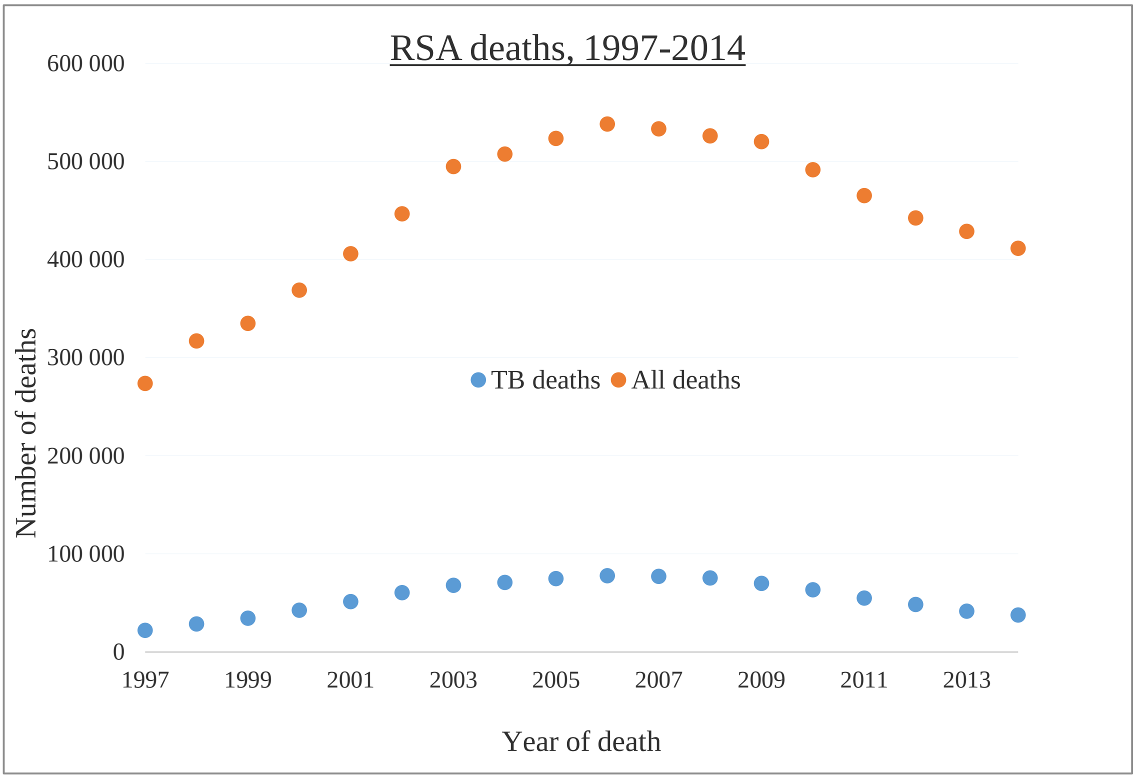

Figure 6.1: Distribution of deaths and TB deaths in South Africa 1997-2014

6.1.2 Summary Statistics for socio economic and demographic variables

A profile of people who died of TB in South Africa for the period 2004-2014 is shown in Table 6.1 below by selected variables. More than half of people who died from (55,7%) while females accounted for 44,1%. This is evidence that more males die of TB than females. In South Africa this might be attributed to the common knowledge that most man are involved in working in mines and there is a strong positive relationship between mine workers and TB (Meressa et al.,2015). The distribution of Tb deaths by population group is reflective of the South African population by race. There are more black Africans in South Africa than any other racial group hence even for TB deaths, there are more black African people dying of TB.

Sex of deceased		
	Frequency	Percent
Male	367161	55,7
Female	291067	44,1
Unknown	23	0,0
Unspecified	1174	0,2
Total	659425	100,0
Population group of deceased		
black African	496071	75,2
Indians	2725	0,4
Whites	1930	0,3
Coloureds	24872	3,8
Asians	587	0,1
Other	300	0
Unspecified	132940	20,2
Total	659425	100

Table 6. 1 Distribution of TB deaths by selected demographic variables

6.1.3 Spatial distribution of TB deaths between different municipalities.

The spatial distribution of TB deaths in South Africa based on raw data is shown in Figure 6.2 below. This assist public health practitioners to identify municipalities where most people die of TB. The data shows that most deaths occur in metropolitan cities, this indicative of the population size in category (A) municipalities as compared to other categories. The darker the area on the map the more deaths occur in that particular municipality. However it becomes important to factor population size and distribution as well as the age structure of the population when analyzing health statistics data. This is discussed in detail in section 6.3.1. The data also shows that there has been appreciable improvements in reducing the number of people dying from TB.

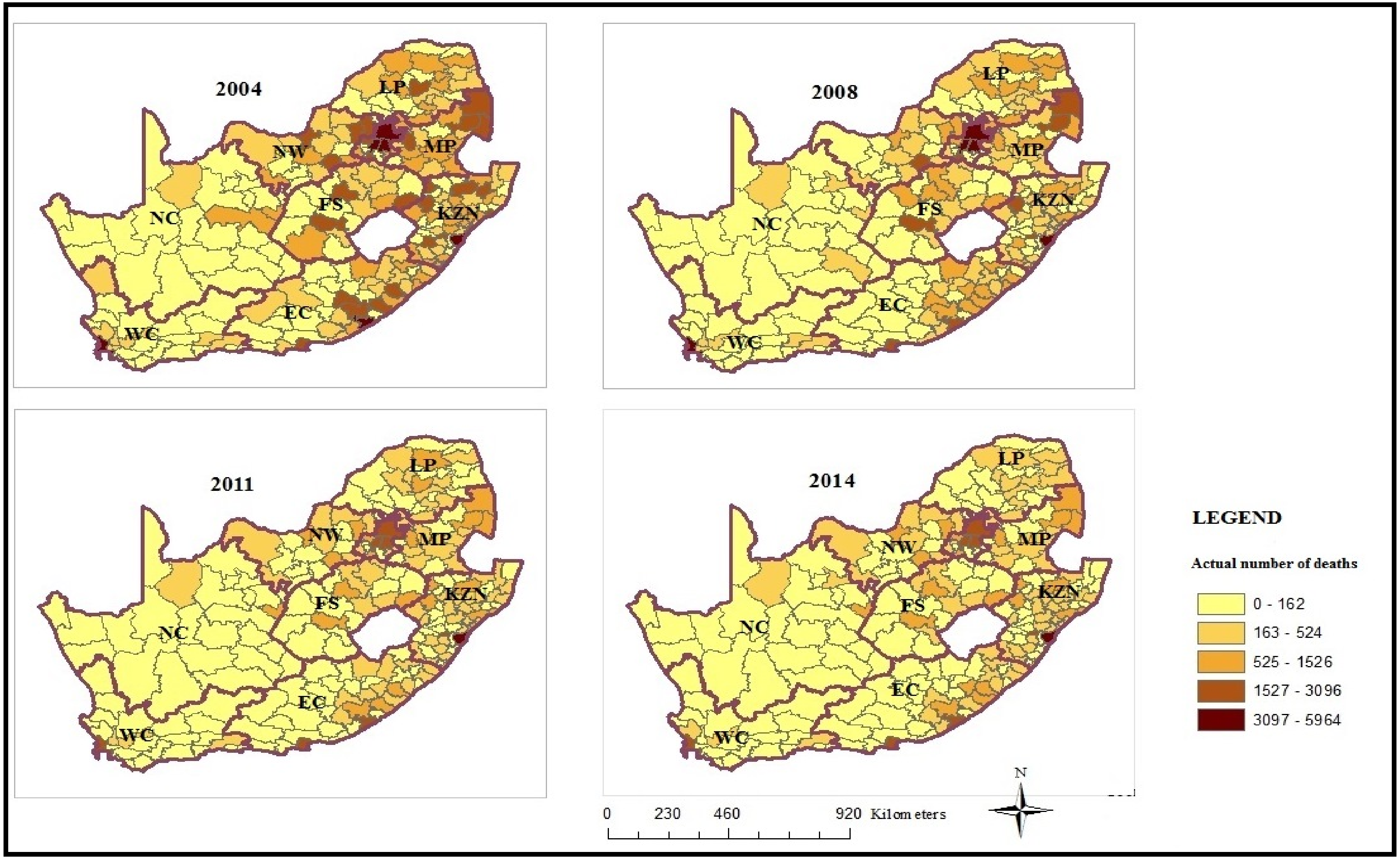

Figure 6.2: Distribution of TB deaths in South Africa (2004-2014)

6.2 Multivariate analysis

This section presents summary statistics and the estimated odds results on TB-related deaths as a result of the covariates (independent variables specified in the methodology section).

6.2.1 Difference in TB deaths by municipal category.

			Municipal category				Total
			A	B1	B2	B3	
Died of TB	No	number	1 620 944	763 583	458 869	1 785 371	4 628 767
		% of total	30.7%	14.4%	8.7%	33.8%	87.5%
	Yes	number	206 650	115 909	72 202	264 664	659 425
		% of total	3.9%	2.2%	1.4%	5.0%	12.5%
Total		number	1 827 594	879 492	531 071	2 050 035	5 288 192
		% of total	34.6%	16.6%	10.0%	38.8%	100.0%

Table 6. 2: TB deaths by municipal category cross tabulation

The cross-tabulated results in Table 6.2 indicate that from the total 5 288 192 deaths recorded, 12.5% (n = 659 425) deaths resulted from TB, while the remaining 87.5% (n=4 628 767. From the 12.5% cases who died of TB, the highest proportion of 5.0% (n=264 664) was found in municipalities in category B3, followed by 3.9% (n=206 650) deaths in municipalities in category 2.2% (n=115 909) deaths in municipalities in category B1, and lastly 1.4% deaths in municipalities in category B2.

The test of mean differences (Appendix G) show that municipalities in category B1 had the highest mean (= 229.496) of TB-related deaths relative to other municipal categories; followed by municipalities in category B3 (mean = 208.087), category B2 (mean = 187.113), and lastly category A (mean = 108.463). This therefore supports the statement that the means of municipal categories are not the same which implies that the likelihood of dying from TB differs by municipal category. The study hypothesized that there is no difference in TB deaths by municipalities irrespective of the municipality infrastructure and budget. However, results show that there is a difference whether one stays in category A municipalities which are metros or category B2 which are large cities.

6.2.2 Chi-Square Test of Association

The Chi-square non-parametric test of statistical significance for bivariate tabular analysis was applied to examine whether there is association between TB deaths and municipal category. The principal rationale of this technique is that it provides the degree of confidence to either reject or not reject the null hypothesis of association between the given variables.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3 649.452	3	0.000
Likelihood Ratio	3 687.572	3	0.000
Number of Valid Cases	5 288 192		

Table 6. 3: Chi-Square Tests

Results in Table 6.3 show that the null hypothesis of association between TB deaths and municipal category could not be rejected. The $\chi^2_{(0.05;\,3)} = 3649$, $p < 0.05$ suggest presence of a statistically significant relationship between TB deaths and municipal category.

Observed			Predicted		
			TB_Not		Percentage Correct
			No	Yes	
Step 0	TB_Not	No	0	4 628 767	0.0
		Yes	0	659 425	100.0
	Overall Percentage				12.5

Table 6. 4: Step 0 – Iteration History and Classification Summary [a,b]

a. No terms in the model.

b. Initial Log-likelihood Function: -2 Log Likelihood = 7330990.750

Based on the base rates of the two self-reported TB-related deaths outcomes with no other information provided, classification statistics in Table 6.4 reveal that it could be correct 12.5% of the time that a selected death case could have died of TB. In other words, 12.5% of observed deaths who died of TB were correctly classified. Inversely, about 87.5% of the death cases were therefore not as a result of TB.

Observed			Predicted		
			TB		Percentage Correct
			No	Yes	
Step 1	TB	No	4 628 767	0	100.0
		Yes	659 425	0	0.0
	Overall Percentage				87.5

Table 6. 5: Classification Summary at 95%

Table 6.5 shows that the improvement in the overall percentage from 12.5% in Step 0 to 87.5% in Step 1 of correctly classified death cases which were not as a result of TB indicate significance of including Age, sex, marital status, education level, occupation group, smoker and population group in the model as predictors. Therefore, the respective predictors (covariates) are significant predictors of TB deaths since adding them to the model significantly increased the power to predict the outcome of TB deaths. The summary model fit statistics (Table 6.7) were given by the change in the -2 Log likelihood, Cox & Snell R-square and Nagelkerke R-square statistics.

-2 Log likelihood	Cox & Snell R-square	Nagelkerke R-square
3755014.87[b]	0.491	0.655

Table 6. 6: Model summary[b]

b Estimation terminated at iteration number 5 because parameter estimates changed by less than 0.001.

The decrease in -2 log likelihood from 7330990.750 in Step 0 (Table 6.4) to 3755014.87 in Step 1 (Table 6.5) indicates improvement in the predictive power of the model. Based on the Cox & Snell R^2, approximately 49.1% overall variation in TB deaths was accounted for by age, sex, marital status, education level, occupation group, smoker and population group. Alternatively, the Nagelkerke R^2 indicates that about 65.5% overall variation in TB deaths was accounted for by age, sex, marital status, education level, occupation group, Smoker and population group up to the time the survey was conducted. Proceeding further, the Omnibus test of model coefficients, and the Hosmer and Lameshow test were performed to evaluate model fit and significance.

Test Statistic	Chi-square	df	Sig.
Omnibus test of model coefficients	3575975.879	7	0.000
Hosmer and Lameshow test	0.000	1	1.000

Table 6. 7: Statistical tests for model goodness-of-fit

Table 6.7 above shows results for the goodness of fit. Given the χ^2 = 3575975.879 (7330990.750 – 3755014.87) in the Omnibus test of model coefficients, the -2 log likelihood statistic for the null model that contained only a constant was 7330990.750 (=3575975.879 + 3755014.87). Therefore, the null hypothesis tested by the Omnibus test of model coefficients that adding the aforementioned independent variables did not significantly increase the power to predict TB deaths was rejected.

Nonetheless, dividing subjects into deciles based on predicted probabilities, the Hosmer and Lameshow χ^2 (8) statistic (= 63320.835; $p < 0.05$) computed from the observed and expected frequencies shows that the model with predictors provided a better fit than the null model. Thus, non-rejection of the null hypothesis (based on the Hosmer and Lameshow test) that predictions made by the model fit perfectly with observed group memberships confirm that age, sex, marital status, education level, occupation group, smoker and population group were indeed significant predictors of TB-related deaths up to the time the survey was conducted.

Step 1	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Age	-0.034	0.000	280174.949	1	0.000	0.966	0.966	0.967
Sex	-0.164	0.002	7361.768	1	0.000	0.848	0.845	0.852
Marital Status	0.000	0.000	0.170	1	0.680	1.000	0.999	1.001
Education level	0.000	0.000	45.708	1	0.000	1.000	1.000	1.000
Occupation Grp	0.000	0.000	107.857	1	0.000	1.000	1.000	1.000
Smoker	0.000	0.000	0.122	1	0.727	1.000	0.999	1.001
Population Grp	-0.026	0.000	3568.072	1	0.000	0.975	0.974	0.975

Table 6. 8: Odds ratios (OR) for TB-related deaths

The odds ratios (Table 6.8) computed by exponentiating the estimated beta coefficients (except marital status) were all statistically significant (based on Wald statistics) at 5% level and lie within their respective 95% confidence intervals. The statistically significant odds ratios each equal to 1 for education level (OR=1.000), occupation group (OR=1.000), and smoker (OR=1.000) indicate presence of equal possibilities that deaths that resulted from TB could have either been caused or not caused by education level, smoker, and occupation group. Nonetheless, the odds ratios each less than 1 for age (OR=0.966), Sex (OR=0.848), and population group (0.975) reveal that the TB-related deaths reported were indeed not caused by the respective covariates or variables. This therefore means marital status is not a predictor of whether one will die of TB or not.

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
0.673	0.000	0.000	0.672	0.673

Table 6. 9: Area under the Receiver Operating Characteristic (ROC) curve – Test Result Variable(s): Predicted Probability

a. *Under the nonparametric assumption*
b. *Null hypothesis: true area = 0.5*

To examine the predictive ability of the model, the area under the ROC curve was computed. The area (= 0.673) under the ROC curve (Table 6.9, and Appendix E) with 95% confidence interval indicate that the model indeed had some predictive power.

6.2.3 Pattern of TB death rates by categories of local municipalities.

Appendices A-D shows patterns of TB specific death rates in South Africa for the period 2004 to 2014. This time series data shows pattern of TB specific death rates by local municipality category. Appendix A shows that amongst metropolitan municipalities, eThekwini metro shows significant reduction in TB death rate from 2004 to 2014. TB death rates were 399 deaths per 100 000 in a population and the rate increased to 487 deaths per 100 000 in 2006 and then it considerably reduced to 196 deaths per 100 000 in a population in 2014. Nelson Mandela Bay metro also indicated great reduction in TB death rates.

Appendix B shows age standardized TB death rates for secondary cities for the period 2004-2014. uMhlathuze local municipality in KwaZulu-Natal province had the greatest reduction in TB death rates from 825 deaths per 100 000 in 2007 to a low 250 deaths per 100 000 in a population. Tlokwe city local municipality remains one of the secondary cities which need attention as it has recoded increases in TB death rates in recent years (2011-2014).

Appendix C shows age standardized TB death rates for large towns for the period 2004-2014. TB specific death rates for Midvaal local municipality in the Gauteng province more than any other municipalities in this categories. It reduced from 1 357 deaths per 100 000 in 2005 to 482 deaths per 100 000 in a population in 2014. Westonaria local municipality in the Gauteng province has constantly had lowest TB deaths through the 10 year period.

Appendix C shows age standardized TB death rates for small and rural towns for the period 2004-2014. In total there are 180 small and rural towns in South Africa. Amongst these Maquassi Hills local municipality in the North West province shows greatest reduction in TB death rates from 2 448 deaths per 100 000 in a population to a record low 150.

6.3 Spatial analysis

This section covers spatial analysis as mentioned on the methodology section. It presents the results of spatial patterns of age standardized TB specific death rates at local municipality level. The analysis were performed in four stages, first being spatial distribution of TB specific death rates followed by Moran’s I which is followed by hot spot analysis then lastly outlier analysis. The last two tools are used for mapping cluster where there has been clustering identified in the first stage of analysis.

6.3.1 Spatial distribution of TB specific death rates

Section 6.2.3 dealt with the distribution of TB death rates by local municipalities for the period 2004 to 2014, however this section deals with only the selected years which are 2004, 2008, 2011 and then lastly 2014. The municipalities were also not divided into the four main categories but just shows TB death rates for all the local municipalities.

It is evident from figure 6.3 below that eThekwini municipality has reduced TB deaths however the mining belt in the North West province as well as North Western parts of the Free State local municipalities remain with the highest TB death rates in the country.

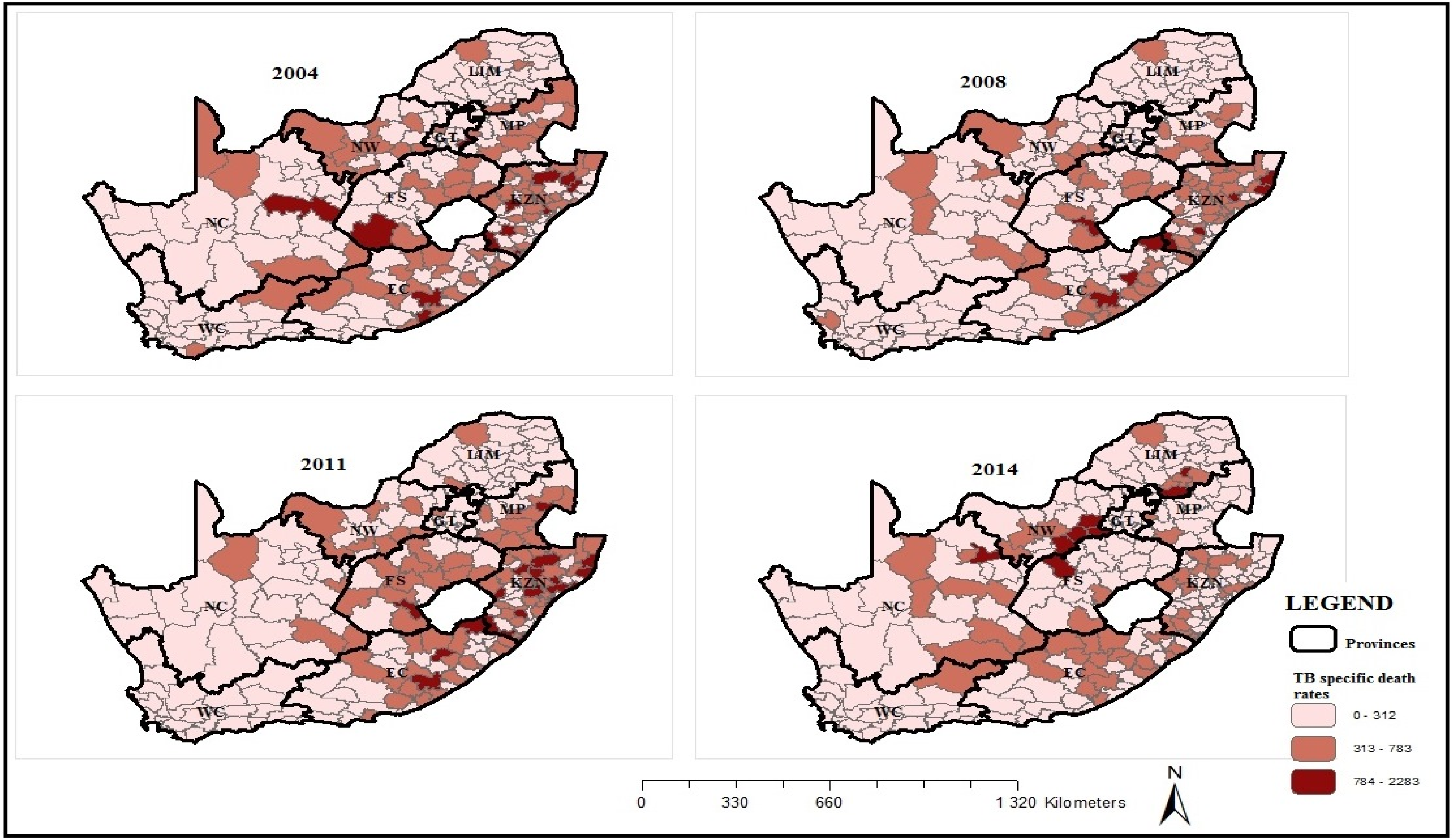

Figure 6.3: Distribution of TB death rates by local municipality (2004, 2008, 2011, 2014)

6.3.2 Morans I

Appendix F shows results from Moran's I. According to Moran's I results, spatial autocorrelation existed in the data and it was a clustered pattern. Given the z-score of 2.8, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

6.3.3 Hot Spot Analysis (Getis-Ord Gi*)

Results from Figure 6.4 show the disparities of TB disease in South African local municipalities as well as indicate the areas which are at risk of more TB deaths. Looking at the map, it is evident that most municipalities in the North West province as well as the Northern Parts of the Northern Cape and Western parts of Free State have had more TB deaths in the country since there are more hotspots (areas where high values cluster) in those areas and Cape Town in the Western Cape has had relatively cold spots. Confidence interval of 99% means there is 1 in 100 chance that the observation would have just occurred naturally.

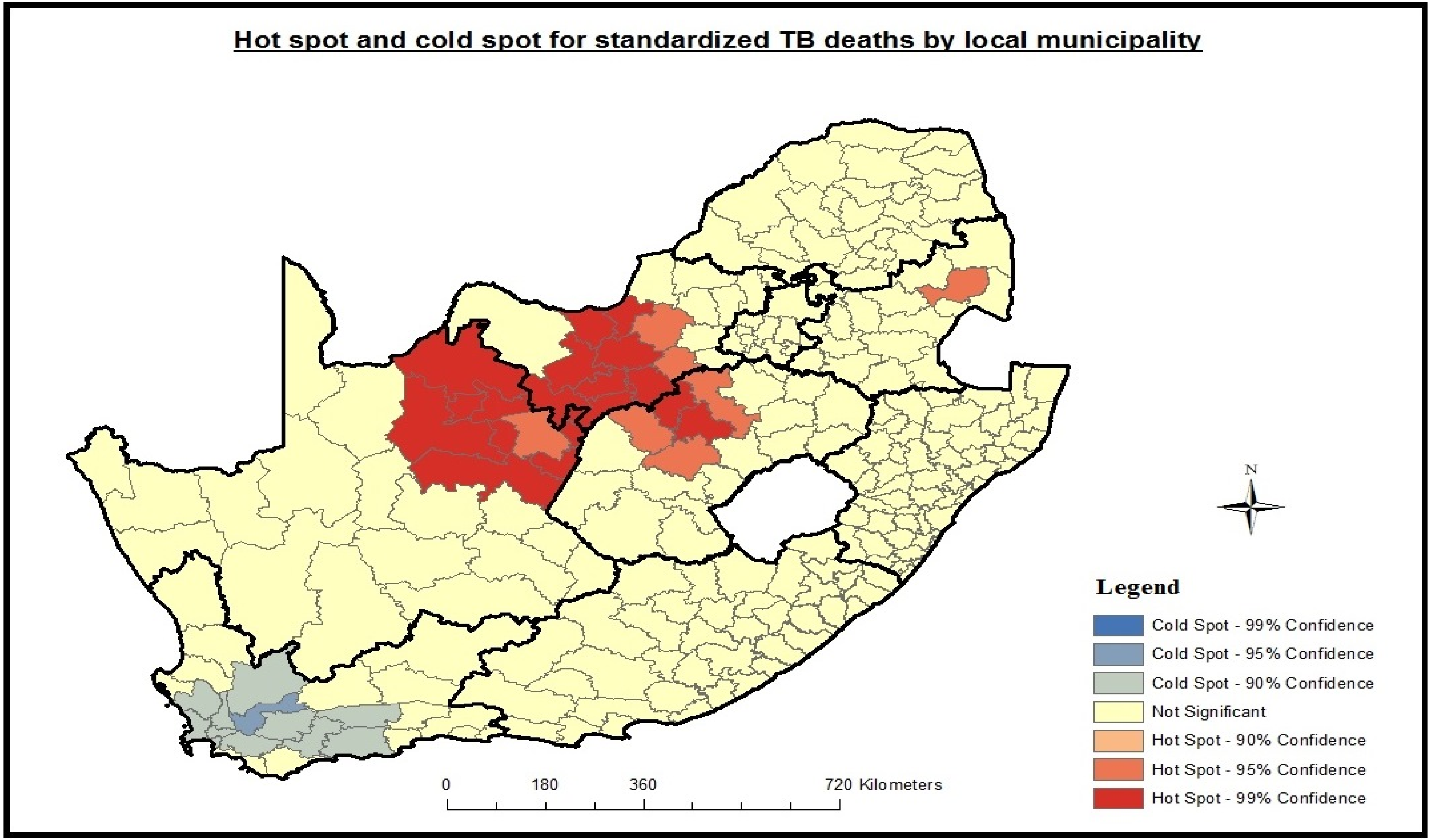

Figure 6.4: Hot spot analysis (Getis Ord*), 2014

6.3.4 Cluster and outlier analysis

G statistic will be high where high values cluster and it will be low where low values cluster Figure 6.5 shows the results of cluster and outlier analysis. The results show that positive values were nearby each other. In the North West Province, City of Matlosana, Naledi and Ventersdorp municipalities had H-H. These are in the mining belt in the North West province and studies have found that there is a positive strong correlation between TB deaths and mining towns. (Kapata et al., 2012).

Appendix H shows the distribution of age standardized TB specific deaths by local municipalities in 2014. Areas greatly affected by the TB deaths taking into account population age structure as well as population size were municipalities in the North West, municipalities in the North of Northern Cape as well as one municipality in Limpopo and Mpumalanga province.

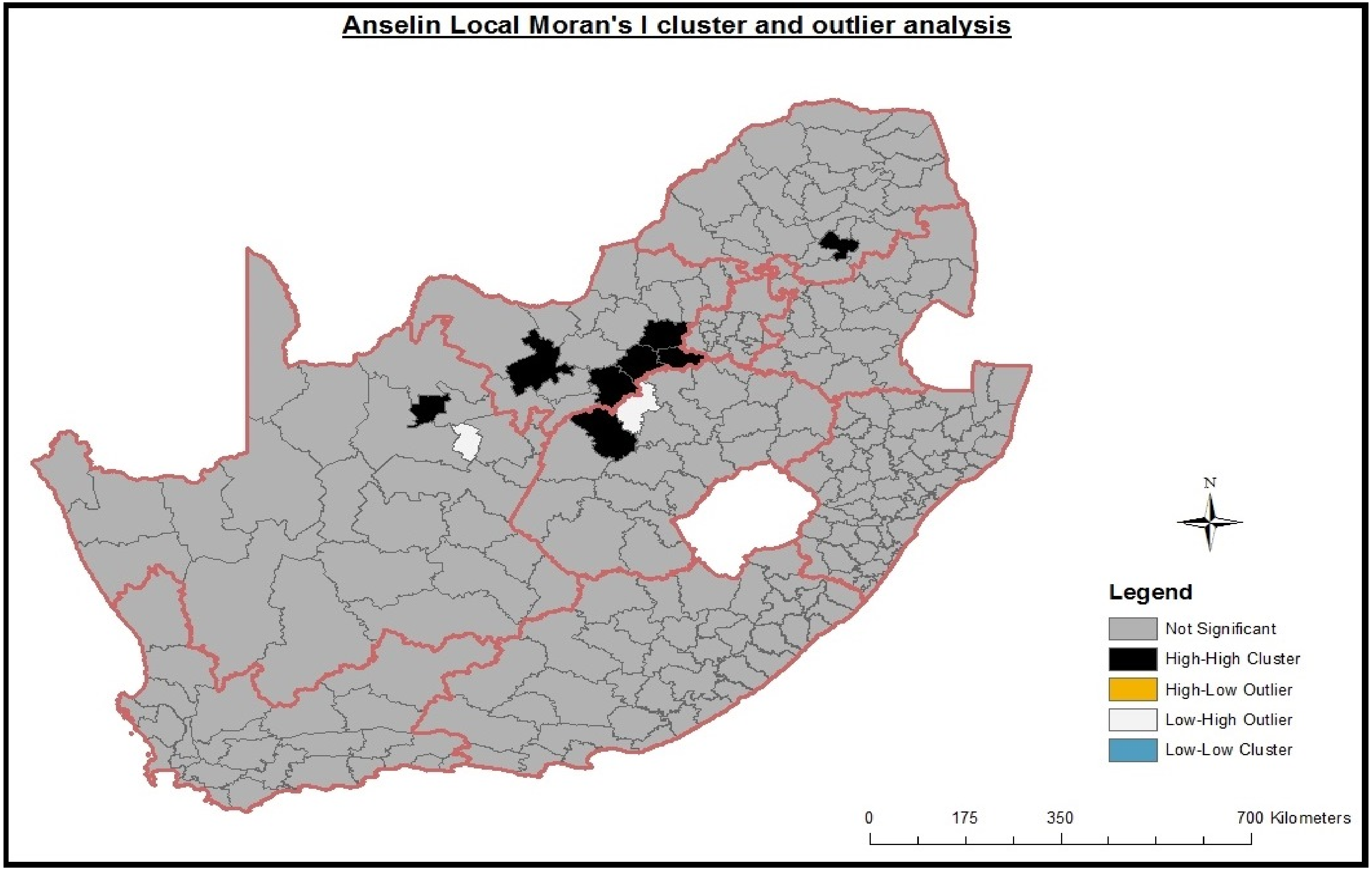

Figure 6.5: Cluster and outlier analysis, 2014

Section 7: Discussion

The literature study found that there has been significant improvements in the fight against tuberculosis in South Africa from all the levels of State, from National until community level. The effectiveness of some of these strategies have been evident in our trends analysis. Municipalities such as eThekwini and uMhlathuze both in KwaZulu-Natal, Midvaal in Gauteng and Maquassi Hills in North West recorded significant improvements in TB deaths in South Africa in for the period 2004 to 2014. There has been different programs which can be attributed to such improvements in TB deaths in these municipalities and adoption of some of these strategies by municipalities which are struggling with TB should be looked at.

One of the strategies implemented to fight TB was the National Tuberculosis Control programme (2004-2008). In some areas, only setting up public sector clinics does not improve intake of medicines by those affected by TB. In this strategy patients received vouches when coming to collect their TB medication in clinics, treatment success rates significantly improved especially for rural municipalities. The probability of treatment success improved drastically the more regularly the vouchers were received by patients. However there are administrative problems with this system as well. Further operational research is needed to explore how best to ensure the consistent and appropriate delivery of such support to those eligible to receive it, and whether, under conditions of higher fidelity, the extent of the benefit on treatment outcomes found in this study can be increased.

The department of health in South Africa introduced the DOTS strategy (DOH, 2000) which was meant to address the problem of high TB death rates. This programme was implemented in most of the municipalities with no results in some municipalities. Most of the challenges experienced by this program was the issue of distance between houses that the DOT supporters had to visit especially in rural municipalities which makes it virtually impossible for them to attend or reach all their patients which meant they couldn't deliver quality services. The main positive about the DOTS strategy was that DOTS supporters made sure that patients take their medication. Municipalities which benefited from DOTS strategy were those where households are closer together and one of those municipalities was eThekwini which recorded great improvements in TB deaths.

TB DOT Supporters work for four hours per day; this is according to their contract. The areas they are working in are so scattered from one another, with them walking long distances with up to eight clients per TB DOT Supporter it becomes impossible for them to reach all the clients each day or if they do reach all clients they do not deliver quality services.

EThekwini metro also benefited mostly from the radius of clinics from individuals homes. A study by (Stevenson et al., 2007) found that health care facility usage diminishes with distance. The distance from health care facility therefore plays a significant role in the use of health care. Appendix I shows the distribution of health care facilities in eThekwini municipality with a 2 km buffer. It can be seen from the figure that most areas are closer to health care facilities thus this can be assumed as one of the reasons for decline in TB deaths. Health Systems Trust, a not for profit organization implemented food parcel strategy programs in eThekwini as well. Appendix J shows the distribution of USIAD programs in the country which support the fight against TB. It should be noted that the municipalities which have recorded improvements in TB deaths are no longer shown as supported.

The eThekwini municipality also has The Bhambayi Settlement Project which was founded in the year 2000 under the National Integrated Program Sites. It provides high standard of directly observed treatment (DOT) support in TB. It services clients mainly in the Inanda community as well as surrounding areas of Ethekwini Municipality. The services they provide is also inclusive of providing adherence classes, screening and identifying TB suspects , DOT Support, education and counselling on TB as well as training volunteers.

Improvements in TB deaths in uMhlathuze municipality are due to the Amakhumbuza Community Development and Health Care supported by the USAID. This project aims at increasing the TB cure rate to 85% within the municipalities and achieves this by improving TB case detection and control, improving TB treatment compliance and increasing uptake of TB testing among HIV patients. However, there was no way of establishing whether improvements in TB deaths were ONLY due to this program for this particular municipality.

The fight against TB is for both government as well as the private sector as it affects both and is costly to any government since there is loss of intellectuals through TB which then negatively impacts the economy. The study established that there are strategies which has worked for other municipalities which can successfully be implemented in other local municipalities of the same category. The challenges experienced in other municipalities can assist in making the programs better.

The high proportion of TB specific deaths in the mining towns in the North West province show that there should be strategies aimed at mining towns and cities as far as TB deaths is concerned. One of the strategies would be to set up clinics which specifically deal with TB in the mining companies which will lead to early detection of TB.

The mining belt municipalities in the North West province, parts of Free State as well as parts of Gauteng province which are predominantly mining municipalities remain the hardest hit by TB deaths in the country. This therefore implies that there should be programs targeting mining municipalities and should have programs tailor made. Adoption of the program implemented by Rustenburg local municipality for the Royal Bafokeng mining operations might prove useful as it managed to reduce TB deaths for people living in the area through incorporation of TB management programs in their wellness programmes. The TB programme provides early detection of TB, monitoring and effective on-mine or on site treatment of all cases of TB by the mines for both permanent staff and contractor employees.

Section 8: Concluding remarks and Policy Implications

The Most of the policies in South Africa are focusing on reducing TB incidence and TB mortality rates, for example the TB strategic plan 2001-2005, the TB strategic plan 2007-2011 as well as the National Strategic Plan 2012-2016 all focused on reducing incidence and Tb mortality rates by 50% but programs should also focus on TB control such as the cure rate for TB treatments. The continuation of high TB death rates is an indication that programs should also be directed to how TB control programs can be improved.

The fight against TB is a multifaceted problem, policies which are directed to population control such as decentralization have an indirect effect on TB incidence rate. Decentralization leads to the reduction of the number of people per square kilometre especially in urban areas thus reducing the risk of TB since there is a substantial risk of infection in crowded living circumstances. This study confirmed findings by (Clark, et.all, 2002) that crowded living circumstances lead to increased incidence rates for infectious diseases and the same can be said for housing density. People living in close proximity causes the spread of TB to be more rapid and easy.

Strategies applied by government in addressing issues of TB should be local municipality based meaning not all strategies adopted by government work the same in all municipalities. The example is the implementation of the DOTS strategy which worked and had positive outcomes for urban municipalities however the same cannot be said for the rural local municipalities as the ANOVA results have indicated, TB deaths affect different local municipalities in different ways and thus strategies to address problems of TB deaths should be municipality oriented. Strategies to deal with TB on metropolitan areas cannot be the same as the strategies to be implemented in predominantly rural municipalities. For example the DOT strategy might be easy to implement in metropolitan areas where households are closer together therefore the volunteers can attend to many patients while rural municipalities have dispersed and would prove difficult to visit as many households as in metros.

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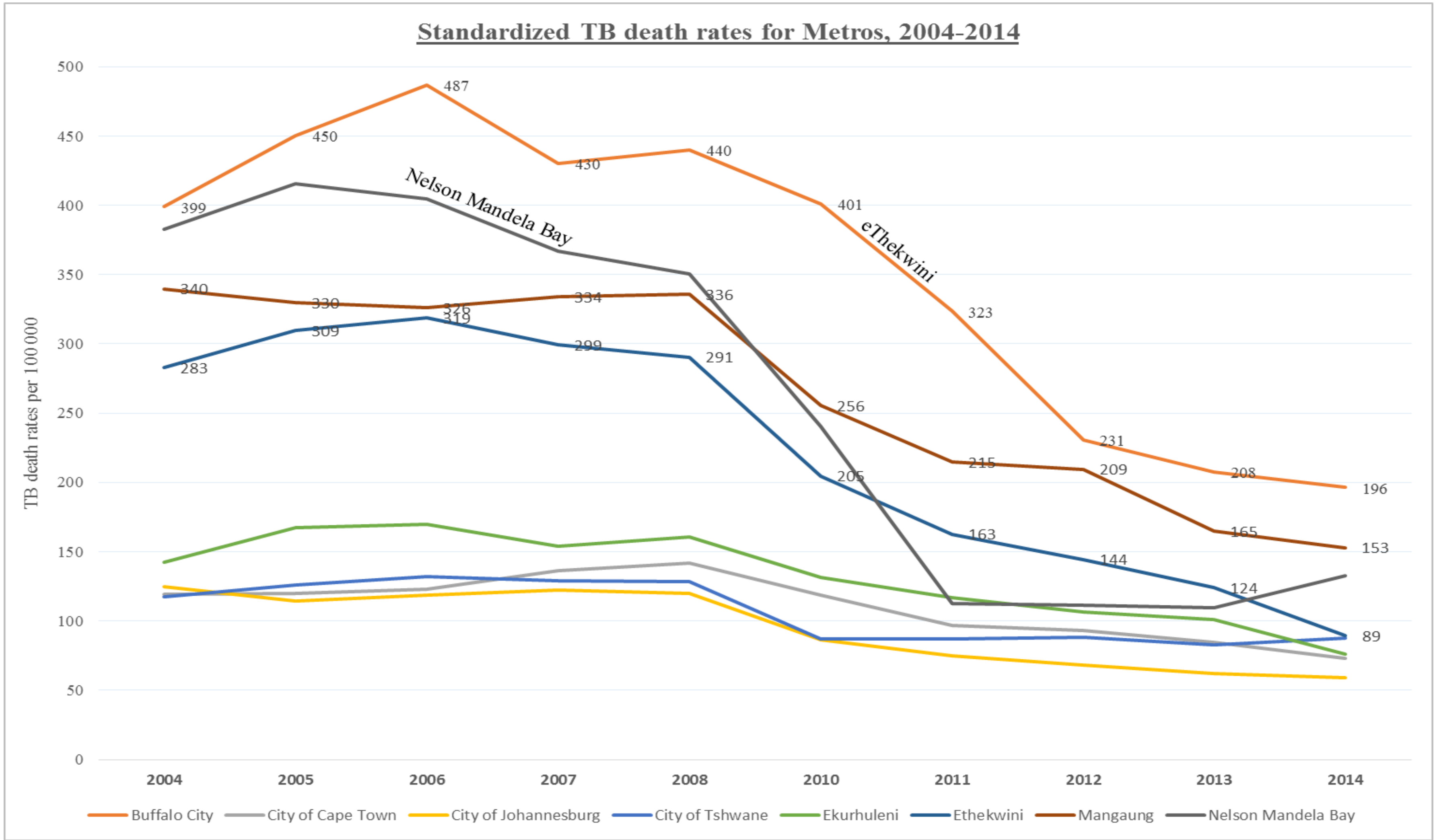
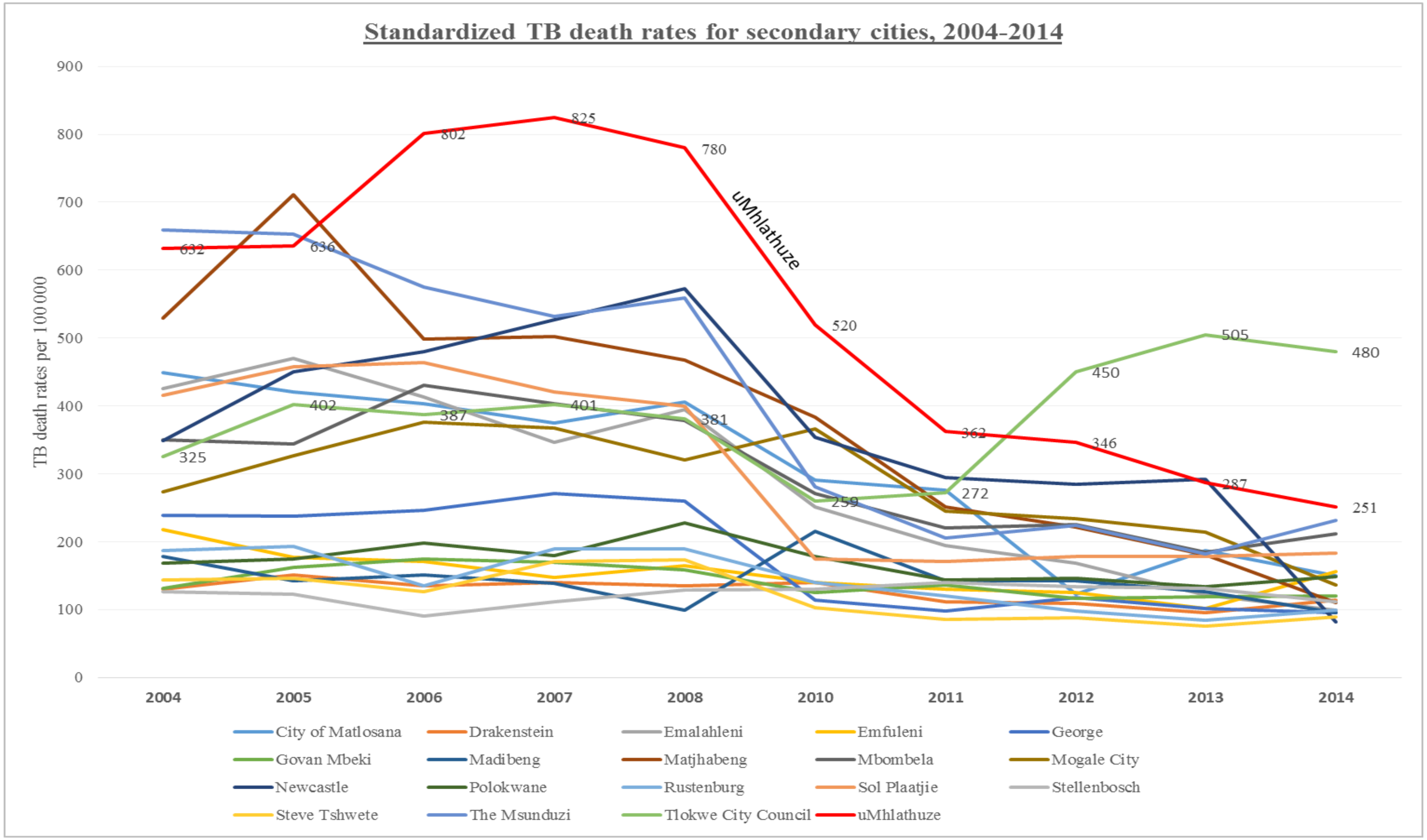
Appendices

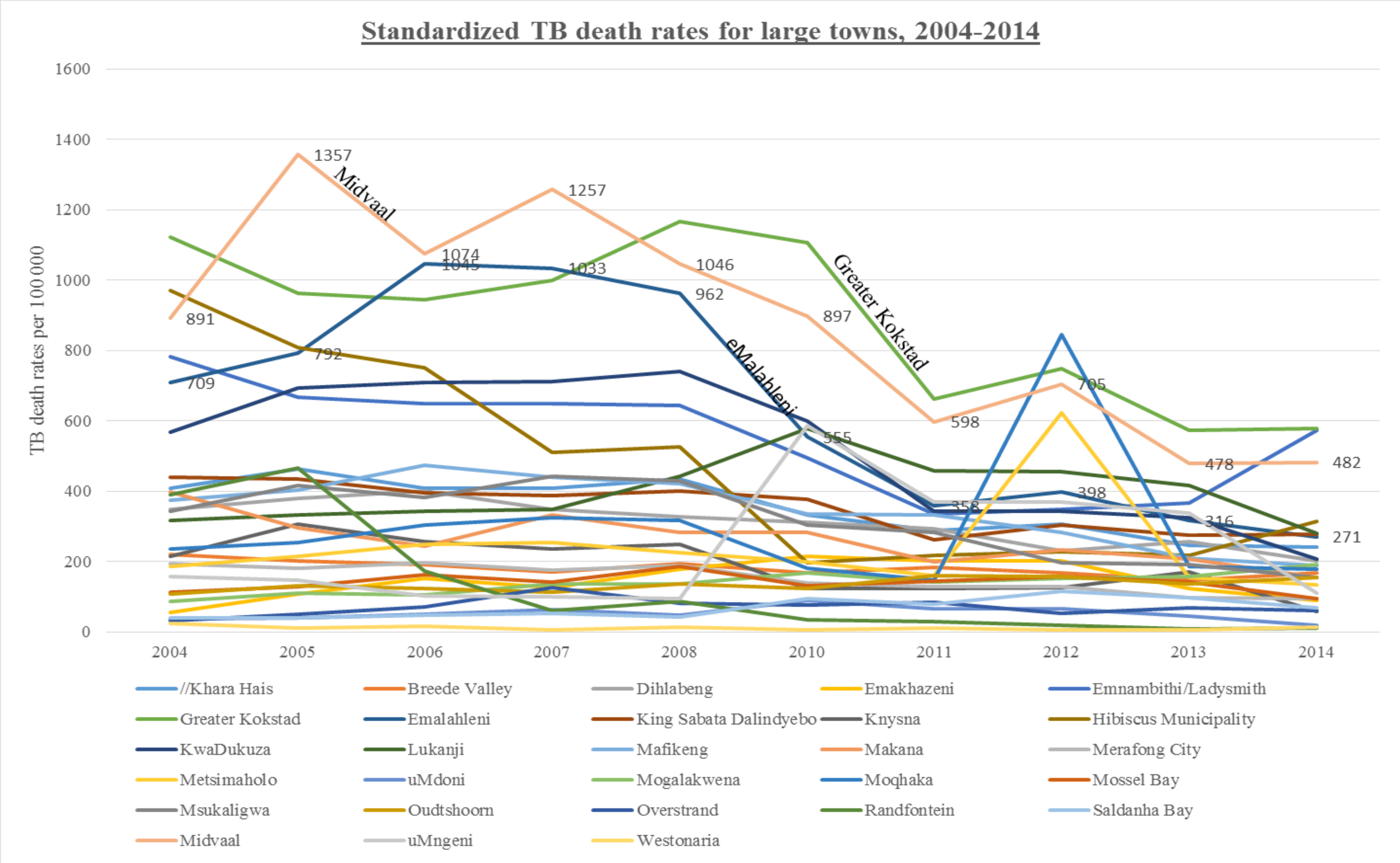
Appendix A: Age standardized TB rates for metros



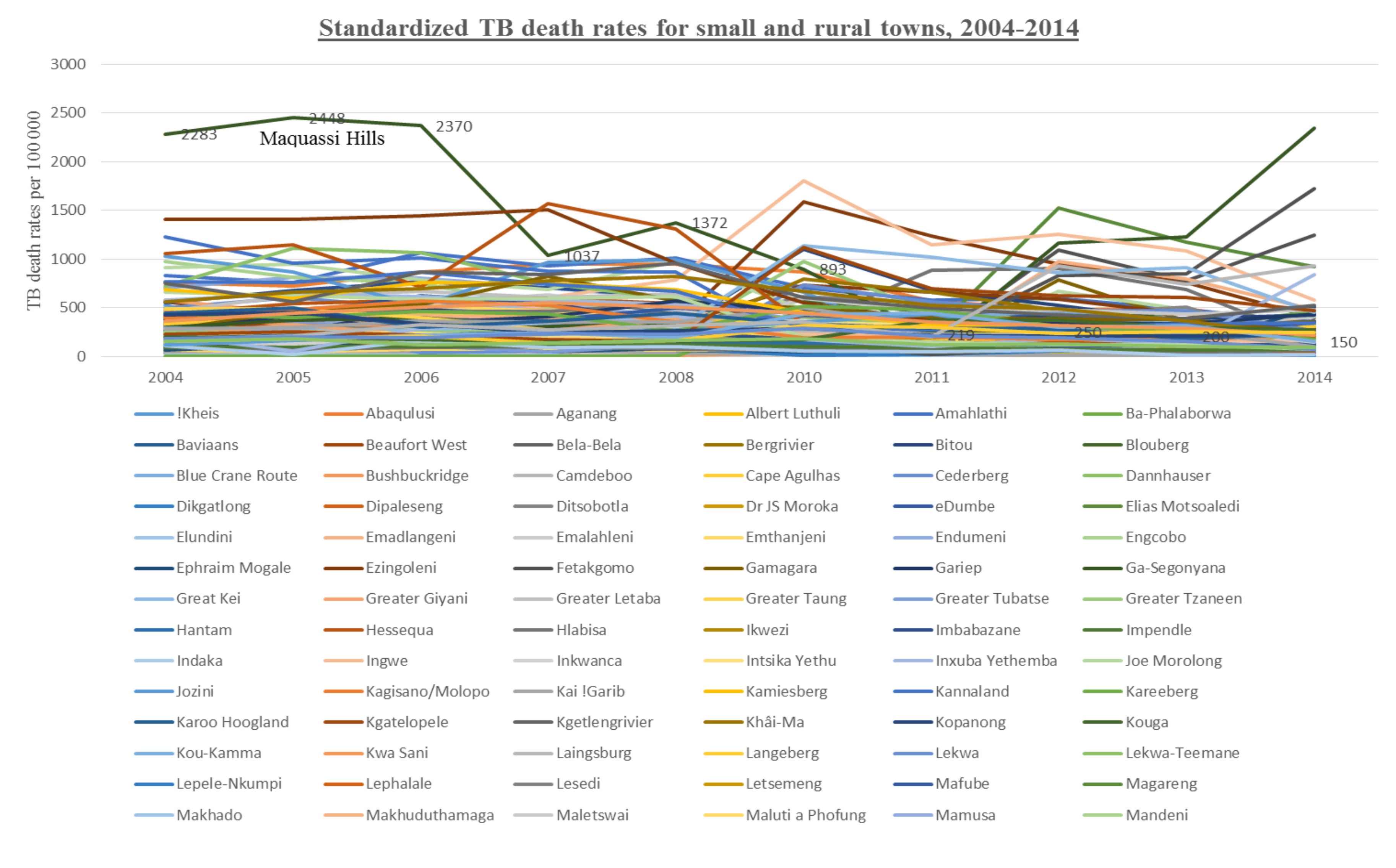
Appendix B: Age standardized TB rates for secondary cities



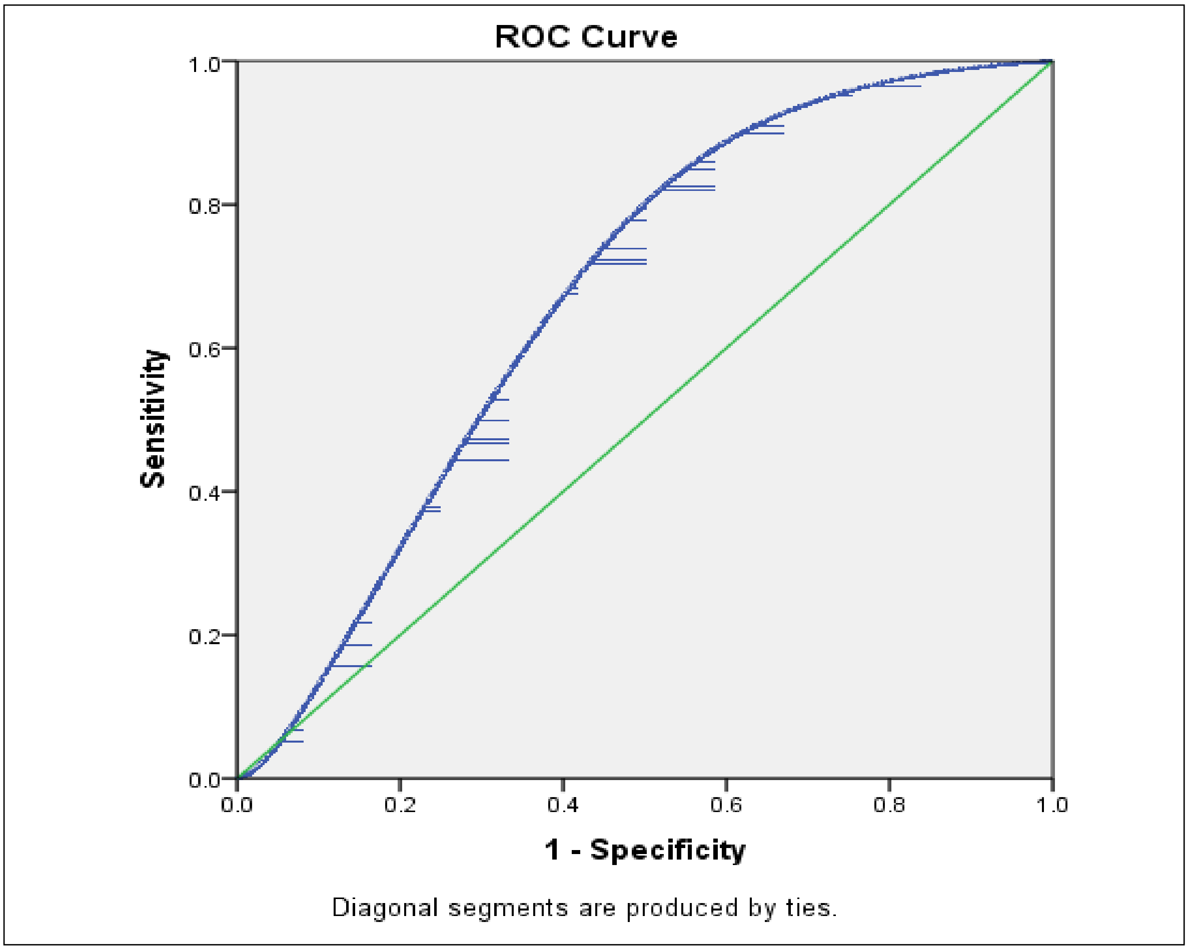
Appendix C: Age standardized TB rates for large towns



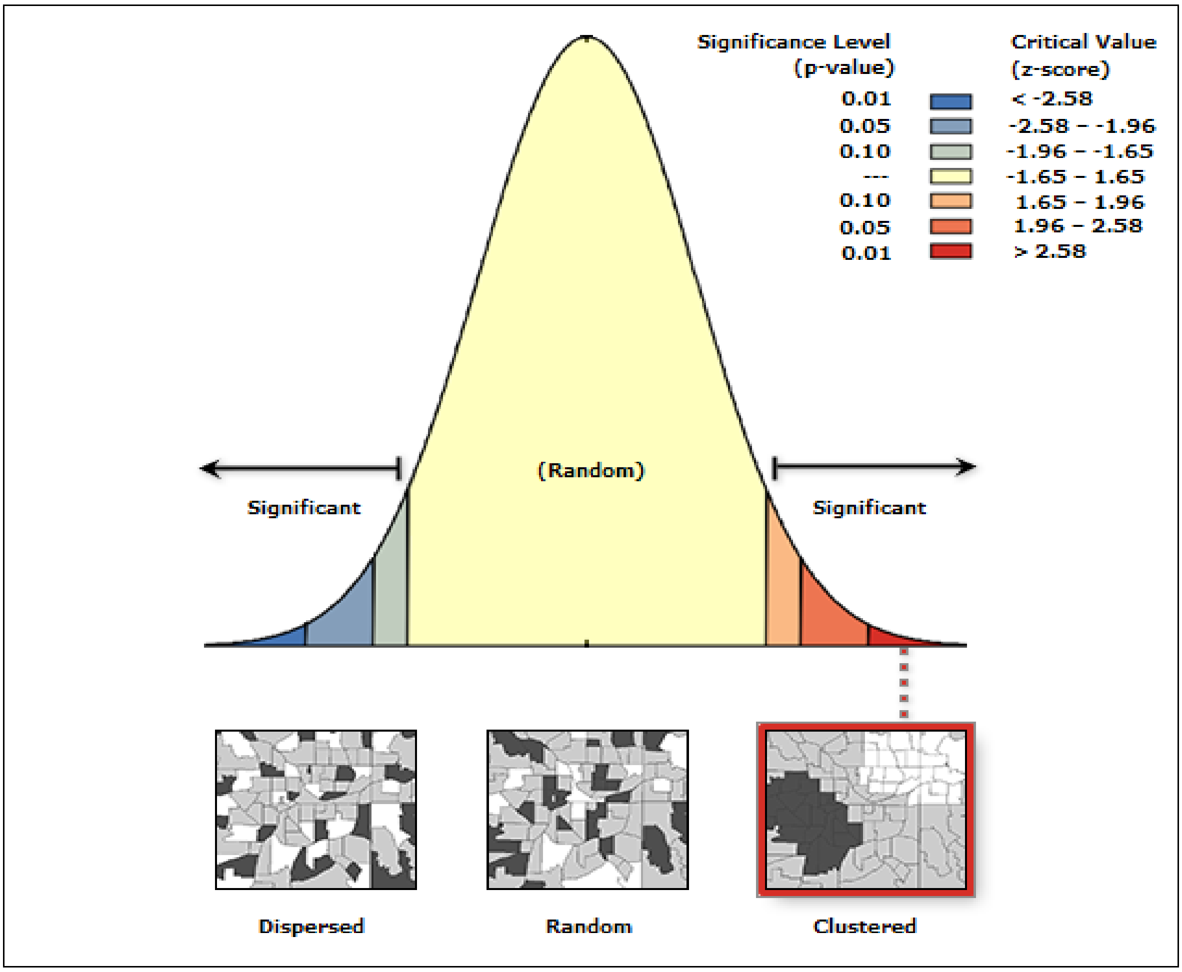
Appendix D: Age standardized TB rates for small and rural towns



Appendix E: Receiver Operating Characteristic (ROC) curve



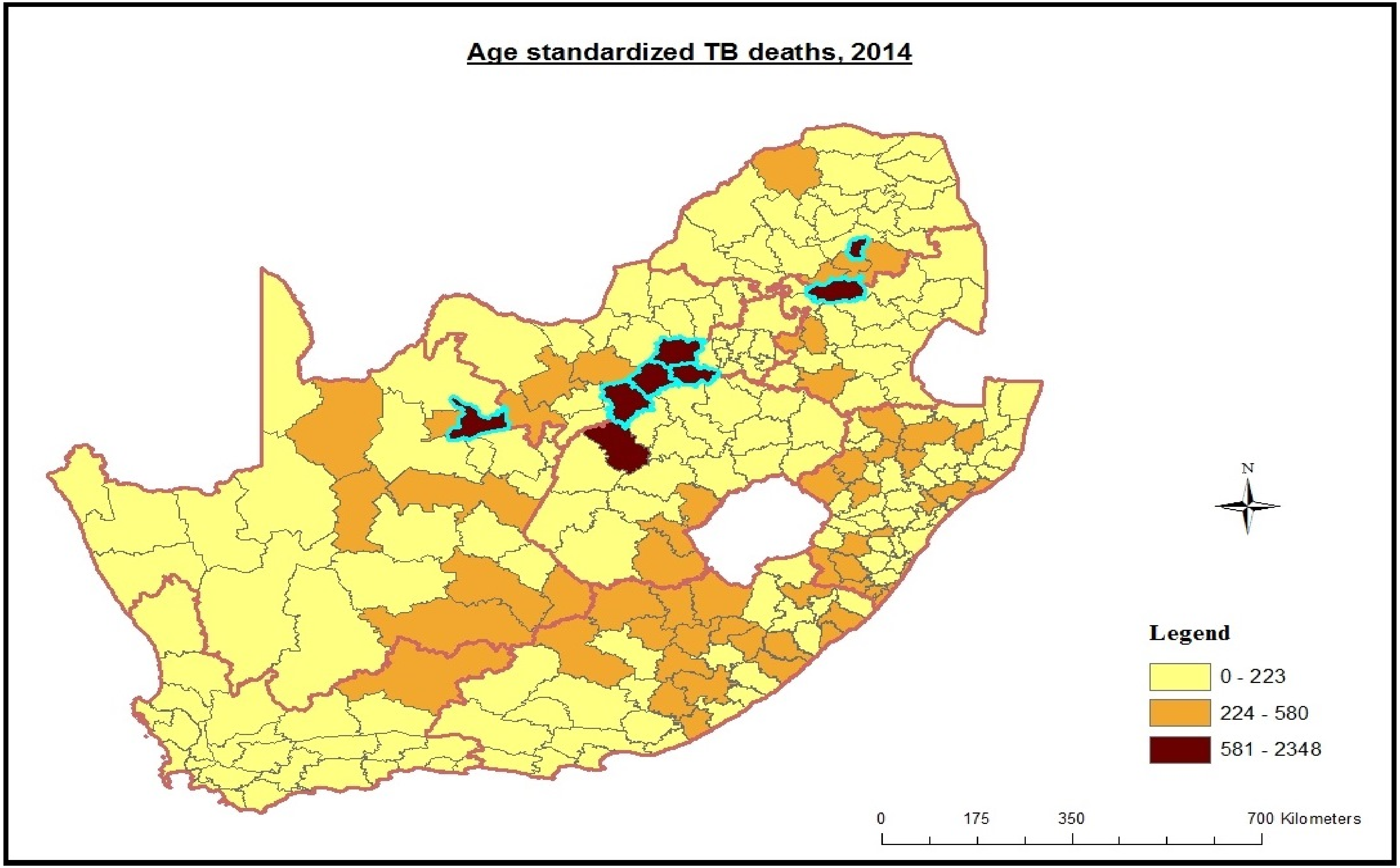
Appendix F: Spatial autocorrelation report



Moran's Index:	0,056755
Expected Index:	-0,004292
Variance:	0,000469
z-score:	2,819273
p-value:	0,004813

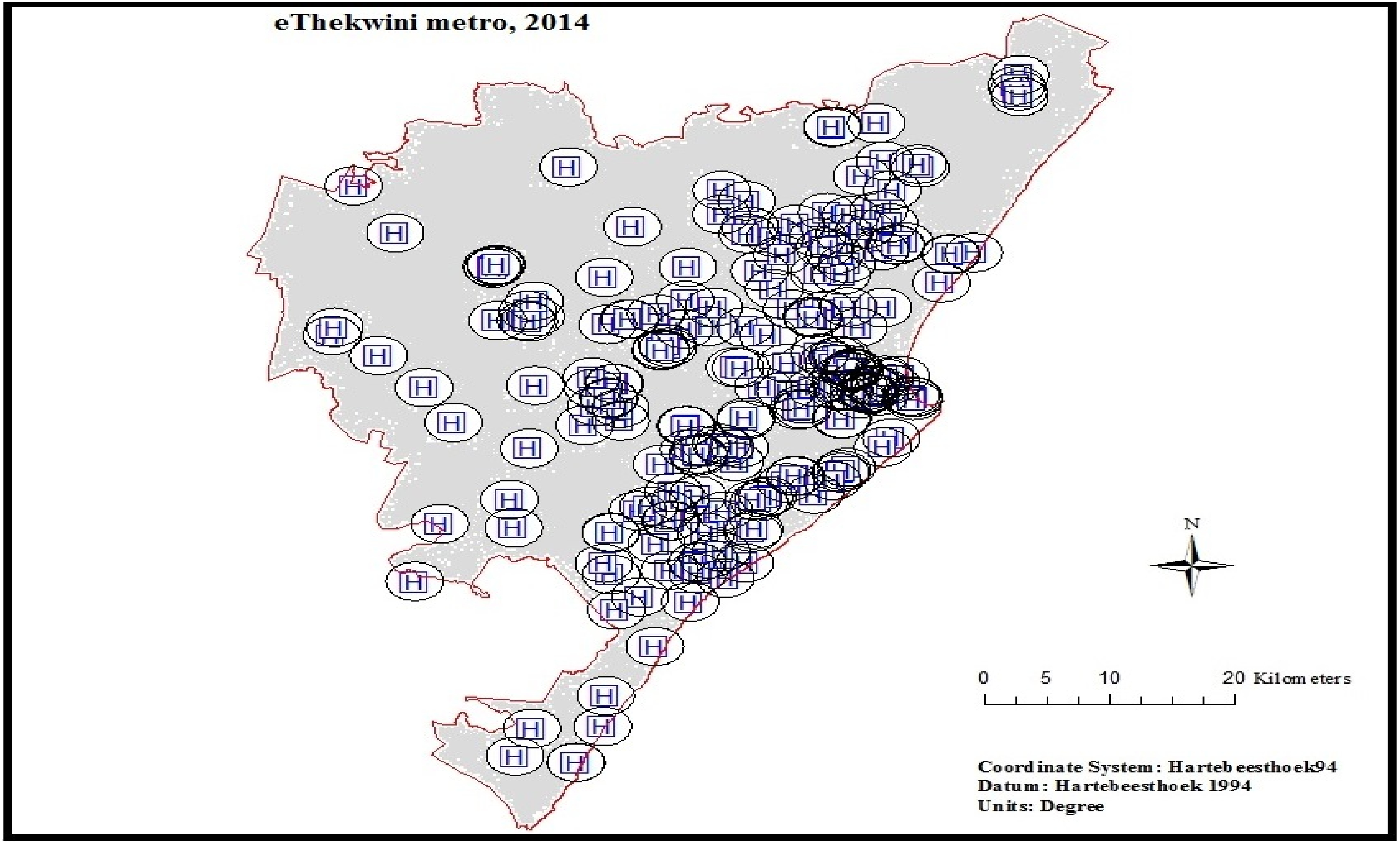
Appendix G: ANOVA test of mean differences

Municipal category	Mean	N	Std. Deviation
A	108.463297554618730	8	47.501432298701720
B1	229.496407435157000	19	281.373303293215430
B2	187.112662331295240	27	150.860342907940240
B3	208.087519553412200	180	260.462459902016600
Total	203.999715915658600	234	247.495282857985200



Appendix H: Age standardized cause specific death rates, 2014

Appendix I: Coverage of health care facilities in eThekwini municipality



Appendix J: Distribution of TB programs (source: USAID_2014)