

AN ECOLOGICAL ANALYSIS OF THE IMPACT OF WEATHER, LAND COVER
AND POLITICS ON CHILDHOOD PNEUMONIA IN TANZANIA

A Dissertation

by

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ABSTRACT

Pneumonia is the main killer of under-five children worldwide. The developing nations suffer the most. But within such countries, the spatial and temporal distribution of pneumonia cases is not uniform; yet little is known of the spatial and temporal distribution of pneumonia or the factors that might affect spatial and temporal variability. This dissertation explores the causes of spatial and temporal variation in under-five pneumonia morbidity in Tanzania.

This study uses an ecological analysis to explore weather, land cover and politics as potential drivers of the observed differences in the distribution of pneumonia. A study is at an ecological level when it examines the population-level health aspects. That is, ecological analyses in health studies evaluate groups of people rather than individuals.

The current study found that weather variables such as temperature and atmospheric pressure partially explained pneumonia variance. The strength of weather-pneumonia association varies over space and time in both seasonal elements (temporal factors) and broadly-defined climate zones (spatial factors). For example, the prevalence rate was higher in the regions with bimodal rainfall compared with the regions with unimodal rainfall, with a statistically difference 117.3 (95% confidence interval: 36.6 to 198.0) cases per 100,000. In addition, within the regions (*mikoa*) with unimodal rainfall regime, however, the rainy season (*msimu*) had lower rates of pneumonia compared to the dry season (*kiangazi*).

Land use and land cover also were partial drivers of pneumonia. Some land cover types—particularly urban areas and croplands—were associated with high rates of childhood pneumonia. In addition, districts (*wilaya*) categorized as urban land cover had high rates of pneumonia compared to those categorized as only rural.

To determine the associations between politics and pneumonia, this study compared the pneumonia cases in the administrative locations that received less central government funding with those locations that were financially rewarded for voting for the ruling party. The locations with lower funding generally had higher rates of childhood pneumonia. However, it is unclear whether these locations had higher rates of childhood pneumonia because of, or in addition, to their funding gaps.

In sum, this dissertation evaluated population-level factors affecting distribution of childhood pneumonia. Like other similarly population-level studies, this dissertation provides an understanding of the coarse-scale dynamics related to childhood pneumonia. By so doing, it contributes to the pneumonia etiology scientific literature.

That is, this dissertation contributes to the understanding of within-nation pneumonia distribution in developing nations. It is the first in Tanzania to evaluate the impact of weather, land cover and politics on childhood pneumonia. By evaluating the impact of weather and land cover, this dissertation also provides an example of non socio-economic factors affecting health inequalities. By analyzing a large landmass of two main climatic types, this dissertation also contributes appreciation of non-stationarity of temporal variations of childhood pneumonia, in addition to the commonly-evaluated spatial variations.

DEDICATION

to

Milka, Solomon and Sincere

and

all of my extended family,

this is for you;

and

for my departed parents:

my father: Fanuel A. Mgendi (*'Kizee cha Mungu'*), for all of the love and care he gave us till he passed away some months before I enrolled into this program;

my mother: Mwendapelu, for the love and for the educational foundation she put for us till she passed away some 30 years ago.

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NOMENCLATURE

TMA	Tanzania Meteorological Agency
MoH&SW	Ministry of Health & Social Welfare
GIS	Geographic Information System
NCEP	The National Centers for Environmental Prediction
NCAR	National Center for Atmospheric Research
MAUP	Modifiable Area Unit Problem
IGBP	International Geosphere-Biosphere Programme
ILRI	International Livestock Research Institute ()
MODIS	Moderate Resolution Imaging Spectroradiometer

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1 INTRODUCTION

1.1 Research Background

Pneumonia¹ is clinically defined as inflammation of the lungs accompanied with the symptoms of fever, chest pain and coughing, and which can be treated with antibiotics therapy (Marrie 1994). Typically, *Streptococcus pneumoniae* and *Haemophilus influenzae* are the main pneumonia-causing bacteria in developing countries (Berman 1991), and in Tanzania, the *Streptococcus pneumoniae* (Uriyo et al. 2006). Pneumonia caused by other microorganisms is normally known as atypical pneumonia, most likely from acquired through healthcare settings (Forge & Marrie 2009). Community-acquired pneumonia, that is, the pneumonia typically transmitted outside the confines of healthcare settings, therefore forms the focus of this dissertation.

According to a WHO / UNICEF report, pneumonia is responsible for more deaths of children globally than any other disease (Wardlaw et al. 2006) . The WHO / UNICEF report also shows that 95% of pneumonia cases are in developing countries, with 74% of the new cases concentrated in only 15 countries. Nine in ten pneumonia-related deaths happen in 40 nations most of which are classified globally as developing (Rudan et al. 2008).

¹ “Pneumonia” is an umbrella term for acute respiratory diseases accompanied with fever. Similarly, ‘childhood pneumonia’ as used in the current dissertation means ‘pneumonia in children aged from zero to 59 months’.

Rudan et al. (2008) further describe the sharp contrasts in the burden of pneumonia between the nations of the world. Half of all children dying from pneumonia are in Africa, despite Africa having a fifth of the global under-five population. Pneumonia deaths are not equally distributed.

Until recently, researchers have paid less attention to what drives in-country geographical differences in the health of children living in a developing nation than they have to the differences between nations. While the international differences in the burden of pneumonia are notable, the national differences which Rudan et al. (2008, 410) describe as “critical inequities” require closer scrutiny. This dissertation therefore explores spatial patterns of the spread of pneumonia within Tanzania by evaluating the political, climatic and land change factors underlying the distribution of the disease in African nation of Tanzania. Tanzania was the preferred case study in this dissertation because it had one of the highest rates of pneumonia in the world as explained below.

Tanzania is one of 15 countries with the highest number of new cases of pneumonia each year. New cases of clinical pneumonia are estimated at 1.9 million cases per year or 0.33 cases per child per year (Rudan et al. 2008). Tanzania is also among the 15 nations worldwide with the highest number of deaths caused by pneumonia (Theodoratou et al. 2011). It is responsible for 11.2% of under-five mortality in Tanzania (Samarasekera 2008). Pneumonia-related death rates are comparatively lower in older age groups (Mayo 2007). Despite these country-wide headline statistics, little is known about the geographical patterns of the childhood pneumonia in Tanzania.

This dissertation addresses the roles of weather, land cover and politics in creating or influencing specific spatial and temporal (geographical) patterns of childhood pneumonia in Tanzania. Due to the constraints inherent in the available data, the current study is a retrospective, population-based ecological-level analysis. In health studies a study is deemed to be at the ecological-level when groups of people rather than individuals are chosen as the unit of analysis. The findings at the group-level cannot reliably be extended to an individual to avoid committing the “ecological fallacy”. Ecological-level studies are nonetheless useful for providing context to the causes and effects of a disease (Schwartz 1994).

1.1.1 Weather and Pneumonia

Weather is known to influence the spread of pneumonia (Fuhrmann 2010; Murray et al. 2012). Chapter 2 explores the associations between pneumonia and weather variables: rainfall, temperature, relative humidity, wind speed and sea-level pressure. Tanzania is an example of a vast country – about the combined size of Texas and Oklahoma (Lawrence, 2009) – that has varied climates. In terms of rainfall, it is divided into two main climatic zones. The northern parts of Tanzania and the north coastal areas experience a bimodal rainy seasons of *masika* and *vuli*, ‘long’ and ‘short rains’ respectively. In contrast, the rest of the country experiences one rainy season (*msimu*), which lasts from October to April (Zorita & Tilya 2002; Timiza 2011). If weather has any influence in childhood pneumonia, the strength of weather-pneumonia association would be expected to vary broadly according to these zones. The strength of weather-pneumonia associations between these climatic zones is explored in chapter 2. The chapter also

identifies and evaluates the strength of weather-pneumonia associations using statistical and Geographical-Weighted Regression (GWR) tools (Brunsdon et al. 1996; Charlton et al. 2009). Previous studies that have examined weather-disease relationships in Tanzania focused on cholera (Mhalu et al. 1987; Muruke et al. 2008) and malaria (Lindsay et al. 2000). This study appears to be the first to examine the influence of weather on pneumonia prevalence in Tanzania. It will provide the baseline for further research on the environmental drivers of childhood pneumonia in Tanzania and developing countries with similar climates.

1.1.2 Land Cover and Pneumonia

Land cover refers to the surface characteristics of the Earth's surface at a given location, while the closely-related concept of land use refers to the purpose human beings derive from the characteristics of the Earth's surface (Lambin et al. 2003). Understanding the link between land cover and disease is of increasing interest to researchers across academic disciplines. Different land cover types have been associated with either being sources or sinks of particulate air pollution, and by extension, the spatial distribution of child mortality from pneumonia. For example, past research has associated both urban and rural land-use/land-cover types with outdoor air pollution in Tanzania. Soil dust and biomass burning (Mkoma et al. 2011), proximity to roads (Jackson 2005), and slash and burn agricultural practices (Reyes et al. 2005) have been established as important outdoor sources of particulate matter in the air. The current dissertation research is also the first to directly examine the role played by land cover in the spread of pneumonia in

Tanzania. As such it contributes to the literature on the confluence of land science and environmental health.

1.1.3 Politics and Pneumonia

I use the framework of distributive politics (Brown & Staeheli 2003; Donovan & Duncan 2009) to explore the association between the prevalence of childhood pneumonia and the post-colonial (Young 2004) hegemonic party (Magaloni 2006) budget allocation practices. A hegemonic party is a dominant ruling party which gets re-elected through elections it cannot possibly lose (Hyde & Marinov 2011). Such dominant parties always strive to have formidable victories to portray an image of invincibility (Magaloni 2006). Tanzania's ruling party, *Chama cha Mapinduzi*, CCM ("The Party of Revolution") is described as a hegemonic party (Weinstein 2011), at worst, or as ambiguous (Diamond 2002), at best. After the previous general elections, CCM reduced financial allocations to local governments as a punishment for places that did not vote for CCM, and financially rewarded the places that did vote overwhelmingly for CCM (Weinstein 2011). In chapter 4 I compare the prevalence of childhood pneumonia between the "rewarded" and the "punished" locations. In so doing, this study contributes to the literatures of health and political geography, by linking politics and geography of health. Linking politics to the geography of health can help uncover winners and losers in society's seemingly apolitical themes (O'Brien & Leichenko 2003), an example of which is human health. In the situation of human health, investigating politics can reveal historical, social, economic and political factors embedded in an epidemiology (Mayer 1996). Moreover, at the local government-level low health budgets and "disproportionate funds allocation," among

other factors, were have influenced the rates of pneumonia in India (Deb et al. 2011). It is unclear what association the budget allocation has with pneumonia in Tanzania because the role of politics in childhood pneumonia in Tanzania at the local government level (which the current dissertation focuses on) remains largely unexplored.

1.1.4 Summary

The findings from this dissertation can also inform future research on pneumonia in Tanzania and in other countries with similar contexts. Of late, there is renewed interest in addressing childhood pneumonia in developing nations. The Pneumonia Etiology Research for Child Health (PERCH) project is one such initiative. PERCH evaluates the etiology of pneumonia in seven nations in order to understand the present and predict the future etiology of pneumonia (Adegbola 2012; Levine et al. 2012). Although Tanzania is not one of the PERCH sites, the findings from this study may be useful in understanding the spatio-temporal patterns of the etiology of pneumonia.

1.2 Objectives of Research

In summary the current study seeks to examine how the three factors of weather, land cover and politics affect the epidemiology of pneumonia in a nation with high rates of pneumonia—Tanzania. This dissertation seeks to answer the following main question: do climatological, land cover and political factors influence the spatial and temporal patterns of childhood pneumonia in Tanzania?

Specifically, this dissertation seeks to answer the following sub-questions:

- 1. Does weather affect the distribution of pneumonia in Tanzania, if so, how?*
- 2. Do land cover types affect the distribution of pneumonia in Tanzania, if so, how?*

What is the association between politically-influenced health budget distributions with pneumonia distribution Tanzania?

2.1 Introduction

In recent years, the link between weather and pneumonia has become an increasingly important topic in public health and meteorological sciences. While researchers in these fields have determined the biophysical mechanisms through which weather can influence pneumonia in laboratory experimental settings (Fuhrmann 2010), research outside controlled laboratory environments has shown mixed results. For example, researchers have associated different weather variables to pneumonia differently in separate locations. While previous studies have indicated cooler temperatures were associated with higher rates of pneumonia (Mäkinen et al. 2009; Oluleye & Akinbobola 2010; Tchidjou et al. 2010), other studies have also shown the rates of pneumonia increased with rising temperature (Onozuka et al. 2009). The results show weather-pneumonia associations beyond the experimental settings vary, and are difficult to generalize uniformly to other locations.

Weather conditions can affect the general patterns of spread of pneumonia by modifying the environmental factors conducive for wider distribution of microorganisms responsible for pneumonia (Fuhrmann 2010). The dispersion of pneumonia microorganisms between distant geographical areas may therefore be of more importance in deciphering patterns of the epidemiology of pneumonia than the transmission of pneumonia within small communities. To take a case point, in all reviewed studies (such as Mäkinen et al. 2009; Oluleye and Akinbobola 2010; Onozuka et al. 2009), the

researchers observed seasonal patterns on the incidence of pneumonia, suggesting important links to weather.

The link between weather and pneumonia is rooted in biological basis beyond empirical associations. Consider White's (2009) description of the link between pneumonia and sun's ultra-violet (UV) radiations: The sun's UV radiations are associated with improved immunity in the body, because they are associated with the production of vitamin D. Deprivation of sunlight can consequently reduce immunity. Furthermore, he describes the UV rays as having bactericidal effects, killing the microorganism exposed to the radiation. Sunshine, and the other weather types associated with it, can therefore be significant factors linked to pneumonia. For instance, UV radiation can also be absorbed by Ozone, the gas whose concentrations near the surface are linked to meteorological variables such as solar radiation, temperature and wind speed (Singla et al. 2012). In addition, overcast skies also interfere with the UV radiation (Mateos et al. 2009). The ultra-violet rays which are part of the sun's radiation, show a biophysical link that is influenced by weather. Moreover, apart from UV rays, results from experiments on animals have shown transmission of influenza virus is also affected by air temperature and relative humidity (Lowen et al. 2007). Other studies have reported that changes in atmospheric pressure can directly affect lung cells and therefore result in pneumonia (Scott et al. 1989). The other characteristics of weather such as temperature, rainfall, relative humidity, and wind speed have also been empirically linked to the spread of infectious diseases like pneumonia (Altizer et al. 2006). Moreover, weather has strong influence on urban heat island phenomenon (Oke 1982; Morris et al. 2001). Long-term

heat stress is known to compromise immunity against pneumonia (Tulapurkar et al. 2011).

Notably, the effects of weather on bacteria are more marked in the transmission of pneumonia between young children (White et al. 2009). This is to say, external factors that can be affected by weather are more important predictors of childhood pneumonia, compared to internal factors such as immunity changes due to weather. For these reasons, it is warranted to study the effects of weather on children's rates of pneumonia infection.

Despite weather being of importance to understand the broader effects on the differences in pneumonia prevalence across geographical areas (Fuhrmann 2010), few researchers have conducted studies over large geographical areas which have multiple climates. National studies have been done in the United States (Doshi 2008; Shaman et al. 2011), England (Langford & Bentham 1995) and Taiwan (Lin et al. 2009). The majority of other studies have focused on the town or province level (for example, Mäkinen et al. 2009; Oluleye and Akinbobola 2010; Onozuka et al. 2009), without observing the wider patterns of pneumonia distribution. This study uses Tanzania as an example of a vast country - about the combined size of Texas and Oklahoma (Lawrence, 2009) - that has varied climates. Temperature, sea level pressure, relative humidity, rainfall and wind speed are the variables used in this study.

Table 1, Table 2 and Table 3 show the distribution of weather characteristics in the 2004 - 2008 time period and the accompanying long-term mean values. There is appreciable of the weather variables, such as, variability of rainfall. Temperature ranges, on average, remain fairly constant, partly due to the tropical location of Tanzania.

Table 1: Aggregate Tanzania monthly pneumonia prevalence and weather for 2004

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Temperature (°C)	1260	11.4	17.0	28.5	21.8	2.4
Mean Minimum Temperature (°C)	1260	20.4	10.2	30.6	18.3	4.5
Mean Maximum Temperature (°C)	1260	20.6	15.8	36.5	25.3	4.4
Rainfall (mm)	1260	401.1	.3	401.4	63.6	69.9
Relative Humidity (%)	1260	59.7	35.5	95.1	70.7	12.1
Wind Speed (m/s)	1260	5.7	1.2	6.9	3.7	1.1
Sea Level Pressure (mb)	1260	10.8	1009.0	1019.8	1013.4	2.1
Prevalence (cases per 100,000)	1260	7329.1	.0	7329.1	812.4	724.7
Valid N (listwise)	1260					

Based on NCEP/NCAR dataset

Table 2: Tanzania's monthly long term mean (1968 - 1996) weather characteristics.

	Minimum	Maximum	Mean
Temperature (°C)	17.2	27.3	20.9
Rainfall (mm)	1.3	245.2	78.1
Relative Humidity (%)	42.0	92.5	73.9
Sea Level Pressure (mb)	991.4	1029.0	1010.9
Longterm Windspeed (m/s)	1.6	6.0	3.6

Table 3: Aggregate Tanzania monthly long term mean weather characteristics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Temperature (°C)	1260	10.2	17.2	27.3	20.9	2.4
Rainfall (mm)	1260	244.0	1.3	245.2	78.1	69.1
Relative Humidity (%)	1260	50.5	42.0	92.5	73.9	12.5
Sea Level Pressure (mb)	1260	37.6	991.4	1029.0	1010.9	10.4
Longterm Windspeed (m/s)	1260	4.5	1.6	6.0	3.6	1.1
Valid N (listwise)	1260					

Based on NCEP/NCAR dataset

According to a WHO / UNICEF report, pneumonia is responsible for the deaths of children globally more than any other disease (Wardlaw et al. 2006). The WHO / UNICEF report also show that 95% of pneumonia cases are in developing countries, with

74% of the new cases concentrated in 15 countries only. Tanzania is one of those 15 countries, and has an absolute number of new cases of clinical pneumonia estimated at 1.9 million cases per year or 0.33 cases per child per year (Rudan et al. 2008). Pneumonia is responsible for 11.2% under-five mortality in Tanzania (Samarasekera 2008), whereby the death rates are comparatively lower in the older age groups (Mayo 2007). Children under five years are the focus of this study.

So far, however, little attention has been paid to evaluating the weather-pneumonia association in a data-scarce, climatic heterogeneous, high-pneumonia-burden countries. Little is known of intra-country differences in the burden of pneumonia (Rudan et al. 2008). In addition, most weather-pneumonia studies have been conducted in data-rich developed countries (Crighton et al. 2008; Onozuka et al. 2009) where data of high temporal and spatial resolutions were available, and climate was largely homogeneous. In the few weather-pneumonia studies that were conducted in Africa, researchers also considered small geographical areas with uniform climate such as the cities of Nairobi (Ye et al. 2009) Yaounde (Tchidjou et al. 2010) and Lagos (Oluleye & Akinbobola 2010). Weather-pneumonia relationships in a data-scarce, climatic heterogeneous, high-pneumonia-burdened country such as Tanzania remain poorly understood.

2.2 Etiologic Agents

Viral and bacterial microorganisms are etiological agents of pneumonia. The microorganisms cause pneumonia, the inflammation of lungs characterized with symptoms of fever, chest pain and coughing, which can be treated with antibiotics in

about 10 to 21 days of therapy (Marrie 1994). Berman (1991) further emphasizes the importance of microorganisms in the spread of pneumonia and points out that out of all pathogens; bacteria and virus are the main pneumonia-causing microorganisms. Viral pneumonia usually affects the upper-respiratory tract, while bacterial pneumonia commonly affects lower respiratory tract. Bacterial pneumonia is the more debilitating in terms of fever and fatality than viral pneumonia. *Streptococcus pneumoniae* and *Haemophilus influenza* are the main bacteria responsible for pneumonia in developing countries (Berman 1991). In Tanzania, *Streptococcus pneumoniae* are the main bacterial agents for pneumonia in children (Uriyo et al. 2006).

Research shows that the survival of pneumonia-causing microorganisms when they are outside human body, depend upon weather, among other factors (Theunissen et al. 1993). The dependency of pathogens on favorable weather suggests that any weather conditions that affect the pneumonia-causing micro-organisms will tend to also have effect on pneumonia infections. In a nation with non-uniform climates, research on the influence of weather on the epidemiology of pneumonia is of practical and scientific value.

In Kilifi, Kenya, researchers demonstrated that the number of the pneumonia-causing bacteria extracted from healthy children, varied depending on rainy season (Abdullahi et al. 2008). Similarly, in Bondo district, also in Kenya, the rainy seasons were shown to be associated with peak pneumonia rates (Tornheim et al. 2007). In the tropics, rainfall is an important descriptor of seasonality. Empirical studies in the tropics demonstrate that there is an association between rainfall and pneumonia (Chan et al.

2002). Therefore, the spatial and temporal patterns of pneumonia are expected to differ in Tanzania if weather-based seasonality is an important predictor of pneumonia.

This study appears to be first to examine the influence of weather on pneumonia prevalence in Tanzania. Previous studies that have examined weather-disease relationships in Tanzania have focused on cholera (Mhalu et al. 1987; Muruke et al. 2008) and malaria (Lindsay et al. 2000). It is hoped that this study will spur further research of the environmental drivers of childhood pneumonia in Tanzania and other developing countries, and inform policy for practical actions.

In sum, this chapter seeks to answer the following main question: what are the spatial and temporal patterns of the associations between weather and pneumonia in Tanzania? Specifically, this study seeks to answer the following sub-questions:

- (i) Do the weather and pneumonia linkages vary according to climate-based spatial aggregations?
- (ii) Do the weather and pneumonia linkages vary according to climate-based temporal aggregations?
- (iii) What are the linkages between weather and pneumonia, and robust are they?

This being the first study to investigate weather and pneumonia in Tanzania, contributes to form baseline understanding of the association between weather and pneumonia. The current research also benefits from the experiences from previous research on weather and other diseases in Tanzania. Previous studies have shown weather conditions are extremely variable in Tanzania. In 1997 - 98, the El Niño-Southern

Oscillation (ENSO) event in South Pacific is a good example. The El Nino resulted in strong rainfall in most parts of Tanzania. Yet, the effects of increased rainfalls on malaria varied across Tanzania. For example, malaria cases decreased in villages along the slopes of Usambara Mountains, despite appreciable increase in rainfall (Lindsay et al. 2000). By contrast, in the hilly Kagera region, malaria increased because of El Nino, as it was also the case in the mostly flat Morogoro region. However, in Kagera, the effects of malaria on birthweight were clearly seen following the 1997 - 1998 ENSO event, while in Morogoro the effects were hardly discernible because of the endemicity of malaria in the region (Wort et al. 2004). That is, the same ENSO event increased rainfall in all the three regions. Yet, in two regions, Kagera and Morogoro, malaria incidence increased, whereby in Tanga region, the malaria cases decreased. The effects of malaria on birthweight were seen in only one region, Kagera, where malaria is not endemic. There were no notable differences in the birthweights in Morogoro region. This reinforces the need for case studies to ascertain the effects of weather on disease.

Childhood Pneumonia remains a burden in Tanzania, and is one of 13 diseases recorded in the surveillance database (Rumisha et al. 2004). For example, in Bukoba district, Kagera region; and in Tanga district, Tanga region pneumonia is one of the top-three diseases recorded in the newly updated health database, the other two top diseases being malaria and diarrhea (Rumisha et al. 2004). Exploring the driving factors for pneumonia will therefore go long way towards saving more lives of children, whereas focusing on the role of meteorology contributes to this purpose.

Tanzania is also experiencing changing climates, with reneging snows of Mount Kilimanjaro as a well-known example (Shemsanga et al. 2010). To prepare for climate variability and its effects on human health, Tanzania's ministry of health has created the integrated diseases surveillance response system (Shemsanga et al. 2010). Knowing the spatial and temporal patterns of the distribution of pneumonia can help to plan for the actions required to deal with outbreaks. One such action is vaccinating the vulnerable populations.

Literature shows that even when there is an outbreak, vaccinations are an important strategy to deal with pneumonia. Vaccinating against *Streptococcus pneumoniae* in Tanzania was seen as a cost-effective measure on monetary and quality of life terms compared to the alternatives of leaving the *status quo* as it is (Tasslimi et al. 2011). In another example, an outbreak of pneumonia in Canada vaccinations against *Streptococcus pneumoniae* were used as the intervention (Romney et al. 2008).

Therefore, the knowledge of the seasonality of pneumonia incidences can help to prepare health personnel how to respond to surges of pneumonia prevalence. Research further shows that vaccinations are also important because some strains of *Streptococcus pneumoniae* are resistant to some antibiotics. In one study, *Streptococcus pneumoniae* bacteria were extracted from 35% of healthy under-five sampled children in Dar es Salaam, Tanzania. These bacteria were tested for resistance against common antibiotics used to treat pneumonia. The isolated *Streptococcus pneumoniae* bacteria showed resistance to one or more type of antibiotics (Moyo et al. 2012). The findings of the current study therefore have implications on the surveillance of childhood pneumonia in

Tanzania. With more understanding of the patterns of pneumonia incidences, the ministry responsible for health and the health facilities can collaborate closely in monitoring pneumonia. This is even more important, when considering that not many of the Tanzania's healthcare facilities have the capabilities or resources to routinely conduct laboratory-based surveillance for childhood pneumonia. In East Africa, "the majority of hospitals had not isolated *S. pneumoniae* for years" (Amos et al. 2009).

2.3 Tanzania: Background

Tanzania is located in South-Eastern part of Africa. The northern frontier of the country cuts across middle of Lake Victoria just below the Equator at 1°S, bordering Kenya and Uganda. Ruvuma River which is the borderline between Tanzania and Mozambique is located at about 12°S. To the east there is the Indian Ocean at about 40°E, while to the western border is located at about 30°E in the middle of Lake Tanganyika between Tanzania and The Democratic Republic of Congo (DRC). Tanzania also shares borders with Malawi, Zambia, Rwanda and Burundi.

'Tanzania in Figures 2010' (National Bureau of Statistics 2011) summarizes the geography and people of Tanzania. While the 2002 official census of Tanzania counted 33.5 million people, there were an estimated 41.9 million people in Tanzania by 2010. The population densities were 20 and 39 persons per square kilometer in 2002 and 2010 respectively.

Tanzania demographic and health survey 2010 (National Bureau of Statistics & ORC Macro 2011) provides further insight of the state of health in Tanzania. Three-quarters of all children aged between 12 to 23 months were fully immunized. Overall

majority (97%) of the children were vaccinated at least against one disease. Four percent of children under age five had suffered from acute respiratory infection (ARI) within two weeks preceding the survey, while majority (71%) of the children was taken to a health facility. The infant and the under-5 mortality rates of 51 and 81 per 1,000 live births respectively are still on the higher side.

Overall, the climate of Tanzania is tropical. Table 2 shows Tanzania's aggregate monthly long term mean (1968 - 1996) weather characteristics. The values are from GIS analysis of data obtained from NCEP Reanalysis data (Kalnay et al. 1996), provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at <http://www.esrl.noaa.gov/psd/>. On average, a typical month has 20.9°C mean monthly temperature, 78.1 mm of rainfall and 73.9% relative humidity. The maximum and minimum values suggest notable variations of climates within the nation. The variations of climate within Tanzania can be seen in maps of the climate variables in Tanzania's administrative regions (*mikoa*), based on GIS analysis of data obtained from NCEP/NCAR reanalysis dataset. The map of long-term mean monthly temperature shows the influence of proximity to Indian Ocean to the general trend of climate, depicted in Figure 1. Generally, the eastern regions near the Indian Ocean are warmer than the hinterland regions. Figure 2 shows long term mean monthly relative humidity. Again proximity to the Indian Ocean shows its influence.

Rainfall regimes in East Africa exist in two main seasons: *masika*, the more reliable 'long rains' season, from March to May, and *vuli*, the more variable 'short rains' season from October to November (Camberlin & Philippon 2002). The northern parts of

Tanzania and along the North coastal areas experience the bimodal rainy seasons of *masika* and *vuli* ‘long’ and ‘short’ rains respectively. In contrast, the rest of the country experiences one rain season (*msimu*) which starts from October to April (Zorita & Tilya 2002; Timiza 2011). The rainy seasons are known to impact the lives and livelihood of people in Tanzania, and the seasons have strongly been linked to the patterns of diseases such as malaria (Kijazi 2010).

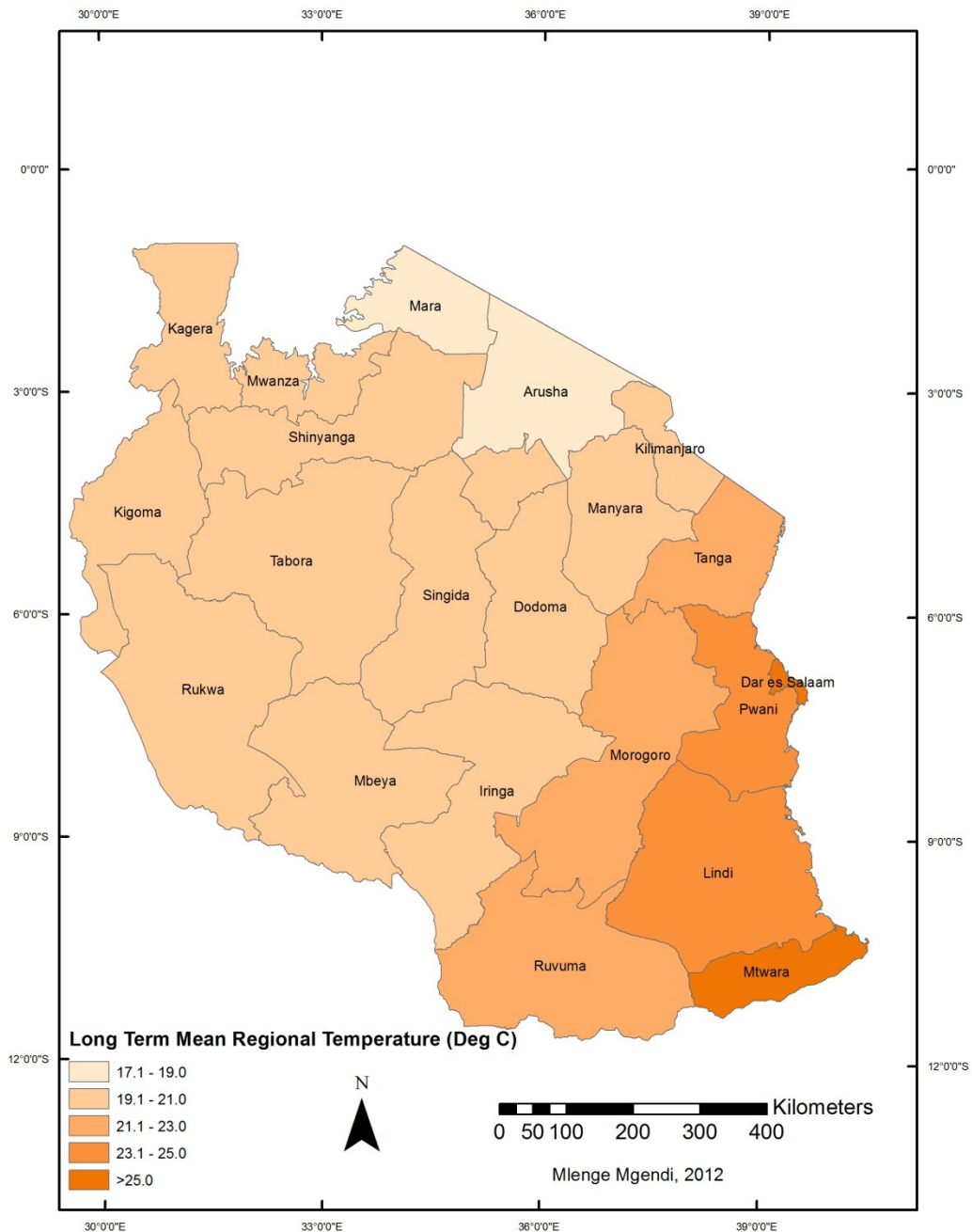


Figure 1: Long term mean (1968 – 1996) temperature in Tanzania’s administrative regions (*mikoja*)
 This and following weather maps above do not show water bodies and isles. [Data source: NCEP/NCAR reanalysis].

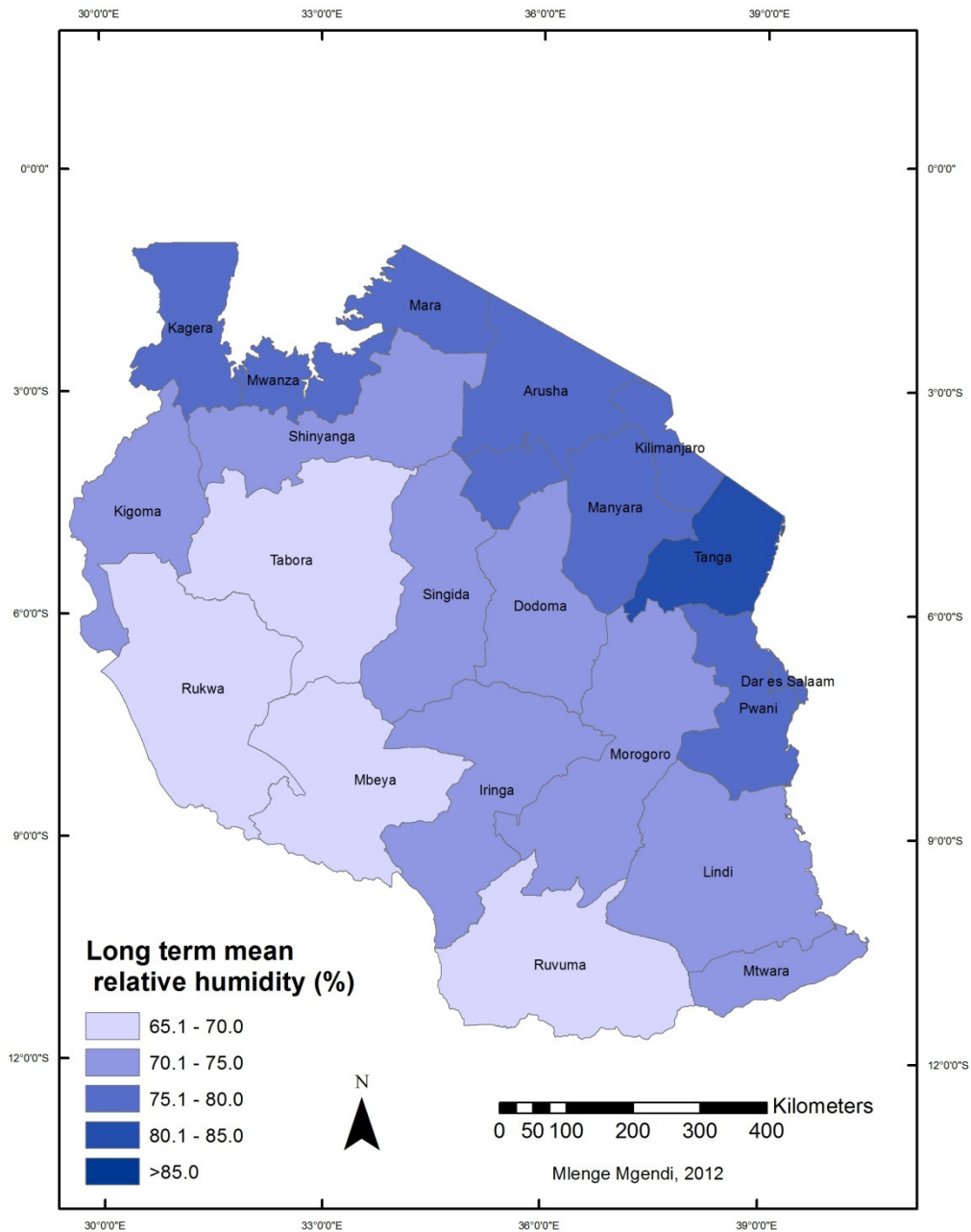


Figure 2: Long term mean (1968 – 1996) relative humidity in Tanzania’s administrative regions (*mikoa*).

[Data source: NCEP/NCAR reanalysis].

The eastern regions near the Indian Ocean, and the regions near Lake Victoria to the north, are more humid than the inland regions. The mean monthly rainfall is similarly unequally distributed as shown in Figure 3 below.

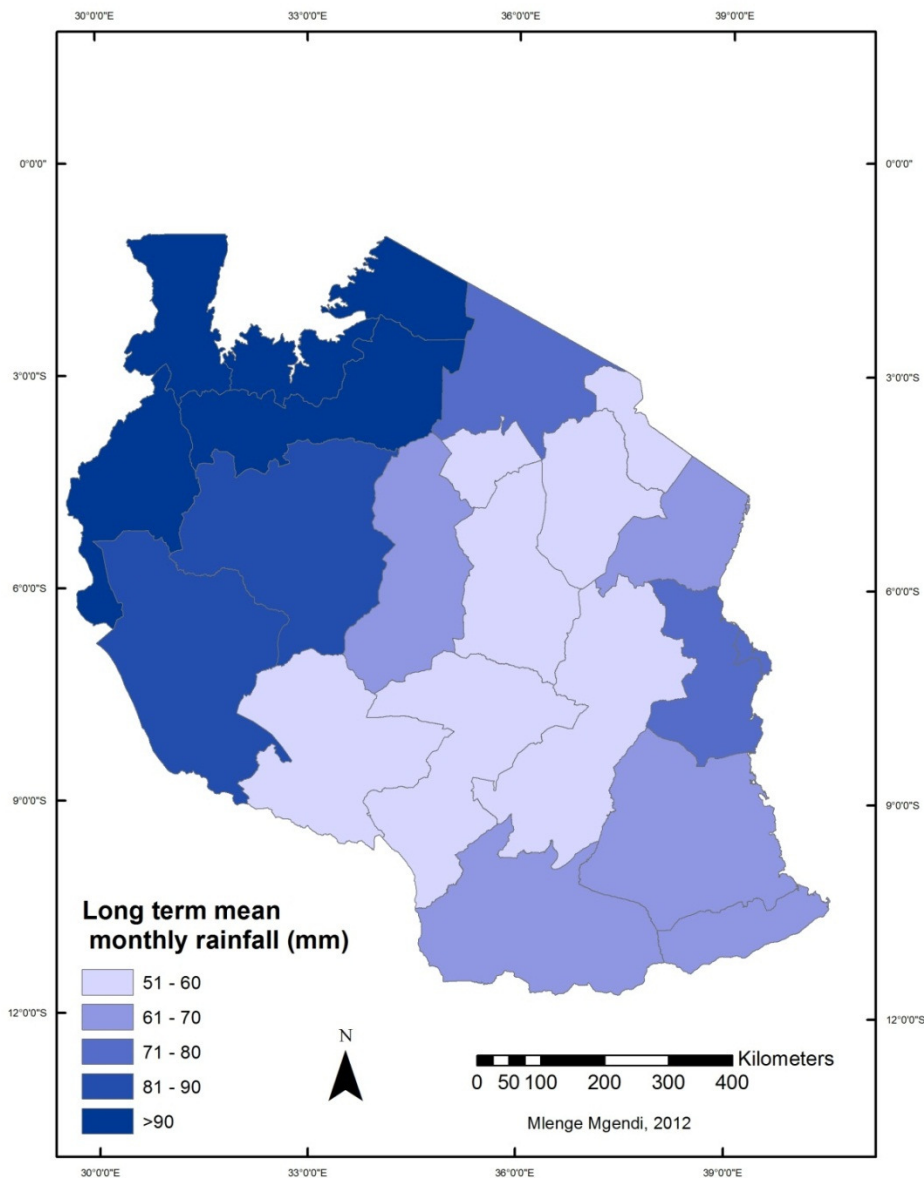


Figure 3: Long term mean (1968 – 1996) monthly rainfall in Tanzania’s administrative regions (*mikoa*).

[Data source: NCEP/NCAR reanalysis].

2.4 Data and Methods

It is challenging to acquire data for developing nations like Tanzania. The current study goal of exploring spatial and temporal dynamics of pneumonia is such data-intensive application. To discern the patterns, weather and pneumonia data of synchronized spatio-temporal resolution were needed.

2.4.1 The Weather Data

Two sets of weather data were obtained: station and reanalysis datasets. The station-dataset contained data from individual weather stations. Conversely, the reanalysis-dataset was areal-based.

The station dataset was obtained from two sources: directly from the Tanzania Meteorological Agency (TMA) and from Global Surface Summary of Day (GSOD) Data (<http://www7.ncdc.noaa.gov/CDO/cdoselect.cmd?datasetabbv=GSOD&countryabbv=&geo-regionabbv>). The GSOD dataset is also from TMA through World Meteorological Organization (WMO). Processing these station data required filling-in the missing values, interpolating from point data to surface map, and thereafter apportioning the values to the administrative regions. Each step of this process modified the original values and hence raised concerns about difficulty in replicating the study due to the deviations from the directly observed data.

The National Centers for Environmental Prediction / National Center for Atmospheric Research (NCEP/NCAR) Reanalysis dataset was selected because it had all the variables of interest for the study. The NCEP/NCAR variables also spanned the 2004

to 2008 time period available as gridded - areal in nature - allowing for preservation of the original data prior to the one-step apportionment to the administrative regions.

The NCEP/NCAR dataset is derived from global weather observations and models (Kalnay et al. 1996) as might be the case for other global datasets, the NCEP/NCAR dataset had the advantage of more coverage of Africa as compared to the other datasets (Collins 2011). Another added advantage of the NCEP/NCAR dataset, is that a number of past studies have used NCEP/NCAR datasets to examine climatological applications in Tanzania. One such study reported that although the NCEP/NCAR dataset systematically underestimated bi-modal rainfall during peaks of rainy seasons, it was nevertheless able to reproduce the mean seasonal rainfall cycle and that NCEP/NCAR estimations were closer to observations in uni-modal rainfall areas (Poccard et al. 2000). The analysis by Poccard et al (2000) also appeared to show that as years went by, even in locations it was underestimating, the NCEP/NCAR dataset was closer to observations compared to the early years. Other researchers similarly compared NCEP/NCAR with station data (Zorita & Tilya 2002), then utilized NCEP/NCAR monthly precipitation, air temperature and other variables to characterize the bi-modal rainfall in northern Tanzania.

Therefore, despite its rather coarse spatial resolution (pixel size of 2.5 degree latitude and longitude), NCEP/NCAR dataset appears to sufficiently characterize the variability of weather conditions in Tanzania. In this study's preliminary analysis, the NCEP/NCAR also showed statistically-significant correlations to the station weather data obtained from the Tanzania Meteorological Agency (Figure 4). The Pearson correlation

coefficient (0.74) was statistically significant at $p=0.01$ two-tailed. While the monthly weather data were fairly coarse temporally, they still gave the impression to sufficiently capture the short term weather variations (bursts of cold or wet or stormy weather) that may trigger pneumonia outbreaks. The NCEP/NCAR reanalysis dataset was selected for these reasons for use in the study instead of the station data.

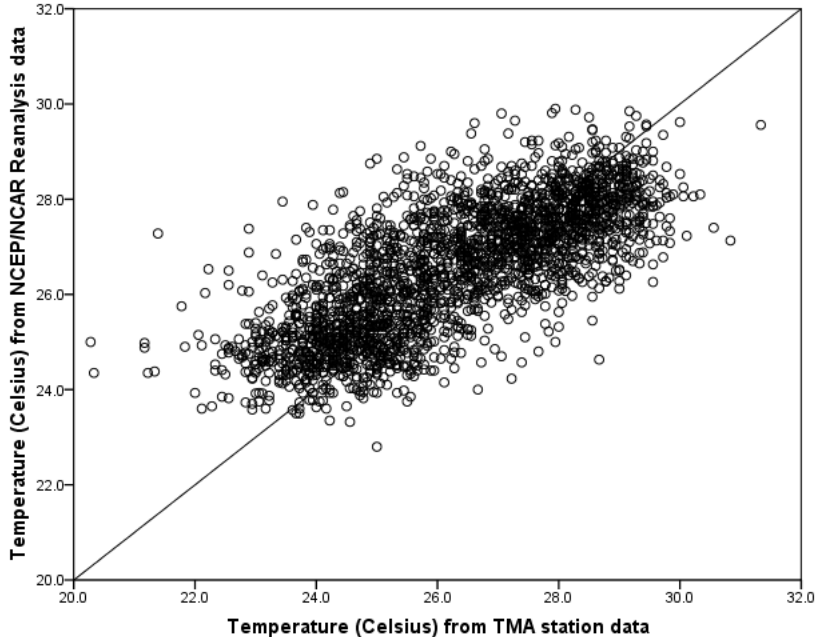


Figure 4: Comparisons between temperature records from NCEP/NCAR Reanalysis and Tanzania Meteorological Agency Dar es Salaam Airport station.

2.4.2 Pneumonia Data

The monthly pneumonia cases data covering the time period from 2004–2008 in the 21 “regions” (*mikoa*) were obtained from The Ministry of Health and Social Welfare (MoH&SW). A region (*mkoa*) is the Tanzania’s second-level administrative grouping. Zanzibar is part of the United Republic of Tanzania, and is semi-autonomous with a separate ministry of health. Zanzibar was excluded from this study. The Tanzania’s under-five population data needed for the calculation of pneumonia prevalence were extracted from population projections based on the 2002 Tanzania’s last national census (National Bureau of Statistics 2006).

The National Bureau of Statistics (NBS) projected the 2002 census data into multiyear estimations, adjusting for factors such as mortality and fertility rates, socio-economic factors and life expectancy at birth, the factors which affect mid-year base population. The monthly pneumonia data obtained covered the 2004 to 2008 time period for each region. No further attempt was done to interpolate from the projected yearly population data to the monthly population data. The regional monthly pneumonia prevalence values were then computed as the number cases per 100,000 children.

The pneumonia data represented only the children who accessed formal health care that were diagnosed with any form of pneumonia. While this limitation might lead to bias by missing out the children who were solely treated using traditional medicines, it is fair to speculate that the dataset does represent the overall trends of the incidences of pneumonia. One reason for this cautious optimism is that those parents who opt for the traditional medicines have been known to also seek hospital care if the condition of the

sick child does not improve with the traditional medicine or for the diseases such as pneumonia which have fever as one of the symptoms (Gilson et al. 1994). It is also plausible to attribute the *changes* in the reported cases of pneumonia at a particular location to the factors other than the access to health facilities, because the choice between traditional and biomedicine treatment is fairly constant over short period of time.

2.4.3 Identifying Missing Data

Some of the pneumonia data points obtained from the ministry of health had to be discarded as missing. The 2006 data for Shinyanga region (12 data points), and January 2006 for Arusha region (one data point) were regarded as missing because the accompanying metadata noted they represented only a geographical portion of these regions. The accuracy of April and May 2005 data for Dodoma region was also suspect because the two data points were exactly the same in terms of number of children who fell ill and those who lost their lives, and were therefore also marked as missing.

The 1245 data points were pooled from remaining from the original 1260 in order to determine outliers by using a criterion of three standard deviations from mean (Wiggins 2000). The data that fell outside of the three standard deviations of monthly prevalence were considered to be the outliers. There were 15 outlying values identified in seven regions: Dodoma (February 2005, September 2008, July 2006, September 2007 and December 2006), Kagera in April 2005, Mara in November 2007, Mbeya (August 2004 and August 2008), Morogoro (September 2004 and July 2006), Ruvuma in April 2005, and Shinyanga (January and May 2007; and January 2008). These outliers were excluded

from further analysis. Some of these prevalence outliers were too large compared to the immediate preceding and following months, yet the number of deaths from pneumonia remained fairly constant in the same consecutive months. These anomalous data points might have been caused by data entry errors propagated through the chain of reporting. Nevertheless, the outliers represented only 1.2% of the overall dataset, hence their removal was deemed not to be highly detrimental.

2.4.4 Replacing Missing Values

In total, 2.4% of the original pneumonia 1260 monthly data points were missing or identified as outliers. The NORM software standalone version 2.03 (Schafer 1999) was applied to replace the missing values, by using multiple imputation method. The multiple imputation method can be seen as a systematic way of infilling missing data, achieved by first analyzing what information can be deduced by the existing data, before using computations to estimate missing values without distorting the inference that could be reached (Wayman 2003).

The multiple imputation method was selected because literature suggested it was preferable to use it instead of mean or median replacement alternatives (Zhou et al. 2001). A number of public health and climatology researchers have also found the multiple imputation method to be more robust than the mean or median replacement alternatives (such as Hui et al. 2004; Zhou et al. 2001). The multiple imputation methods have been described as “statistically principled” with preservation of tendencies of the dataset (Wayman 2003).

Additional sensitivity tests were conducted to investigate how replacing the missing data might influence the results. The tests were done by comparing the multiple imputation method against other options of handling missing data: listwise deletion and mean replacement. Original values were randomly removed from a complete dataset, and the three methods were alternately applied to handle the missing data. Results (refer to the Appendix B) confirmed that the multiple imputation method was the most robust and provided the same inferences as the original (i.e., the complete) dataset. The map of mean monthly pneumonia prevalence from 2004 to 2008 is shown in Figure 5. The map shows pneumonia prevalence had notable spatial variability within the nation for the five-years period from year 2004 to 2008.

2.4.5 Associating Weather with Pneumonia: an Ecological Design

An exploration of weather-pneumonia relationship can take many forms in terms of the timing of the study, sampling design and the investigated person (i.e., whether an infant child, older child or an adult). The study timing can be prospective in which the participants are observed for future pneumonia cases (such as, Mäkinen et al. 2009) or retrospective in which the past pneumonia cases are recalled (for example, Crighton et al. 2007). The sampling design has to choose data from a subset of the population (for instance, Mäkinen et al. 2009) or using the entire population (such as, Crighton et al. 2007). Thirdly, choice has to be made between an individual (such as, Mäkinen et al. 2009) or group of individuals (for instance, Crighton et al. 2007) as the focus of analysis.

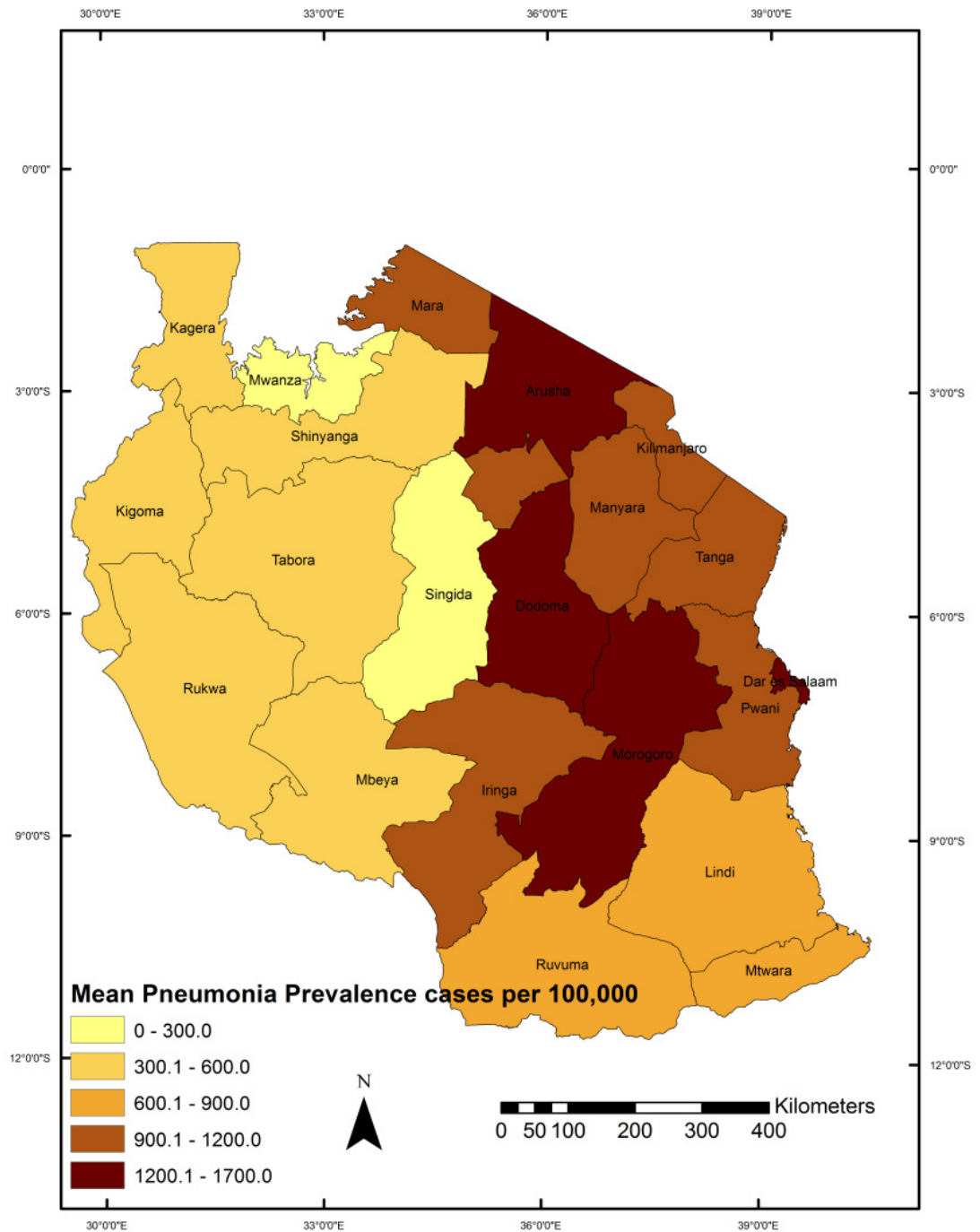


Figure 5: Mean monthly childhood pneumonia prevalence (cases per 100,000 children) in Tanzania for the years 2004 to 2008.

A study is at the ecological-level when the groups of people rather than individuals are chosen as the unit of analysis. While the findings at the group-level cannot reliably be extended to an individual in the group to avoid committing “ecological fallacy”, ecological-level studies are nonetheless useful for providing context to the cause and effects of a disease (Schwartz 1994). Due to the constraints inherent in the available data, the current research used retrospective, population-based and ecological-level as the method of analysis.

This study set out to find association between weather and pneumonia in Tanzania. In the first step, Geographic Information Systems (GIS) and statistical analyses were used to collate, characterize and summarize the monthly pneumonia prevalence and the corresponding monthly weather. Then, the effects of the fixed factors of location and time were explored by using univariate ANOVA. The stepwise regression analyses of weather against pneumonia were also run in considerations of both space and time. Finally, the Geographical-Weighted Regression (GWR) tools (Brunsdon et al. 1996; Charlton et al. 2009) were used to conduct more robust spatial analyses. The methods of data analysis are explained in further details below.

2.4.6 Statistical Analysis

The statistical analysis consisted of processing the weather and pneumonia data covering 60 months starting from January 2004 to December 2008 time period. Stepwise regression was performed using SPSS/PASW 18 in order to determine the weather-pneumonia associations across the different spatial and temporal scales. The weather-pneumonia temporal associations were sought for each month from January to

December, each season (defined by rainfall regimes of “short rains”; “long rains” and dry seasons), by quarters and by grouping months determined using clustering. The weather-pneumonia spatial associations were also sought for each administrative region and for groups of regions that were grouped by meteorological zones as used by the Tanzanian Meteorological Agency (<http://www.meteo.go.tz/wfo/index.php>). As a guard against multicollinearity, the Variance Inflation Factor (VIF) values were considered. Only models that had a VIF values less than 10 were reported.

The mean monthly values and departures from long-term mean monthly values (anomalies) for each of the weather variable were regressed as independent variables to the pneumonia prevalence dependent variable. The regression analysis was meant to provide insight as to the empirical importance of weather as a driver of pneumonia prevalence. In so doing, the meteorological factors and their relationship to pneumonia were represented by the regression model. One of the common ways of testing the robustness of a regression model is to use part of the data to generate the model and test the model against the rest of the data. However, due to the limited amount of monthly prevalence data (60 months for each region (*mkoa*), the bootstrap technique was used to evaluate the performance of the selected models by sampling the data with replacement and hence testing the robustness and stability of the statistical relationships (such as, Efron and Tibshirani 1993; Quiring 2004). The procedure generated 1,000 samples of monthly weather and pneumonia data randomly drawn from the original dataset. The 1,000 regression models were used to estimate the regression parameters. The resulting parameter estimates were within the 95% confidence limits of the original model,

suggesting the model was robust. While the above mentioned ordinary least square (OLS) regression was repeated at the varied extents in space and in time, OLS only provided basic considerations of spatial locations.

The Geographical-Weighted Regression (GWR), tools on the contrary provides an opportunity to conduct more robust spatial analyses. Geographically Weighted Regression (GWR) acknowledges a possibility that the regression coefficients are not uniform across the study area. Brunsdon et al. (1996) describe this possibility of variation across the space as spatial nonstationarity of regression models. Nonstationarity may be caused by differences in culture, differences in situation and other factors that may not be universally similar in whole of the study area. In the study, for example, the factors may be climate, urbanization, slash and burn agricultural practices, daily temperature range and general social and economic factors.

Ordinary Least Square (OLS) regression makes assumptions of data independence. In case of geographical data such assumption may not always be true. GWR is useful in the situations where regression parameters show strong spatial patterns (Charlton et al. 2009).

Regression's main purpose is to predict values where none existed. GWR adds reliability to such predictions, especially if the underlying data do not fit with the main assumptions of OLS regression. GWR is useful in evaluating prediction uncertainties (Harris et al. 2011).

For example, researchers in Massachusetts used GWR to explore the association between wealth of the local population and land cover represented by impervious surface

/ green vegetation (Ogneva-Himmelberger et al. 2009). Their analysis was empirical and ecological at the census block group level. GWR showed the strength of impervious surface as a predictor of the wealth of population varied over the study area.

The variations of strength of regression model were also demonstrated in another study in Asia. GWR methods were used to explore the association of dengue fever , population and weather in Malaysia. The strengths of association found were shown to vary between the various locations (Seng et al. 2005).

Unlike the ordinary least square regression, in GWR the regression coefficients can vary across the space. Maps can then be produced that show how the regression parameters vary in space. Hence, instead of just one global equation that spans the entire study area, GWR results into a number of local equations in the same study area. GWR is another form of multiple regressions that consider spatial heterogeneity.(Brunsdon et al. 1998).

In summary, GWR handles the shortcomings of using ordinary least square (OLS) regression analysis (Charlton et al. 2009). To deal with the spatial heterogeneity, the GWR make use of bandwidth to assign weights to different parts of the study area (Byrne et al. 2009). With such accommodations to the spatial variations, localized regression parameters are generated and the strengths of associations can be explored across the study area.

The GWR method has, however, attracted some criticism. An example is that the GWR implementation in ArcMap (ESRI) software uses blackbox approach with fewer options to the user, and does not estimate the global parameters nor report their

statistical significance (López-Carr et al. 2012). Probably the criticism has been on the harsher side because the GWR method is explained in details elsewhere (Brunsdon et al. 1998; Charlton et al. 2009). Moreover, the website of ESRI, the makers of ArcMap software (<http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//005p00000021000000>) provides more information about the implementation of GWR in the Arcmap 10 software. The options provided to operate the GWR tool are explained and some examples given. The GWR analyses in this study were implemented in ArcGIS 10 software from ESRI.

2.5 Results

The 2004 - 2008 mean monthly prevalence of childhood pneumonia in Tanzania ranged from 80.3 to 1640.3 cases per 100,000 children. The nation's mean monthly prevalence was 812.4 (95% confidence interval: 772.4 - 852.5) cases per 100,000 children. That is, nationally, there were yearly 9,748.8 episodes of pneumonia per 100,000 under-five children. Expressed differently, there were 0.10 episodes of pneumonia per child-year (ecy) in the 2004 - 2008 time period. The number of episodes of pneumonia per child per year found in the current study is lower than the 0.33 ecy value predicted by Rudan et al. (2008).

2.5.1 National Extent

In the current study, the effect of geographical location (regions) and time (month) on the prevalence of pneumonia were examined by using the univariate analysis of variance with Tukey adjustment for multiple comparisons. The analysis showed that

both month ($p < 0.001$, power = 0.996) and region (*mkoa*) ($p < 0.001$, power > 0.999) were important in determining the prevalence, while interaction between month and region was unimportant ($p > 0.999$, power > 0.999); $R^2 = 0.336$ (Adjusted $R^2 = 0.320$). Overall, the location and time explained 32% of the variations in the nationwide pneumonia prevalence.

Subsequently, in addition to running the stepwise regression analysis at the nationwide scope, the process was repeated using different spatial and temporal groupings of the data. Mean monthly temperature, mean minimum monthly temperature, mean maximum monthly temperature, relative humidity, sea level pressure, wind speed, precipitation and their departures from long term mean values (“anomalies”) were the independent variables in the stepwise regression analysis on pneumonia prevalence. The level of significance of $\alpha = 0.05$ was used in all of the analyses. The most parsimonious of the statistically-significant models was selected if the additional variables did not bring much difference in R^2 . The number of times a weather variable appeared in the statistically significant models at different temporal and spatial scales was used to determine importance of the variable relative to the other weather variable in this study.

The relative importance of each weather variable was evaluated depending on the number of times the variable appeared in the statistically-significant regression models in the various spatial and temporal configurations. Relative importance of the weather variables in this study depicted as the number of times a variable appeared in the statistically significant models at the different temporal and spatial extents.

The administrative regions at the national extent pooled in time shows temperature to be the most important weather factor affecting pneumonia. The pneumonia cases at the monthly temporal resolution when were pooled spatially in all regions (*mikoa*), the atmospheric pressure appeared in the most models. Overall, the atmospheric pressure and temperature weather events were the most important predictor weather conditions, with relative humidity closely following (Figure 6).

That is, when disregarding the time component, temperature (minimum, mean, maximum and anomalies) was frequently selected as an important variable across different regions. Out of 21 regions, 15 had statistically significant regression models where the maximum variance explained was about 20%. On the other hand, atmospheric pressure (mean and anomalies) was the most frequent variables in the significant models in the different months of the year, when the regions were pooled together. This relative importance of the variables suggests that at a given year, temperature is the most important driver of weather-pneumonia interaction at different administrative regions (*mikoa*). Conversely, it also suggests that atmospheric pressure is the most important variable explaining the effects of weather on pneumonia at a given administrative region (*mkoa*) in different months.

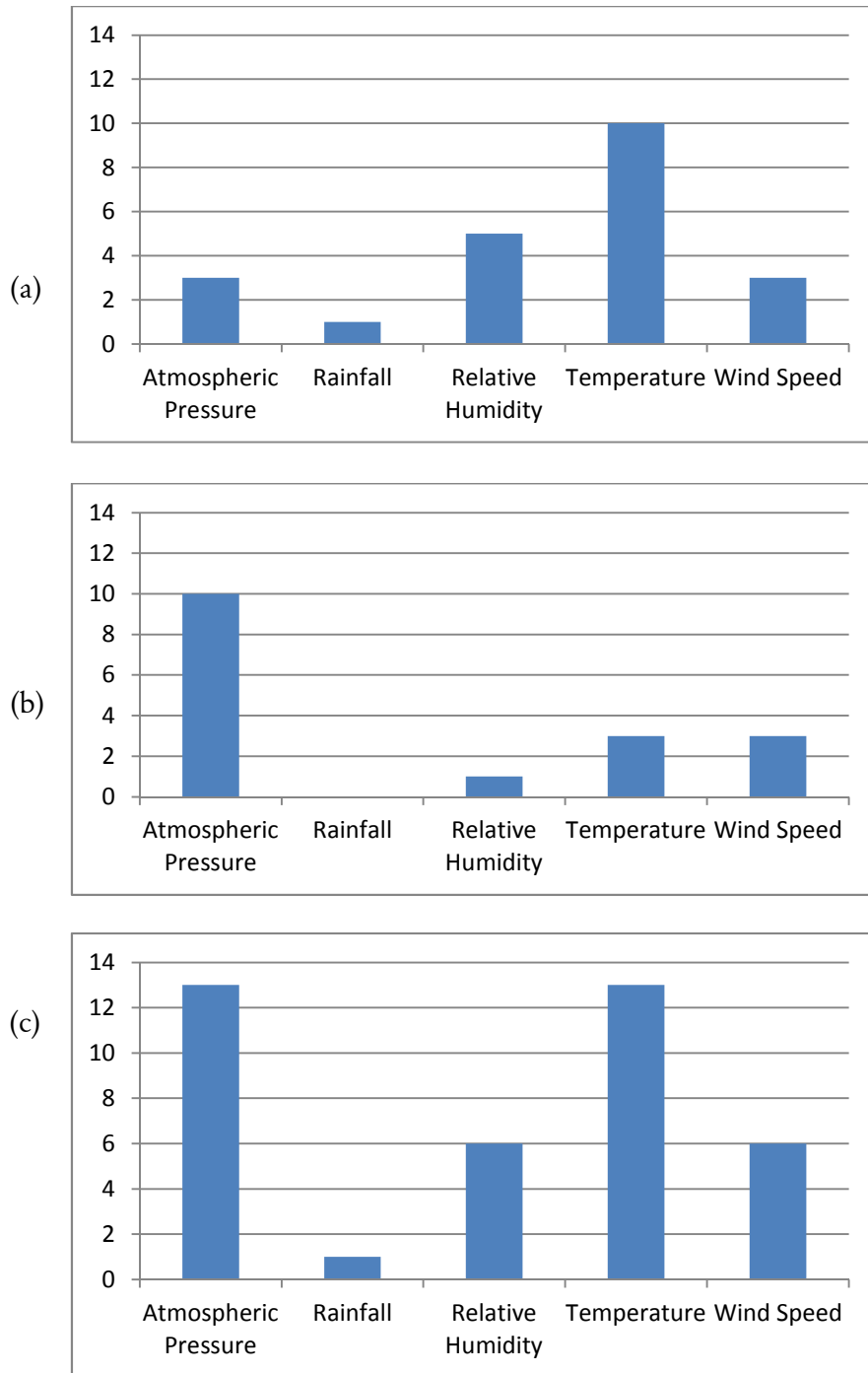


Figure 6: Relative importance of the weather variables in this study depicted as the number of times a variable appeared in the statistically significant models at different temporal and spatial scales.

Pooled (a) both in space and time (b) only spatially (c) only temporally

2.5.2 Climatic Zone Analysis

The Tanzania's Meteorological Agency (TMA) divides the nation into seven climatic zones. The regression analysis was repeated, confined to regions that roughly define each zone. The weather-pneumonia associations varied according to the climatic zone.

Weather variables explained 41% of pneumonia prevalence in the zone of South-Western Highlands as shown in Figure 8. The departures from the normal atmospheric pressure values (mb), wind speed (m/s), relative humidity (%) and rainfall (mm) were the most important variables in determining the prevalence of pneumonia expressed as cases per 100,000 children (Adjusted $R^2 = 0.41$, $p < 0.001$). Bootstrapping analysis showed the model was robust.

Pneumonia prevalence was associated with increased relative humidity and decreases in sea level pressure, wind speed and rainfall in the South-Western Highlands zone. As the Figure 8 shows, the performance regression models for the climate zones in Tanzania varied among the climatic zones. The weather in the South-Western Highlands zone explained about 40% of variance in the annual number of pneumonia cases per 100,000 children. The proportion of the variance attributable to weather was smaller in the rest of the zones as visually shown in Figure 7 and Figure 8.

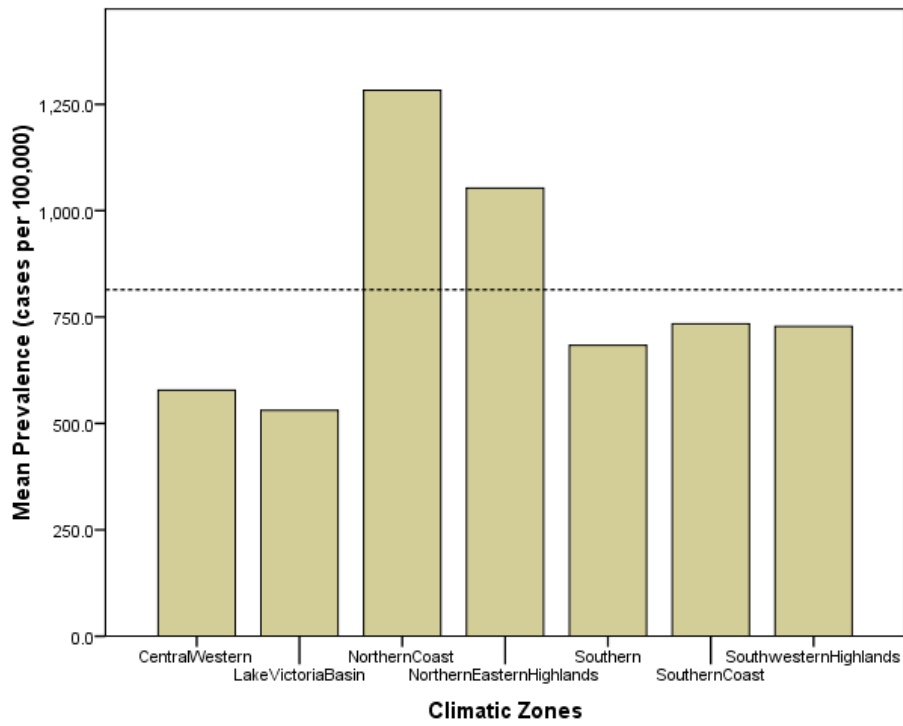


Figure 7: The distribution of pneumonia prevalence (cases per 100,000 children) per climatic zone. The dotted line shows the national average.

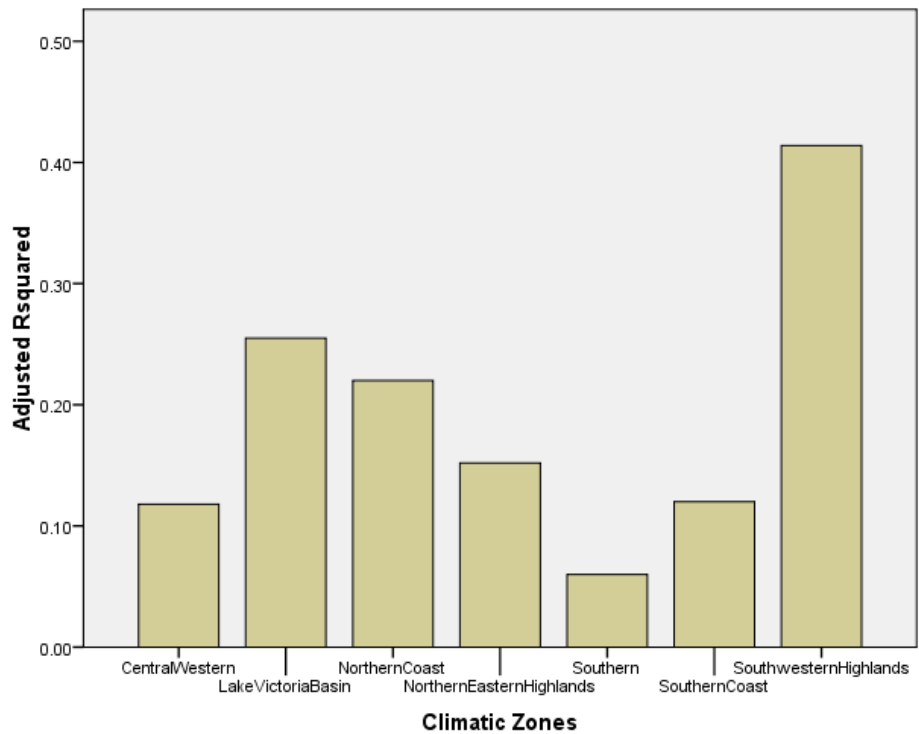


Figure 8: Regression model performance for the climate zones in Tanzania. Weather in the South-Western Highlands zone explained about 40% of variance in the annual number of pneumonia cases per 100,000 children.

However, the Tanzania's climatic zones are generally divided into the two main rainfall regimes: unimodal and bimodal. Based on the TMA map of climatic zones and rainfall regimes created by Timiza (2011), I assigned each region on whether it is in bimodal or unimodal climate. Dar es Salaam, Tanga, Kilimanjaro, Arusha, Manyara, Shinyanga, Mwanza, Mara and Kagera were deemed to be within the bi-modal rainfall regime. The rest of the regions were categorized to be in the unimodal rainfall regime. Figure 9 shows the administrative regions and the rainfall regime they fall into.

As explained before, the seasons in the two regimes are distinct. In the unimodal area, there are two main seasons: the rainy season (*msimu* rains) and the dry (*kiangazi*) season. The bimodal regions have two rain seasons of 'long' and 'short rains' (*masika* and *vuli*) and an interlude of dry (*kiangazi*) season. The seasons do not wholly overlap between the rainfall regimes. Therefore, I split the administrative regions into two pools of regions based on the rainfall regimes. I also split the months according to seasons in the rainfall regimes, shown in Table 4.

Table 4: Summary location and timing of the two main rainfall regimes in Tanzania.

Rainfall Regime	Season	Start	End	Local Name
Bimodal				
Dar es Salaam, Tanga, Kilimanjaro, Arusha, Manyara, Shinyanga, Mwanza, Mara, kagera	'Long rains'	March	May	<i>Masika</i>
	'Short rains'	October	November	<i>Vuli</i>
	Dry	December	February	<i>Kiangazi</i>
		June	September	
Unimodal				
The rest of regions	Rainy	October	April	<i>Msimu</i>
	Dry	May	September	<i>Kiangazi</i>

Based on existing literature (Camberlin & Philippon 2002; Zorita & Tilya 2002; Timiza 2011).

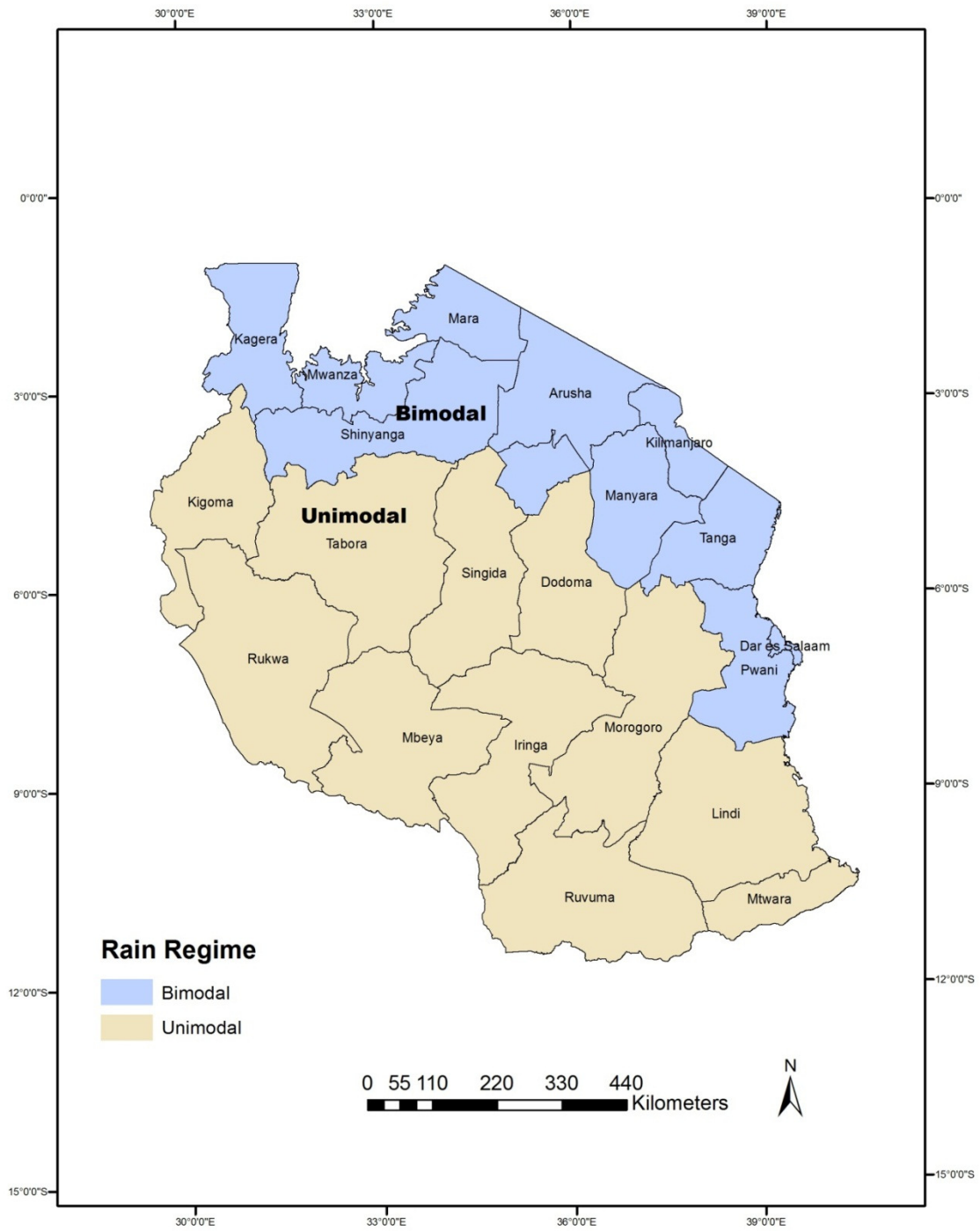


Figure 9: Tanzania’s administrative regions (*mikoa*), arranged according to the rainfall regime.

Univariate ANOVA showed pneumonia prevalence rate was higher in the bimodal compared with the unimodal rainfall administrative group of regions. The difference between the bimodal and unimodal was 117.3 (95% confidence interval: 36.6 to 198.0) cases per 100,000. The differences were statistically significant.

Within the regions (*mikoa*) with unimodal rainfall regime, however, the rainy season (*msimu*) had lower rates of pneumonia compared to the dry season (*kiangazi*). In the dry season, the unimodal zone had 101.9 more cases per 100,000 children than during the rainy season (95% confidence interval: 8.7 to 195.2). On the contrary, within the bimodal zone, the ‘long rains’ season had 260.7 (95% confidence interval: 87.6 to 433.7) more cases of pneumonia per 100,000 children, than during the ‘short rain’ season. The differences between dry season and the two rain seasons were not statistically significant.

Ordinary Least Square (OLS) regression analysis within the bimodal zone showed the effect of seasons. The most parsimonious model had sea level pressure anomalies as its only variable, with adjusted R^2 value of 0.16. The most parsimonious models remained with the same variable of sea-level pressure anomalies during the dry, ‘long’ and ‘short rain’ seasons. The adjusted R^2 values were 0.21, 0.19 and 0.07 respectively. Similar patterns were observed in the case of the unimodal zone, with the sea-level pressure anomalies being the only variable. During rainy season (*msimu*), the most parsimonious model had the adjusted R^2 value of 0.12, whereby the dry season (*kiangazi*) had 0.10.

The sea-level pressure *anomalies* were derived by subtracting long-term sea-level pressure values from the current readings. Negative values means current readings were

lower than long-term average. The decrease in sea-level pressure *anomalies* therefore means increase in sea-level pressure or simply, the current sea level pressure readings are increasing. The sea-level pressure coefficients in the OLS models above all had negative values. The negative coefficients implied increase in pneumonia rates from decrease in the *anomalies*. In other words, pneumonia increased when the monthly sea-level pressure decreased.

The variation of sea-level pressure anomalies may imply effects of the migration of the inter-tropical convergence zone (ITCZ). ITCZ affects many weather variables in East Africa and is characterized by low sea-level pressure, among other characteristics (Suzuki 2011; Riddle & Wilks 2012). In other words, sea level pressure is a marker for the rest of weather characteristics.

By using the same variables selected in the OLS models, comparison was made between OLS and Geographically-Weighted Regression (GWR). The R^2 values from GWR analysis showed improvement over the OLS model performance. The variation of regression parameters are mapped in Figure 10, Figure 11 and Figure 12.

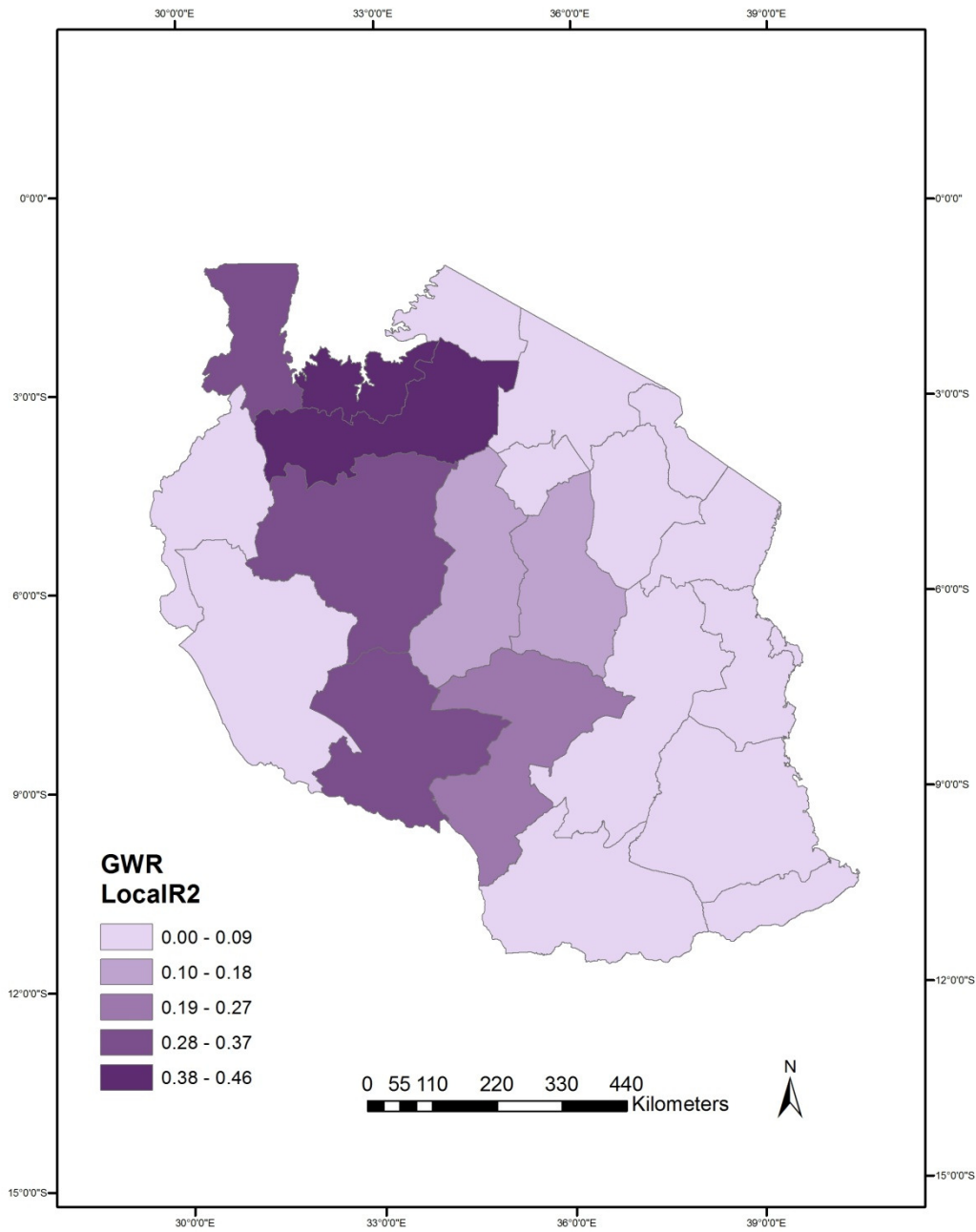


Figure 10: Variation of R^2 values from GWR analysis at the national extent. The explanatory variable was sea-level pressure anomalies. Dependent variable is monthly pneumonia prevalence.

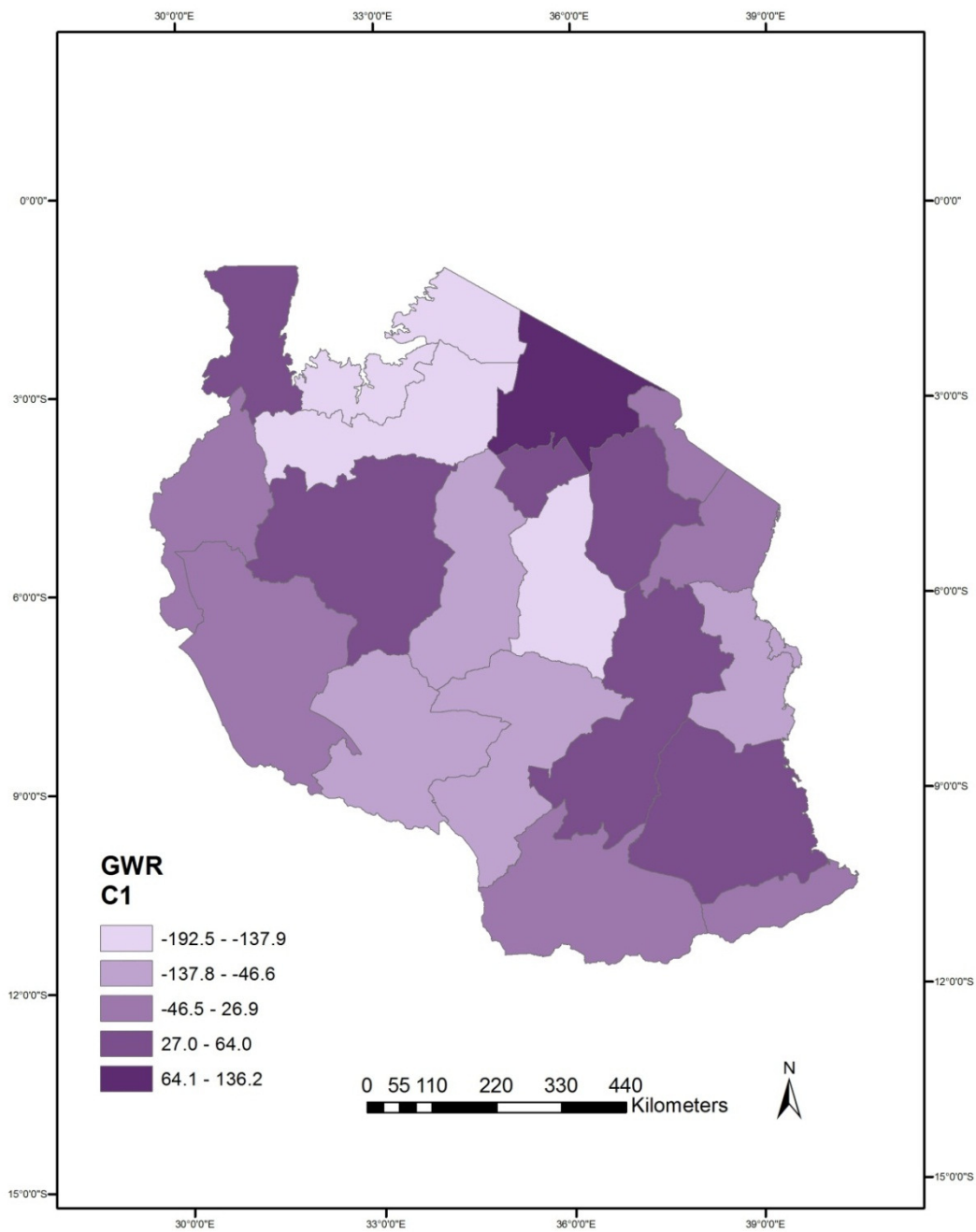


Figure 11: Variation of regression coefficient (C1) from GWR analysis at the national extent.
 The independent variable was sea-level pressure anomalies. Dependent variable is monthly pneumonia prevalence. The value and sign of the coefficient is not uniform across the study area.

The maps show regression parameters vary across the country, suggesting varied levels of strength of weather-pneumonia association. For example, Figure 10 shows variation of R^2 values from GWR analysis at the national extent. It shows the strength of weather-pneumonia association is higher along the corridor of central regions to Lake Victoria. These are regions with lower rates of pneumonia. The Figure 11 shows an output map of regression coefficient (C1) from GWR analysis at the national extent. The regression coefficient shows how much pneumonia prevalence changes with unit change in the independent variable. The map suggests regionalized understanding of *how* weather is associated with pneumonia, because the coefficient varies appreciably over the study area. The GWR analysis captures the pneumonia patterns very well, as shown in Figure 12. The map show the pneumonia prevalence values predicted from GWR analysis.

Further OLS-GWR comparisons over the entire nation, by rainfall regime and by rainfall seasons are shown in Table 5. GWR explains more of the variance than what OLS explains. Nevertheless, the key finding from both the OLS and GWR analyses is that weather-pneumonia relationship is more pronounced when considering the areas with uniform climate, and specific seasons within the climate zone.

Table 5: Comparison of Geographically-Weighted Regression (GWR) models with ordinary least square regression (OLS) models.

Spatial temporal extents	Variables	Sign of		
		OLS coefficient	Stepwise OLS Adjusted R ²	GWR Adjusted R ²
National, pooled in time	Sea-level pressure anomalies	-ve	0.13	0.27
Bimodal regions	Sea-level pressure anomalies	-ve	0.16	0.26
Unimodal	Sea-level pressure anomalies	-ve	0.13	0.16
	Mean Temperature	-ve		
Bimodal : 'Long rain' season	Sea-level pressure anomalies	-ve	0.19	0.24
Unimodal Rainy season	Sea-level pressure anomalies	-ve	0.12	0.39

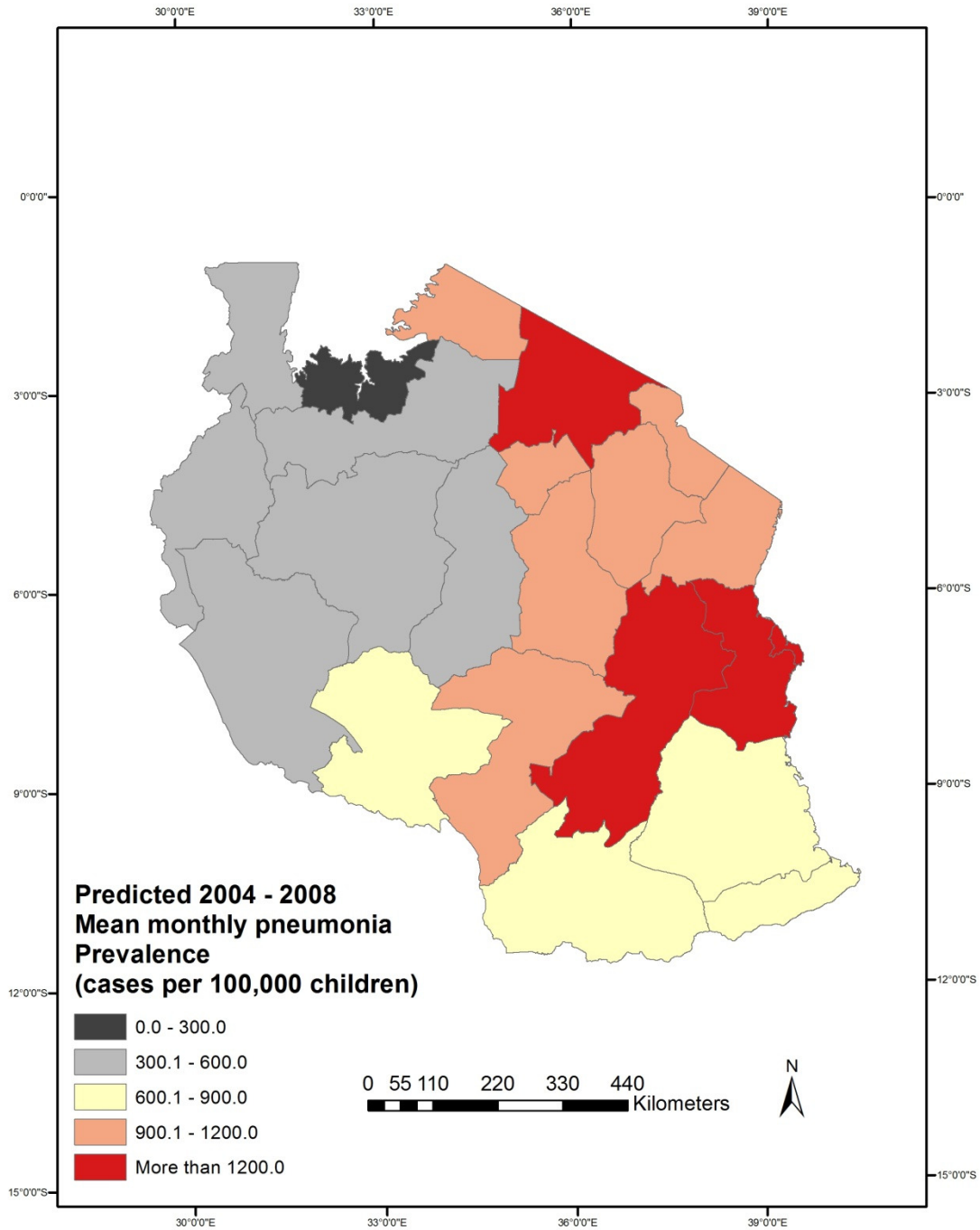


Figure 12: Mean predicted pneumonia prevalence values, from GWR analysis of sea-level pressure anomalies.

2.6 Discussions and Conclusions

The findings of the current study suggest that the weather is a statistically significant predictor of pneumonia. The findings also indicate that the role of weather in influencing the prevalence of pneumonia varies in space and in time. Which is the most influential weather component also varies in the space and in time.

The association between weather and pneumonia varied when viewed at the national spatial scale, pooled in time, and when viewed according to the major rain seasons. The differences in pneumonia prevalence between the unimodal and bimodal rainfall regimes were significant. The differences were also noted between the seasons within each of the rainfall regime.

Ordinary least square regression (OLS) is known to have limitations in handling spatially-varying phenomena. The strength of the weather-pneumonia association was therefore ascertained by using a more robust method of geographically-weighted regression (GWR). With GWR, it was possible to visualize the variation of regression parameters across the study area, instead of using one global regression equation.

Sea level pressure is the weather variable that featured prominently among the weather predictors of pneumonia. The changes in the mean and the departures from long-term mean sea level pressure values appeared to have effect on the prevalence of pneumonia. The sea level pressure remained an important predictor together with other weather variables at the other spatial and temporal resolutions.

It seems possible that these results are due to the fact that low atmospheric pressure affects the physiological abilities of respiration (Scott et al. 1989; West 2003). In

Japan, sea level pressure was associated with asthma attacks (Hashimoto et al. 2004). On the other hand, another possibility is that, the importance of atmospheric pressure is its link to other weather characteristics, for instance, through the Inter-tropical Convergence Zone, ITCZ.

In Tanzania, the weather variables are also affected by the migration of ITCZ (Sumner 1982; Kijazi & Reason 2005). It has been suggested that the cycles of ITCZ predict cholera outbreak in Tanzania (Muruke et al. 2008). Further research is recommended to explore the link of ITCZ as predictor of pneumonia prevalence.

2.7 Limitations and Strengths

Finally, a number of important limitations need to be considered. First, the current study has only examined pneumonia data grouped by administrative regions and not the individual patients. The results have to be cautiously interpreted to avoid the pitfall of using group data to make inference at the individual level. Thirdly, the study did not differentiate between toddlers and older children among the under-five children despite the fact that the infants could be at bigger risk to pneumonia than bigger children. This study did not consider other important factors that influence pneumonia prevalence such as human behavior, nutrition, crowding, levels of exposure to weather, comorbidities and immunization. Moreover, the weather and pneumonia datasets that were used in this study were acquired at different spatial resolutions, with implications on the possible slight variations due to aggregations.

While the evidence of the associations does not suffice to establish the cause-effect relationship between weather and pneumonia, knowing how the weather impacts

pneumonia is an important step towards more understanding of the etiology of the childhood pneumonia. The statistically significant findings suggest it is likely that such connections exist between weather and childhood pneumonia.

One of the strengths of this study is that it is the first to investigate the role of weather on childhood pneumonia in Tanzania. By being the first, it provides the opportunity for testing new specific hypothesis at refined spatial and temporal resolutions at the individual levels. This study was also national-wide, therefore covering all of the climatic zones in the country.

Weather is an important predictor of the distribution of childhood pneumonia in Tanzania. Relative humidity, temperature and sea-level pressure emerged as reliable predictors of childhood pneumonia. The evidence from this study suggests that climatic zones and seasons explain portion of the pneumonia prevalence variance. The current study also contributes to the GWR literature, in the applied climatology of health in Africa and similar places.

3 LINKING LAND USE AND LAND COVER TO CHILDHOOD PNEUMONIA IN TANZANIA

3.1 Introduction

In addition to weather and climate trends, which were covered in Chapter 2, the current research sought to discover ways that land use (LU) and land cover (LC) affect the geographical distribution of pneumonia. Land use and land cover are closely related concepts used to describe the Earth's surface. Land cover refers to the characteristics of the Earth's surface at a given location, while land use refers to the purpose human beings derive from the characteristics of the Earth's surface at any particular place (land cover) (Lambin et al. 2003).

Understanding the link between LULC and disease has increasingly becoming the research subject of interest among many different groups of researchers across a number of academic disciplines. For example, a group of international experts in ecology, health and land science met to specifically evaluate the ways LULC can affect diseases (Patz et al. 2004). The participants of the meeting formed The Working Group on Land Use Change and Disease Emergence in order to focus the experts' efforts on the subject of LULC-disease linkages (Patz et al. 2004).

These researchers then produced a list of a number of possible processes that drive LULC-disease linkage. The Working Group on Land Use Change and Disease Emergence identified changing the biophysical environment; movement of pathogens, goods and people; urbanization; and agriculture as prominent processes driving the

LULC-disease linkages (Patz et al. 2004). Each of the identified process is further discussed.

First, for the changing biophysical environment, deforestation, extractive industries and habitat fragmentation are the LULC sub processes that influences the emergence and spread of infectious diseases. Deforestation brings about new possibilities for human exposure, altering the environment required for the survival of the pathogens, and resulting in an increased number of cases of disease. The extractive industries exacerbate human health by introducing pollutants to the environment, while habitat fragmentation changes the ecological balance that affects the vectors of infectious diseases (Patz et al. 2004).

Secondly, movements of livestock and pet through trade or grazing systems have the potential to transport the harmful microorganisms from one location to another. The animal movements add the probability of new disease outbreak occurring. Animal movements also increase the likelihood of transmission of new infectious diseases from domesticated animals, wild animals and plants to humans. The possibilities increase with due to human migration and high density urban areas (Patz et al. 2004).

Thirdly, crop irrigation and food-borne disease sub-processes of agricultural LULC are another pathway for human infection sub-processes increase the suitability for survival of vectors of human diseases, exposure to harmful chemicals by farm workers and new outbreaks of disease. Irrigation also reduces the amount of water downstream, whereby introducing new public health concerns (Patz et al. 2004).

Fourthly, human congestion and encroachment of other land cover types from urbanization leads to increased probability of human-pathogens encounters. High density urban areas and the increased use of natural resources can accelerate the rates of infection. Such effects include the emergence of new or exotic infectious diseases (Patz et al. 2004).

Other researchers have envisioned the LULC-disease link in similar ways to The Working Group on Land Use Change and Disease Emergence. Eisenberg et al (2007) provide a good example of similar LULC-disease theorization. In what they call the “Environmental Change and Infectious Disease (EnvID) framework”, they suggest three main components of LULC-disease linkages: environmental change, disease and transmission. According to EnvID, the LULC types represent some of the environmental change sub-processes which increase exposure to disease. The LULC types exhibit varying levels of impact to unaffected populations.

Overall, the LULC-disease linkages discussed above can be grouped into four main categories: urbanization, agricultural change, changing the biophysical environment, and movement of pathogens, goods and people. These are the important factors in the etiology of many types of infectious diseases. The most reported LULC-disease linkages are those whose vectors are mosquitoes, ticks and birds (Norris 2004; Ogden et al. 2006; Peterson et al. 2008). Nonetheless, albeit to a lesser extent, researchers have linked LULC to other health concerns or outcomes such as temperature-related stressor exacerbated by urban heat island effects (Lo & Quattrochi 2003), obesity (Frank

et al. 2004), air quality and other health concerns such as unintentional injuries, diabetes and cardiovascular disease (Frank et al. 2006).

The current dissertation focuses on the LULC-links to respiratory diseases. The prominent way previous researchers presented LULC-respiratory disease was to associate air pollution exposure, surrogated by land uses, to the respiratory disease health outcomes. For example, researchers in Cincinnati, Ohio monitored the proximity of infants to highway and road stops and wheezing and regressed these observations with land use regression methods (Ryan et al. 2007). They found that land uses with high volumes of traffic and those with frequent stops resulted in different exposure levels to infants based on where they live. Another study in Munich, Germany, investigated the effect of land use-mediated exposure to pollution in a cohort of newly-born babies by spatially associating concentrations of air pollution to symptoms of respiratory diseases and infections (Morgenstern et al. 2007). Exposure to air pollutants, aggravated by proximity to the roads, was found to increase the likelihood of infants suffering from respiratory diseases and infections. Similarly, associations of adverse health outcomes from proximity to air pollution land cover sources were reported in Japan, in adults who had long term exposures; and also in Canada (Yorifuji et al. 2010; Neupane et al. 2010a; Gilbert et al. 2005).

As seen from the examples above, many of the LULC-respiratory disease research has been conducted in developed countries. The research in these countries utilized LULC information at the pollution-monitoring measurement sites and extended the exposure estimations to similar LULC classes located far from the monitoring stations

(Gilbert et al. 2005; Neupane et al. 2010b; Yorifuji et al. 2010). The availability of permanent air-pollution monitoring sites in developed countries is one of the things that facilitated such research. Most developing countries, like Tanzania, are devoid of adequate permanent air-quality monitoring stations.

It is therefore challenging to replicate research requiring permanent monitoring sites in the developing countries. This context suggests the need to utilize customized approaches in investigating environmental risk factors that exacerbate pneumonia outside the developed nations.

Still, some air-pollution research is conducted in developing countries using the few available pollution measuring instruments. Consider such studies in Tanzania (Mtango et al. 1992; Kilabuko & Nakai 2007; Kilabuko et al. 2007). Researchers went about associating acute respiratory infections with particulate matter from indoor pollution due to the use of biomass fuels, charcoal and kerosene. In the case of the outdoor pollution studies in Tanzania, soil dust (Mkoma et al. 2011), proximity to roads (Jackson 2005) and slash and burn agricultural practices common in Tanzania (Reyes et al. 2005) have been identified as important sources of particulate matter in the air. Researchers in Tanzania also found that vegetation was a natural barrier to pollution from particulate matter (Jackson 2005). These outdoor pollution studies, though, did not go as far as associating land cover to pollution leading to pneumonia. In the absence of permanent air pollution monitoring stations, land cover appears to be a plausible option to associate pneumonia cases with the different sources and sinks of air pollution.

This research is the first to overtly examine the role played by land cover in the spread of pneumonia in Tanzania. It contributes to the literature on the confluence of land science and environmental health. Specifically, the dissertation sought to answer the following question: does land cover explain spatial variations in pneumonia prevalence?

The current dissertation looks at air pollution as one of pathways through which LULC can be linked to pneumonia. Different types of LULC can be sources or sinks of air pollutants, subsequently the likelihood of LULC moderating the pollutants' effects to populations (Foley et al. 2005). Not only does LULC have the potential to influence the distribution of pneumonia, LULC also provides a point of intervention to reduce the burden of diseases in a community (Patz et al. 2004). For example, society can intervene by modifying configurations of land uses and covers to reduce air pollutants which are detrimental to human health. So far, however, there has been little discussion about the links between LULC and pneumonia, with little impact on the LULC-pneumonia associations.

Nonetheless, it is noteworthy to point out some of previous that did not find strong evidence for land cover - pneumonia association. For example, researchers did not attribute respiratory outcomes from dust (Bennion et al. 2007) and diesel exhaust particulate pollution (El-Zein et al. 2007) in Uzbekistan and Lebanon respectively.

In Lebanon, the government banned diesel vehicles from public roads because the vehicles were thought to degrade the air quality by adding pollutants to the atmosphere. By comparing rates of respiratory diseases before and the after ban, the researchers expected to observe stark differences between the rates of respiratory diseases in the two

time periods. During the first year after the ban, the rates of respiratory diseases decreased as expected. However, in the second year after the ban, the rates of respiratory illnesses did not decrease as expected. Though initially there appeared to be benefits in banning diesel vehicles, it was inconclusive as to why in the second year after the ban there was resurgence of respiratory health problems. There were a number of possible explanations for this: the continued ban of diesel autos; clandestine use diesel exhaust emission; demographics changes; or even the possibility that the initial air quality was so bad that the effects lingered (El-Zein et al. 2007).

In Uzbekistan, adjacent to Aral Sea (Bennion et al. 2007), researchers noted geographical differences in the rates of respiratory illnesses, though they found no evidence to support the notion that dust deposition was responsible for the respiratory illnesses. They studied the direct effects of dust to lungs, and it was not possible to rule out possible effects of microorganisms that were a component of dust (Bennion et al. 2007).

Despite so few inconclusive studies, evidence of the effect of air pollution on human respiratory systems has been reported. Recent works have identified a number of pollutants that can be tied to land use LULC in terms of their possible effects on respiratory disease (Bosson et al. 2008; Chiu et al. 2009; Esplugues et al. 2011); and air pollutant has been linked to health outcomes such as difficulties in breathing, the need to seek healthcare, or even loss of life (Bosson et al. 2008; Chiu et al. 2009; Esplugues et al. 2011).

In my own view, the uncertainty over the role of LULC in the spread of respiratory diseases stem from the indirect ways researchers have handled land cover. For the role of LULC in disease to be clear, there is a need to explicitly use LULC data while attempting to discover any effects LULC might have on respiratory illnesses. My research addresses the ‘LULC ambiguity’ research gap by explicitly using LULC information in attempt to establish any effect LULC has on childhood pneumonia.

3.2 Land Cover and Pneumonia Conceptual Framework

Past inquiry has depicted infectious diseases as a global health threat. Not only are infectious diseases responsible for most sicknesses and deaths of human beings; the probability of infection is a threat to all living persons (Wolfe et al. 2007). Globally, infectious and parasitic diseases, other than respiratory infections, are responsible for the deaths of 16.7% of females and 15.6% of males, while respiratory infections are responsible for the deaths of 7.1% of the males and 7.4% of women (*The Global Burden of Disease 2004 Update* 2008).

Some researchers have sought to associate infectious diseases with LULC. Their inquiries have attempted to discover how LULC explains outbreaks or distribution of infectious diseases and other ailments (Curran et al. 2000; Lo & Quattrochi 2003; Ezenwa et al. 2007; Pradier et al. 2008; Wagner et al. 2008). Their research has associated changing rates of disease prevalence to (planned and unplanned) urbanization, expanded agricultural activities, and removal of forest (Patz et al. 2008). However, this research has placed more emphasis on vectors of diseases rampant in developing countries, such as the tsetse fly (sleeping sickness) and mosquito which causes various tropical diseases (Rogers

1991; Rogers & Randolph 1991; Lindblade et al. 2000; Lambin 2003; Norris 2004; Brown et al. 2008), and little on respiratory diseases.

Therefore, the current dissertation uses Tanzania as a case study to test for land cover - pneumonia associations. Pneumonia is responsible for 11.2% of under-five mortality in Tanzania (Samarasekera 2008). There are an estimated 1.9 million new cases of clinical pneumonia in Tanzania annually; that is, 0.33 cases per child per year (Rudan et al. 2008). The death rates are comparatively lower in the older Tanzanian population. For example, records from the main hospital of Temeke Municipality in Dar es Salaam Region (Mayo 2007), show that children under-five were 53% of all pneumonia cases for the 2000 - 2002 time-period. Under-five children are the age group of interest in the current research.

Different land cover types can be associated with disease as either being sources or sinks of particulate air pollution, and by extension, the spatial distribution of child mortality pneumonia cases. Past research has associated both urban and rural LULC types with outdoor air pollution in Tanzania. Soil dust and biomass burning (Mkoma et al. 2011), proximity to roads (Jackson 2005), and slash and burn agricultural practices (Reyes et al. 2005) are important outdoor sources of airborne particulate matter.

For the indoor sources of particulate matter, biomass-based cooking fuels represent the biggest source of particulate matter (Kilabuko et al. 2007). Tanzanian households face similar sources of indoor particulate matter. Only 1.1% of Tanzania's population uses electricity for cooking (National Bureau of Statistics & ORC Macro

2011). Therefore, outdoor sources of pollution are important factor in the differences in exposure to airborne particulate matter between different locations.

In addition to the direct effects of outdoor particulate pollution, other factors also play a part in the spread of pneumonia. In Tanzania, *Streptococcus pneumoniae* are the main bacterial agent for pneumonia in children (Uriyo et al. 2006). Berman (1991) further emphasizes the importance of microorganisms in the spread of pneumonia. He points out that out of all microorganisms, bacteria and viruses are the main pneumonia-causing microorganisms. Viral pneumonia usually affects the upper-respiratory tract, while the bacterial pneumonia commonly affects lower respiratory tract. Bacterial pneumonia is the more debilitating in terms of fever and fatalities compared to viral pneumonia. *S. pneumoniae* and *Haemophilus influenzae* are the main bacteria responsible for pneumonia in developing countries (Berman 1991). Essentially, I am arguing that any LULC type that affects the pneumonia-causing microorganisms will tend to also have effects on rates of pneumonia infections.

3.3 Biophysical Basis for the LULC-pneumonia Link

For the LULC-pneumonia link to be plausible there has to be biophysical basis for the associations. Researchers have described how airborne particulate matter can affect the epidemiology of pneumonia. Particulate matter suspended in the air is known to suppress a person immunity against *Streptococcus pneumoniae* (Zelikoff et al. 2003). Not all particulate matter has the same effect. To take a case in point, particulate matter from specifically urban and built-up areas increases the chance of *Streptococcus pneumoniae* infections (Mushtaq et al. 2011a).

It follows then, that overcrowding in unplanned urban areas increases the possibilities of infection both within a household and outdoors (Reis et al. 2008). Overcrowding is a problem in Tanzania's unplanned urban areas. The majority of Tanzania's urban settlements are in informal settlements where houses are too near to each other, and access is limited. Recent data from the property tax database indicates 80% of buildings are on informal land (Lusugga Kironde 2006). In other words, there is likelihood that overcrowded, unplanned urban areas pose bigger risks to respiratory diseases compared to other LU LC types in Tanzania.

I do not exclude the likelihood of the influence of different LULC types in rural areas or other, lower population density, urban areas. Soil dust and the products of biomass burning from slash and burn agricultural practices (Reyes et al. 2005; Mkoma et al. 2011) are important outdoor sources of particulate matter in the Tanzania's rural areas. Therefore, both rural and urban areas have LULCs which can be-related to causes of pneumonia.

This study hypothesizes that locations with high pneumonia prevalence will be highly correlated to proportions of land covers associated with the production of particulate matter than those locations with lesser proportions of these land cover types. Agricultural, bare soils and urban areas are example of land cover types expected to be sources of particulate matter. Conversely, locations with higher proportions of natural vegetation cover are more likely to be negatively correlated with pneumonia.

To test this hypothesis, this study was designed so that remote-sensing-derived land-cover types could be correlated against prevalence of all types of pneumonia in

under-five children. Because of financial constraints, Tanzania's pneumonia diagnoses normally do not go all the way to the identification of the microorganism; this situation is similar to the other Sub-Saharan African countries such as Mozambique (Sigauque et al. 2009).

The Tanzania National Bureau of Statistics (NBS) classifies fourth-level "ward (*kata*)" administrative units into urban, rural and mixed urban-rural. According to GIS layers downloaded from International Livestock Research Institute (ILRI) website (<http://192.156.137.110/gis/search.asp?id=442>), NBS designated each ward to one of these three categories in the 2002 population census. The urban-rural divide provides an opportunity to test the hypothesis of the current research. If the hypothesis above is true, the districts with urban wards will have more cases of pneumonia per population compared with mixed or rural wards.

3.4 Tanzania: Salient Facts

Tanzania is located in south-eastern part of Africa. Its northern frontier cuts across Lake Victoria at 1°S, bordering Kenya and Uganda. The Ruvuma River forms the border between Tanzania and Mozambique at approximately 12°S. The western border is located at about 30°E bisecting Lake Tanganyika between Tanzania and The Democratic Republic of Congo (DRC). The east of the country borders the Indian Ocean. Tanzania also shares borders with Malawi, Zambia, Rwanda and Burundi.

'Tanzania in Figures 2010' (National Bureau of Statistics 2011) summarizes the geography and people of Tanzania. While the 2002 official census of Tanzania counted 33.5 million people, there were an estimated 41.9 million people in Tanzania by 2010. The population

densities of 20 (2002) and 39 (2010) persons per km² indicate a rather sparse population density.

Most of households in Tanzania depend on biomass as their main fuel. The majority of Tanzanians (97.2%) use charcoal, firewood, straw, dung or crop waste as fuel for cooking. The difference between rural and urban areas is not big, with 89.1% of urban and 99.6% of rural populations using the solid fuels (National Bureau of Statistics 2011). Such usage of biomass for fuel suggests that indoor pollution may play a less prominent role in determining differences in individual exposures to air pollution between rural and urban dwellers.

The Tanzania demographic and health survey 2010 (National Bureau of Statistics & ORC Macro 2011) provides further insights of the state of the nation's health. Three-quarters of all children aged between 12 to 23 months were fully immunized; the majority (97%) of children was vaccinated at least against one disease. Four percent of children under age five had suffered from acute respiratory infection (ARI) within the two weeks preceding the survey, the majority (71%) of those children was taken to a health facility. The infant and the under-5 mortality rates of 51 and 81 per 1,000 live births respectively are still on the high side, though the trend is towards reduced mortality rates.

The land cover in Tanzania is varied. There are a number of ecosystems in the land whose elevation ranges from 0 m to over 5800 m above sea level at the top of Mount Kilimanjaro. The beds of Lake Tanganyika in rift valley are at the Africa's lowest point, while the highest point is at the summit of Mount Kilimanjaro, with general

elevation below 500 m and at about 1000 m in the coastal zone and hinterland respectively (Timiza 2011). Vegetative land cover is dominated by natural and agricultural plants. Majority of Tanzanians engage in subsistence agriculture (Maselli et al. 2009). Forests, woodlands, thickets, bushlands, grasslands, swamps are among the vegetation types found in Tanzania (Pelkey et al. 2000). That is, the climate, land forms and vegetation make land cover Tanzania uniquely heterogeneous and suited for land cover research. In their own words, land cover researchers describe the country: “Tanzania, therefore, provides a microcosm for monitoring vegetative changes in very different types of habitats” (Pelkey et al. 2000); and, “Tanzania was selected as a primary test area due to its environmental heterogeneity, which makes it representative of a variety of artificial and semi-natural ecosystems” (Maselli et al. 2009).

3.5 Data Sources and Methods

3.5.1 Data Sources

Tanzania’s Ministry of Health & Social Welfare (MoH&SW) provided data on monthly cases of childhood pneumonia covering the 2004 – 2008 time periods for administrative regions. I calculated monthly pneumonia prevalence as cases per 100,000 children by combining the pneumonia data with the corresponding under-five projected yearly population from Tanzania’s National Bureau of Statistics (NBS)(National Bureau of Statistics 2006). I used projected data because the last census was in 2002. The 2004 – 2008 mean monthly pneumonia prevalence data are shown in section 2.4.2.

The pneumonia data was made available at the regional (*mkoa*) level. The lack of availability of data at the third administrative level of districts (*wilaya*) posed challenges

in extrapolating the data to finer scales as further discussed in section 3.5.2 below. But I also conducted some of land cover –pneumonia analysis at the regional level. I estimated the pneumonia rates at the administrative levels finer than regions, and further examined the associations of LULC with pneumonia at those scales (section 3.5.2).

It is very important to consider spatial resolution in land cover studies (Millington et al. 2003). In this dissertation I identify the (‘collection 5’) V005 Global 500 m land cover Type product (MCD12Q1) derived from MODIS satellite images as the source for land cover information used in the study. Its temporal resolution coincided with the entire time period of the pneumonia dataset (2004 – 2008), and the data were downloaded from <ftp://e4ftl01.cr.usgs.gov/MOTA/MCD12Q1.005/>. It is a higher spatial resolution (500 m), and improved identification of classes such as built-up compared to the previous versions of the dataset (Friedl et al. 2010). Even so, this dataset was of higher spatial resolution than the smallest (Dar es Salaam) of the administrative regions (*mikoa*). Land cover maps for 2004 - 2008 are shown in Figure 13 to 17. These remote sensing-derived land cover maps show that a high portion of Tanzania was covered by vegetation. The great majority of this vegetation is savanna and woody savanna. Other prominent land covers are broadleaf vegetation, grasslands and croplands. The remaining land cover classes such as urban or built-up and barren or sparse vegetation occupy low portions of the nation’s terrain.

Table 6: Tanzania's 2008 land cover areas across regions (mikoa)*+

Land cover [IGBP class number]	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Evergreen Needleleaf forest [1]	21	.00	25.12	103.04	4.91	6.16
Evergreen Broadleaf Forest [3]	21	.00	7311.27	20816.10	991.24	1762.17
Deciduous Needleleaf Forest [2]	21	.00	1.72	5.15	.25	.47
Deciduous Broadleaf Forest [4]	21	1.50	2292.34	12577.07	598.91	762.80
Mixed Forest [5]	21	.00	34.35	241.49	11.50	10.25
Closed Shrublands [6]	21	4.94	483.41	1279.58	60.93	107.65
Open Shrublands [7]	21	.21	368.35	1392.49	66.31	108.04
Woody savannas [8]	21	152.19	51559.30	288197.30	13723.68	15615.70
Savannas [9]	21	414.08	49803.60	377244.59	17964.03	14647.02
Grasslands [10]	21	34.35	27933.96	112770.72	5370.03	8010.74
Permanent wetlands [11]	21	25.76	766.76	4922.34	234.40	228.11
Croplands [12]	21	37.78	1548.55	10300.83	490.52	401.19
Urban and Built up [13]	21	1.07	286.78	774.70	36.89	62.67
Cropland/Natural vegetation Mosaics [14]	21	525.70	9206.93	53349.12	2540.43	2477.18
Barren or sparse vegetation [16]	21	.00	171.73	694.42	33.07	40.13

* Each land cover was aggregated in each of the 21 regions. From the regional aggregated values, the basic statistics (mean, minimum,

Land cover, in square kilometers

maximum and standard deviation) were computed for each land cover.

+ Excluding permanent ice and snow [15], water [17] and islands.

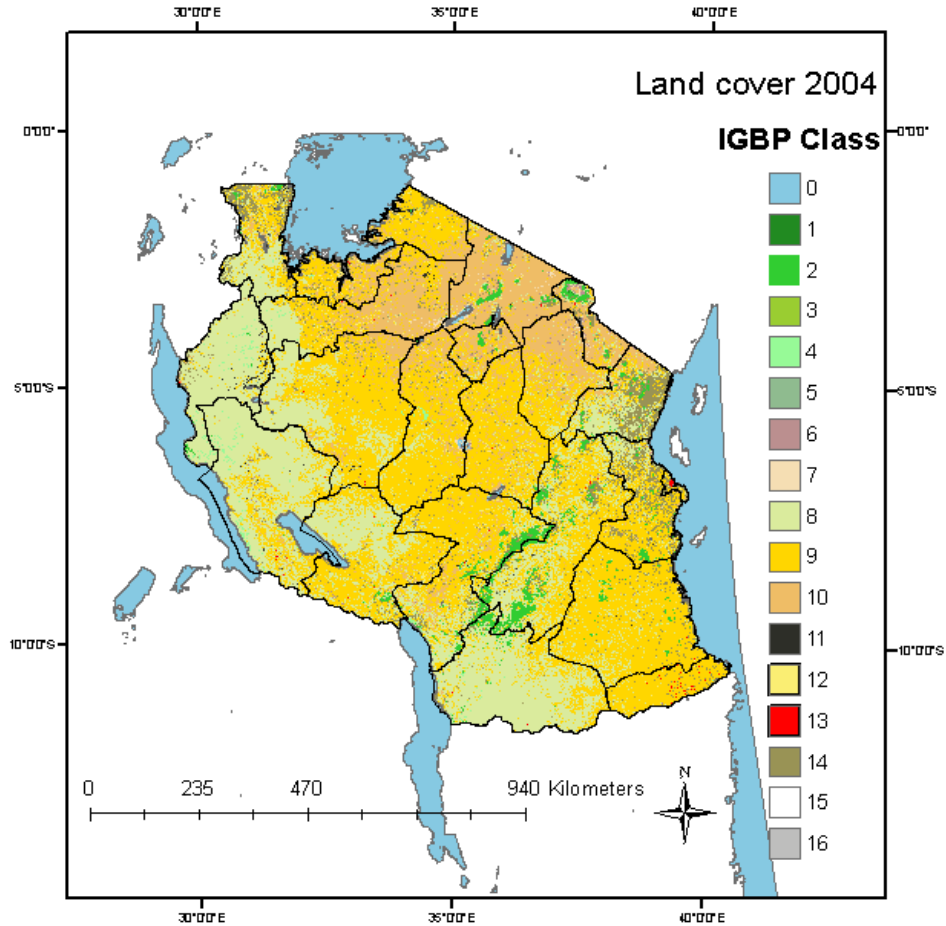


Figure 13: Land cover map of Tanzania, year 2004, extracted from ('collection 5') V005 Global 500 m land cover Type product (MCD12Q1) derived from MODIS satellite images.

- | | |
|---------------------------------|--|
| Water [0] | Grasslands [10] |
| Evergreen Needleleaf forest [1] | Permanent wetlands [11] |
| Deciduous Needleleaf Forest [2] | Croplands [12] |
| Evergreen Broadleaf Forest [3] | Urban and Built up [13] |
| Deciduous Broadleaf Forest [4] | Cropland/Natural vegetation Mosaics [14] |
| Mixed Forest [5] | Permanent ice and snow [15] |
| Closed Shrublands [6] | Barren or sparse vegetation [16] |
| Open Shrublands [7] | |
| Woody savannas [8] | |
| Savannas [9] | |

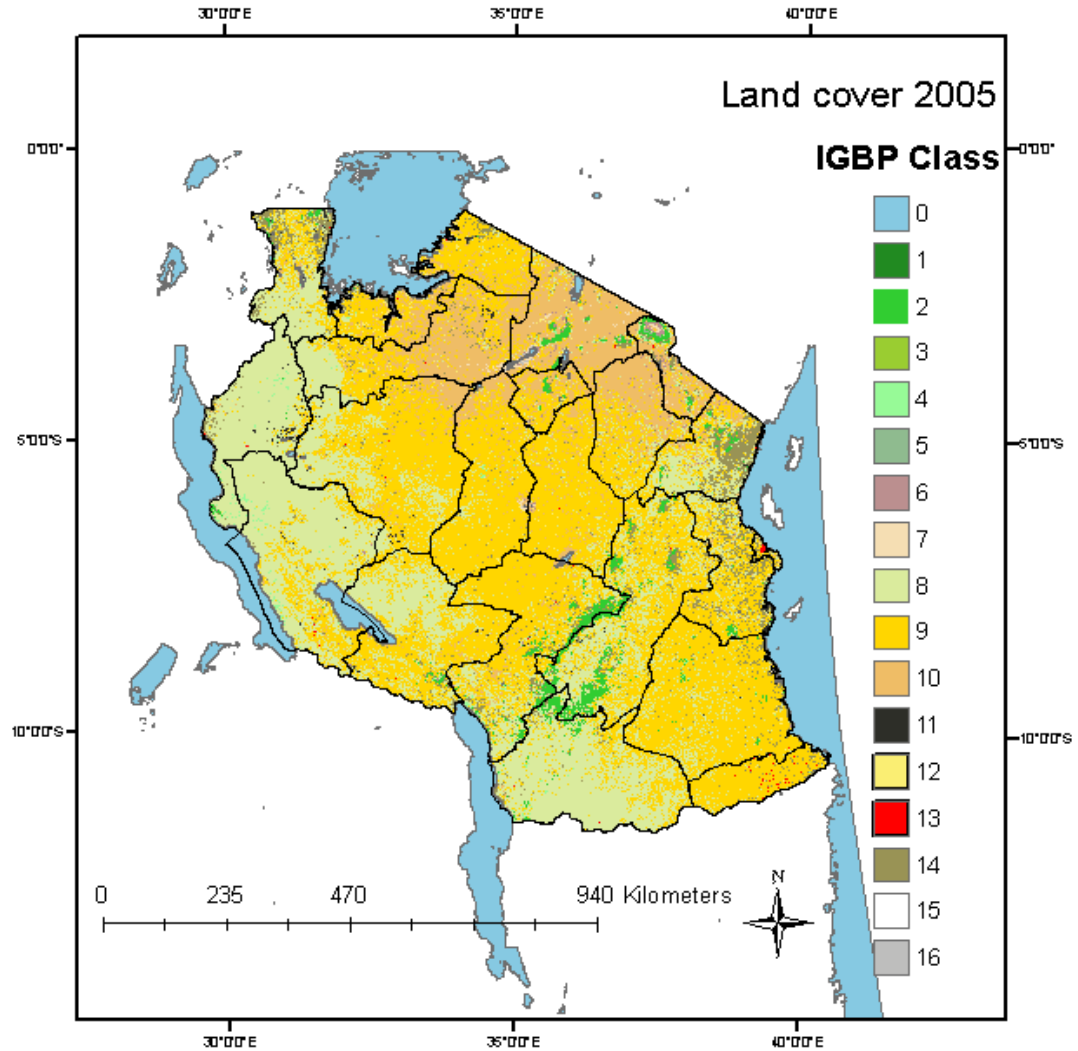


Figure 14: Land cover map of Tanzania, year 2005, extracted from (‘collection 5’) V005 Global 500 m land cover Type product (MCD12Q1) derived from MODIS satellite images.

IGBP classes as per Figure 13.

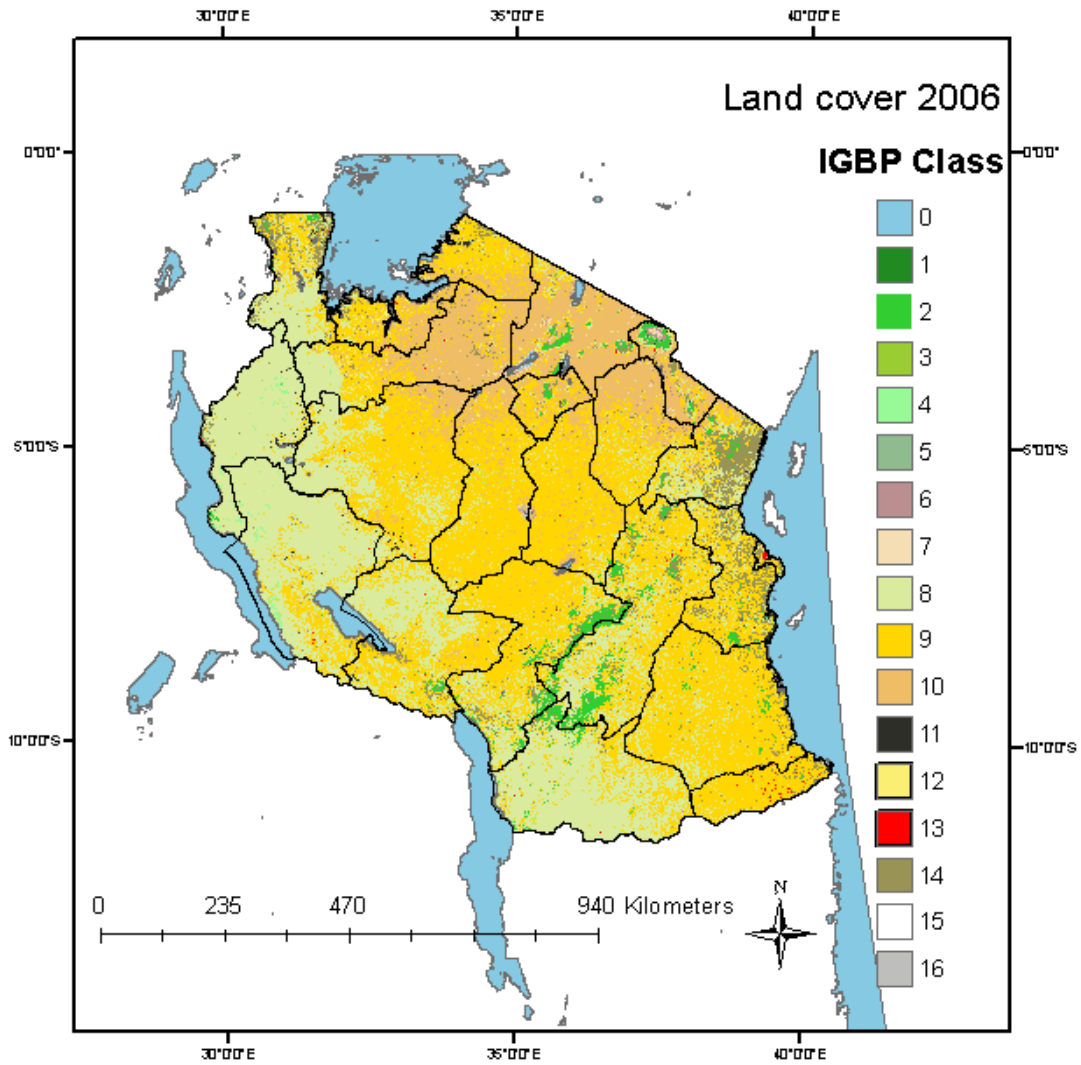


Figure 15: Land cover map of Tanzania, year 2006, extracted from (‘collection 5’) V005 Global 500 m land cover Type product (MCD12Q1) derived from MODIS satellite images.

IGBP classes as per Figure 13.

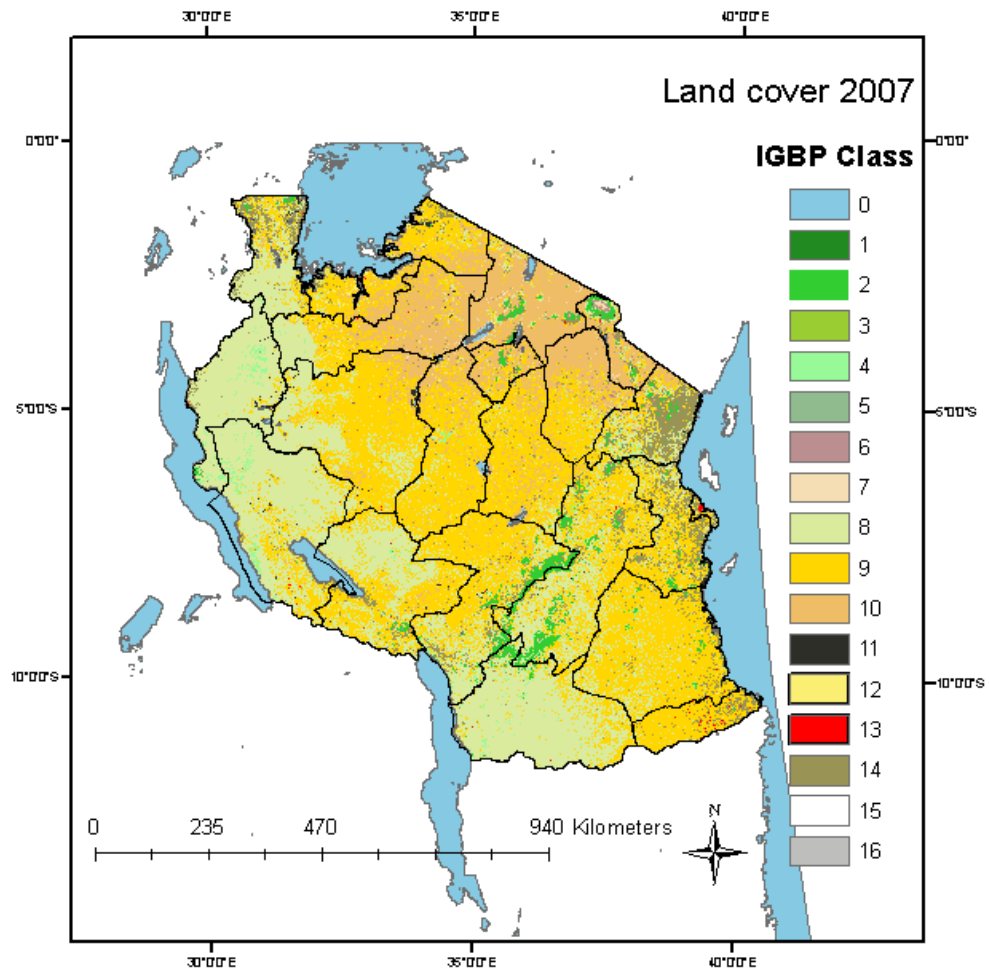


Figure 16: Land cover map of Tanzania, year 2007, extracted from (‘collection 5’) V005 Global 500 m land cover Type product (MCD12Q1) derived from MODIS satellite images.

IGBP classes as per Figure 13.

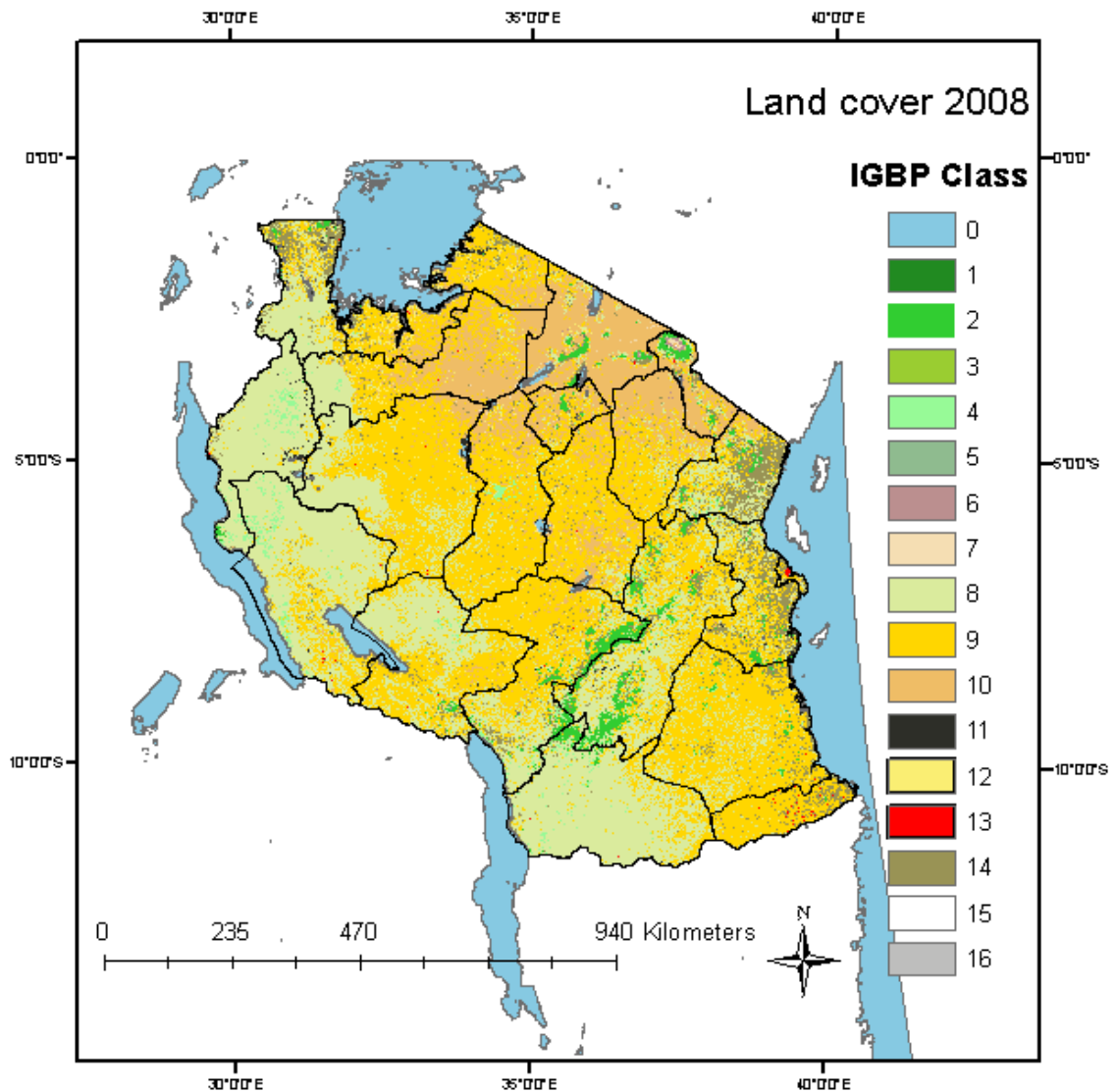


Figure 17: Land cover map of Tanzania, year 2008, extracted from (‘collection 5’) V005 Global 500 m land cover Type product (MCD12Q1) derived from MODIS satellite images.

IGBP classes as per Figure 13.

The land cover classes are unevenly distributed across the 21 administrative regions (*mikoa*) of Tanzania. Table 6 shows year 2008 distribution of the land cover classes in the regions. Some classes like evergreen and deciduous needleleaf forests are completely missing in some regions (minimum of zero square kilometers), while others classes such as croplands, savanna and woody savanna occupy terrain in each of the regions.

At the same time (2004 – 2008), nationwide childhood pneumonia cases were fairly constant at about 812.4 cases per 100,000 children. However, there are notable differences in the distribution of pneumonia cases among the regions (*mikoa*). For more information about the Tanzania’s pneumonia data used in this study see section 2.4.

3.5.2 Methods

As discussed in the preceding sections, the prominent LULC – pneumonia linkage is through degradation of air quality due to urbanization and agricultural practices. Moreover, LULC can influence both the exposure to and degradation of air quality. In estimating the exposure of an individual to air pollution, it is common to use one of the following strategies.

The first strategy is to skip using any air pollution measurements (this is, of course, attractive in countries with underfunded scientific monitoring systems). In such a strategy, a researcher can tie air pollution sources to LULC, but without direct measurements of air pollution parameters. For instance, one independent school district (ISD) in the state of Washington decided to retrofit the school buses with pollution-reducing devices, while a nearby ISD did not (Beatty & Shimshack 2011). A study then

compared children's respiratory diseases in the two ISDs as an opportunity to link air-pollution with respiratory health without direct measurements of air pollution. The fact that the school buses drive through residential areas in both ISDs provided a setting for this natural experiment.

Another example of a natural experiment without monitoring stations, the Lebanese government banned diesel vehicles from using public roads (El-Zein et al. 2007). As is the case in many developing countries, in Lebanon there was scarcity of air-quality monitoring stations. By simply contrasting the rates of hospitalization before and after the ban, researchers were able to evaluate the pollution-respiratory health link (El-Zein et al. 2007).

Similarly, researchers did not use monitoring stations in the city of Tangará da Serra in Brazil to compare the rates of respiratory diseases between the biomass-burning dominated dry season and the rainy season (Rosa et al. 2008). During the dry season, sugar-cane burning is dominant and it produces many airborne pollutants. Therefore, without measuring air pollution directly, it was possible to compare the rates of respiratory hospitalization between times with different levels of agriculturally-generated aerosols.

A second option available to the researcher is to explicitly deploy land use information to extrapolate the few available monitoring stations measurements. In the technique known as "Land Use Regression" (LUR), a few pollution measurements are taken at various LULC types, then by using spatial modeling in a geographical

information systems (GIS) the measurements are extrapolated to the rest of study area (Neupane et al. 2010a; Esplugues et al. 2011).

A third strategy is to only use monitoring stations in estimating exposure to air pollutants. In this strategy, the researcher makes use of the existing monitoring stations which are near and numerous enough to the target group. The measurements at the stations are taken to be the exposure experienced by the target group (Cheng et al. 2007; Hertz-Picciotto et al. 2007; Pope et al. 2007).

A fourth strategy is to use remote sensing techniques to estimate air pollution. This strategy entails processing satellite imagery to calculate some indices of pollution, for example, aerosol optical depth (AOD) which estimates the levels of aerosols in the air (Rappold et al. 2011).

In spite of the availability of different methodological strategies, practical realities can limit the choice of the strategy to use air pollution data in the resource-challenged developing countries. In the studies that cover small geographical area, researchers can make use of the few available air pollution monitoring stations to directly estimate the exposure. However, in the case of larger geographical areas, a few monitoring stations may not suffice. Land use regression (LUR) methods are useful in such situation to extrapolate the existing measurements towards the other areas (Neupane et al. 2010a; Esplugues et al. 2011). In the vast areas, for example, at the national level, the number of available monitoring stations will likely be less than the number required even for the LUR methods. In Tanzania's *de facto* capital city of Dar es Salaam, five air quality measuring units were used during a project to establish baseline air pollution level

(Kombe 2009). Air quality studies in Tanzania (Jackson 2005; Othman 2010; Mkoma et al. 2011) used mobile units. There are no permanent air-quality monitoring stations in Tanzania. In contrast, there are at least 16 permanent, real-time air quality monitoring stations in the Sacramento metropolitan area in California accessible online through <http://www.sparetheair.com/aqirealtime.cfm>.

Therefore, in the current dissertation, I use the first strategy of implying exposure to air pollutants according to the existing land cover. Using this strategy, I compare land cover classes to the rates of pneumonia without using air-pollution monitoring stations. Prior doing the comparison, I used geoprocessing tools in ILWIS v3.8 (52N) and ArcGIS version 10 (ESRI) software to extract the relevant land cover and pneumonia prevalence metrics. Moreover, I used PASW version 18 (IBM) and Excel 2010 (Microsoft) to process the statistical data. In addition to GIS analysis, I also used HDF-EOS to GeoTIFF Conversion Tool (HEG) and ENVI version 4.8 for the requisite digital image processing.

Using the PASW statistical program, I first run a correlation analysis between the proportions of the 17 individual land covers in the regions (*mikoa*) and the mean annual pneumonia rates. Initially, I correlated the 17 land cover classes with pneumonia prevalence. I then explored ways to aggregate the land cover classes in order to improve robustness of the analysis.

There are a number of available datasets to produce and update land cover maps globally and regionally. These initiatives differ in terms of the temporal and spatial attributes of the land cover maps produced. Among other differences the key one is the classification system used. For example, DeVisser and Messina (2009) compared the

available land cover datasets for Kenya. They listed land cover datasets with a combined temporal range of 1995 to 2005. The datasets used in their research were Africover, CLIPcover, GLC2000, IGBP DISCover, UMd GLCC, MODIS Type 1 , MODIS Type 2, MODIS Type 3, MODIS Type 4 and MODIS Type 5 (DeVisser & Messina 2009). Because Kenya and Tanzania are neighboring with similar land covers. Their analyses are applicable to Tanzania. However, the datasets they used with the exception of the MODIS data, none covered the 2004 - 2008 range used in this research.

MODIS collection 5 was updated in 2010 as detailed by Friedl et al. (2010). The MODIS collection 5 land cover data underwent a newer version of a supervised classification algorithm. It is presented at a spatial resolution of 500m and its temporal range is inclusive of the time period of interest to this research (2004 - 2008). The collection 5 dataset included MODIS type 1 to type 5 land cover data. The type 1 dataset consists of 17 land cover classes that follow the IGBP classification system that forms the focus of this review. The IGBP classification system, like other systems in MODIS collection 5, does not separate land cover from land use. For this reason, land cover and land use are used interchangeably in the current research.

The 17 classes in the IGBP classification system used in the MODIS collection 5 land type dataset can be grouped into a fewer numbers of similar classes and a number of contemporary researchers have done so to answer a number of research questions. For example, in describing the MODIS collection 5 dataset, Friedl et al. (2010) organized the 17 classes into nine groups (Friedl et al. 2010). When comparing collection 5 with other land cover products, Tchuenté et al. (2011) reduced 13 IGBP classes they chose as

applicable to the African continent to seven (Kaptué Tchuenté et al. 2011), while Pflugmacher et al. (2011) aggregated the 17 IGBP classes into six (Pflugmacher et al. 2011). In this research, I reduced 17 the land cover classes to six as shown in Table 7, following closely the work of previous researchers (Friedl et al. 2010; Kaptué Tchuenté et al. 2011; Pflugmacher et al. 2011). Because height of trees and extent of the canopy are prominent features the IGBP classification system uses to define the different types of vegetation (FAO 2000), these factors are generally considered when aggregating the classes. In the words of Kaptué Tchuenté et al. (2011, p. 213), “conversion/transformation of the original land cover classes into aggregated classes respects the definition of the legend of each initial class”. The presence or absence of vegetation and the characteristics of the present vegetation have implications on the air quality and hence respiratory health, as discussed in the theoretical framework in section 3.2.

With aggregation, it was possible to run change detection analyses to determine LULC change, what the pathways of the change were, and how these changes relate to the theoretical framework in section 3.2 in page 63. Essentially, the aggregation puts the forests or forest-like vegetation into one class, while the grasslands, croplands, urban and bare ground are also kept as separate classes. These land cover classes are associated acting as air pollution sources and sinks as discussed earlier.

I then compared the aggregated land cover classes with pneumonia prevalence; again using correlation analysis in the PASW statistical package. The aim of this analysis was to see if land cover was still associated with pneumonia. The subsequent ecological analysis in relation to urbanization at district level is discussed in section 3.6 below.

3.6 Results

As discussed in the previous section, I correlated the proportions of the 17 land cover classes in each region against regional pneumonia prevalence. The aggregated land cover classes from 17 to six are shown in Table 8 and 9. The aggregated classes related to bare lands and urban areas were proportionally small compared to the rest of the classes. Croplands are the putative land cover source of air pollution with bigger areal sizes compared to the other putative land cover sources. The grasslands and forests putative sinks cover the majority of the Tanzania's land.

Table 7: Land use / land cover class aggregations

IGBP classes (Friedl et al. 2010) IGBP class # in parenthesis	Friedl et al. (2010)	Pflugmacher et al. (2011)	Tchuenté et al. (2011)	This Study
(1) Evergreen needleleaf forest	Forest	Tree	Forest/mixed forest	Mixed Forests
(3) Deciduous needleleaf forest				
(2) Evergreen broadleaf forest				
(4) Deciduous broadleaf forest				
(5) Mixed forests				
(8) Woody savannas			Woodlands	
(9) Savannas				
(10) Grasslands	Grasses / cereals	Herbaceous	Grassland	Grasslands
(6) Closed shrublands	Shrublands	Shrub	Woodland/shrubland	Mixed Forests
(7) Open Shrublands				
(12) Croplands	Croplands and mosaic	Herbaceous	cropland	Croplands
(14) Cropland/natural vegetation mosaic				
(11) Permanent wetlands	Seasonally or permanently inundated	Mosaic		unclassified
(13) Urban and built-up land	Unvegetated	Barren	Urban and built up	Urban and built up land
(16) Barren or sparsely vegetated			Barren land	Barren or sparsely vegetated
(15) Permanent snow and ice		Mosaic		unclassified
(0) Water			Water bodies	Inland Water

Table 8: Aggregated land cover types over 2004 - 2008 five year time-period.

Land Cover, square Kilometers						
Year	Barren Land or Sparse Vegetation	Croplands	Grasslands	Mixed Forests	Urban and Built Up Land	Grand Total
2004	343 (0.04 %)	59140 (6.7 %)	126506 (14.3 %)	695428 (78.8 %)	767 (0.09 %)	882184
2005	634 (0.07 %)	46495 (5.3 %)	110098 (12.5 %)	724984 (82.2 %)	765 (0.09 %)	882976
2006	590 (0.07 %)	52043 (5.9 %)	118401 (13.4 %)	711055 (80.6 %)	766 (0.09 %)	882854
2007	467 (0.05 %)	62594 (7.1 %)	124931 (14.2 %)	692556 (78.5 %)	766 (0.09 %)	881314
2008	709 (0.08 %)	63681 (7.2 %)	112634 (12.8 %)	703457 (79.7 %)	766 (0.09 %)	881247

Water, islands, wetlands, snow and ice are excluded.

Table 9: Proportions of aggregated land cover classes in each region (*mkoa*) for the time period 2004 to 2008.

Region	Mean percentage of land cover types (2004 - 2008)					Regional Mean
	Barren Land or Sparse Vegetation	Croplands	Grasslands	Mixed Forests	Urban and Built Up Land	
Arusha	0.63	4.01	70.34	20.65	0.03	19.13
Dar es Salaam	0.22	46.47	4.56	37.34	7.50	19.22
Dodoma	0.05	3.22	15.98	79.97	0.03	19.85
Iringa	0.01	6.12	3.95	89.11	0.04	19.85
Kagera	0.09	20.21	2.14	74.55	0.03	19.41
Kigoma	0.02	2.63	0.37	94.21	0.07	19.46
Kilimanjaro	0.18	8.23	50.70	40.04	0.15	19.86
Lindi	0.00	4.69	0.19	94.57	0.07	19.90
Manyara	0.09	2.49	44.87	52.34	0.01	19.96
Mara	0.10	11.02	23.58	62.07	0.10	19.37
Mbeya	0.02	3.75	1.73	91.73	0.02	19.45
Morogoro	0.00	7.04	0.77	92.03	0.04	20.81
Mtwara	0.02	8.98	0.45	88.23	1.57	19.85
Mwanza	0.19	14.38	28.97	53.07	0.11	19.34
Pwani	0.04	24.38	1.19	72.27	0.00	19.58
Rukwa	0.03	2.16	0.92	84.09	0.05	17.45
Ruvuma	0.01	1.54	0.14	97.34	0.04	19.81
Shinyanga	0.00	4.15	47.21	48.33	0.02	19.95
Singida	0.08	2.19	15.29	81.74	0.01	19.86
Tabora	0.01	1.36	8.41	89.42	0.05	19.85
Tanga	0.01	31.21	8.18	59.84	0.05	19.86
National Mean	0.09	10.01	15.71	71.57	0.48	19.61

Both Pearson and Spearman correlations were both used, whereby an association was determined when both correlations were statistically significant. When used together, the two correlations complement each other in describing linear and non-linear land cover-disease associations (Bowden et al. 2011). The following land cover classes were significantly correlated with pneumonia prevalence: evergreen broadleaf (Pearson correlation = 0.312, $p=0.001$; Spearman correlation=0.499, $p<0.001$); woody savannas (Pearson correlation = -0.259, $p=0.008$; Spearman correlation= -0.219, $p=0.025$), permanent wetlands (Pearson correlation = -0.141, $p=0.152$; Spearman correlation= -0.339, $p<0.001$); Urban and Built up (Pearson correlation = 0.332, $p=0.001$; Spearman correlation= -0.089, $p=0.365$); and, croplands and vegetation mosaics (Pearson correlation = 0.265, $p=0.006$; Spearman correlation=0.223, $p=0.022$). The detailed results for all land cover classes are shown in Table 10.

I repeated the correlation analysis using the aggregated land cover classes, again using the correlation analysis function in the PASW package. The aim of this analysis was to verify if land cover was still associated with pneumonia. Croplands were significantly positively correlated with pneumonia (Table 11) as they were with the 17 class analysis. The correlations to pneumonia from the remainder of the aggregated land cover classes were not statistically significant, despite the fact that evergreen broadleaf, woody savanna, urban and built up had been in the 17 classes.

Table 10: Correlation values between mean monthly pneumonia prevalence and proportion of land cover types in the 21 regions (*mikoa*)

Land cover type	Pearson	p Value	Spearman	p Value
Evergreen Needleleaf	.000	1.000	-.041	.675
Evergreen Broadleaf	.312**	.001	.499**	.000
Deciduous Needleleaf	.135	.170	-.036	.717
Deciduous Broadleaf	-.171	.082	-.061	.538
Mixed Forest	.078	.432	.049	.620
Closed Shrub	.098	.318	.161	.101
Open Shrub	.089	.366	.131	.183
Woody savannas	-.259**	.008	-.219*	.025
Savannas	.026	.794	.062	.532
Grasslands	.077	.435	.139	.158
Permanent wetlands	-.141	.152	-.339**	.000
Croplands	.097	.325	.057	.566
Urban and Built up	.332**	.001	-.089	.365
Cropland and vegetation mosaic	.265**	.006	.223*	.022
Barren or sparse vegetation	.110	.265	-.056	.570

Land cover in bold are statistically significant (either of the two tests is significant, and the signs do not disagree if both are significant at 0.05 significance level. The double-starred (**) correlations are also significant at 0.01 level.

Table 11: Correlation between regional proportions of aggregated land cover types and pneumonia prevalence.

COVER			
Barren Land or Sparse Vegetation	Spearman's rho	Correlation Coefficient	.018
		Sig. (2-tailed)	.856
		N	104
Croplands	Spearman's rho	Correlation Coefficient	.232*
		Sig. (2-tailed)	.017
		N	105
Grasslands	Spearman's rho	Correlation Coefficient	.144
		Sig. (2-tailed)	.142
		N	105
Mixed Forests	Spearman's rho	Correlation Coefficient	-.186
		Sig. (2-tailed)	.058
		N	105
Urban and Built Up Land	Spearman's rho	Correlation Coefficient	-.096
		Sig. (2-tailed)	.328
		N	105

*. Correlation is significant at the 0.05 level (2-tailed).

Croplands appeared to have statistically significant correlation with pneumonia.

After these analyses, I interpolated the pneumonia data from regional level to sub-levels of districts (*wilaya*). The interpolation provided an estimation of pneumonia prevalence variations within each administrative region. The pneumonia prevalence at the regional-level was apportioned to the districts based on the family size expressed as the number of persons per household. The rate of pneumonia was assumed to be proportional to the household size. Previous research has shown household size to be an important factor in the distribution of pneumonia (Berman 1991; Victora et al. 1994; McBeth 2010). The pneumonia prevalence rate of a specific month in a region was applied to a district, proportionately to the district's household size relative to the region's. Overall, the districts estimation retained the region's mean prevalence value. Moreover, the interpolation also preserved the pneumonia prevalence temporal trends. The pneumonia prevalence maps at the district level are shown in Figure 20 to 24.

I categorized the districts into rural and urban based on the presence of an urban ward in a district, based on the 2002 census. An urban district contained one or more ward (*kata*) of urban type, while the rural district contained mixed and rural wards, without any of urban wards. The map of districts classified based on urbanization is shown in figure 18. There were 45 urban districts, compared to the 74 rural districts. I compared the rates of pneumonia between these rural and urban districts. The results show that the districts identified as urban had higher rates of pneumonia compared to the areas classified as rural. The high pneumonia rates association with the urban settings remained even with temporal disaggregation (Table 12).

Table 12: Overall comparison of district pneumonia prevalence and urbanization, by year

Year	District Type	Mean Monthly Prevalence
2004	Rural	755.2
	Urban	684.2
2004 Average		728.3
2005	Rural	867.5
	Urban	1043.6
2005 Average		934.1
2006	Rural	763.2
	Urban	939.3
2006 Average		829.8
2007	Rural	770.1
	Urban	750.4
2007 Average		762.6
2008	Rural	738.9
	Urban	685.3
2008 Average		718.6
2004-2008	Rural	779.0
	Urban	820.5
Grand Average		794.7

Prevalence: cases per 100,000 children

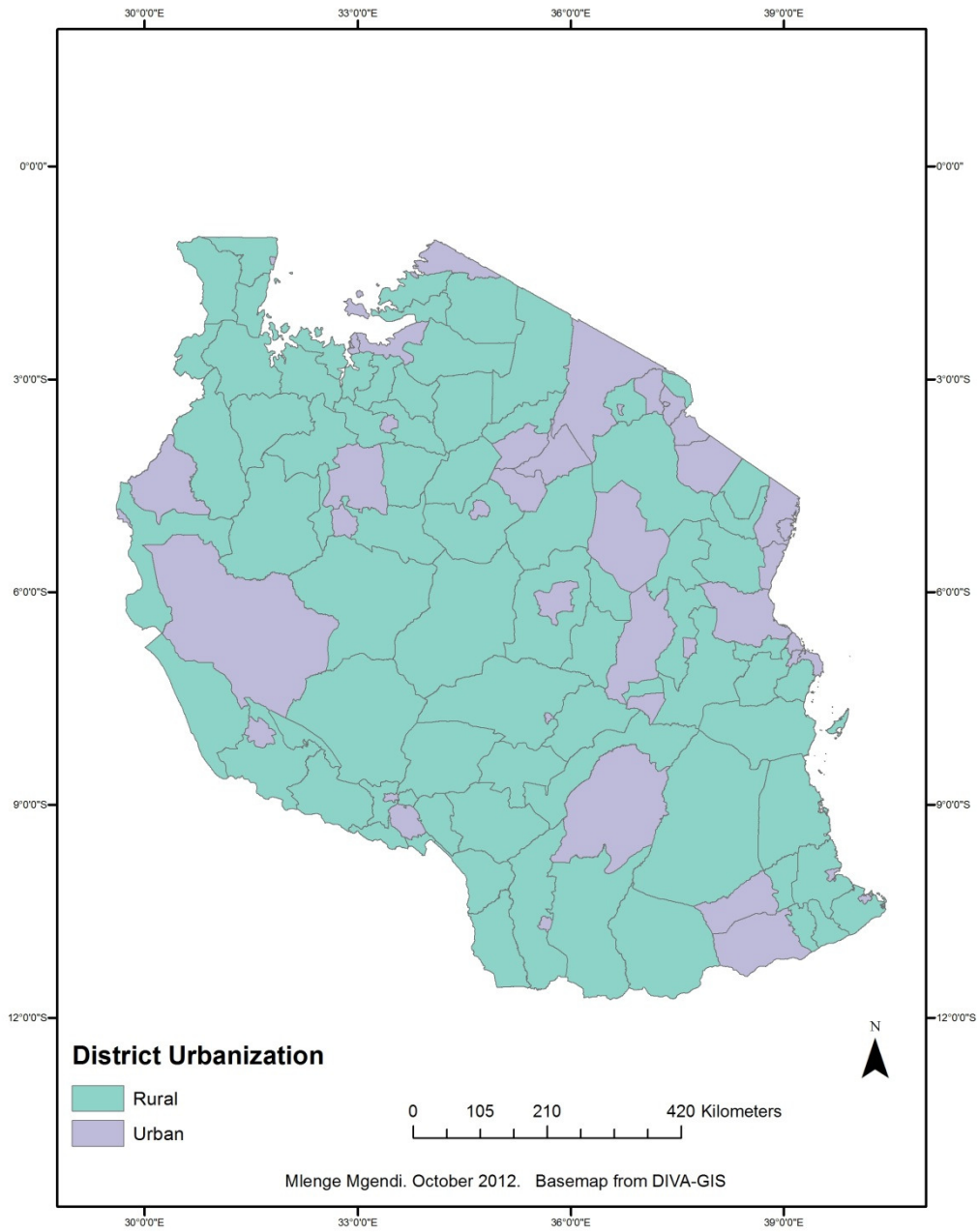


Figure 18: Tanzania districts, according to urbanization.

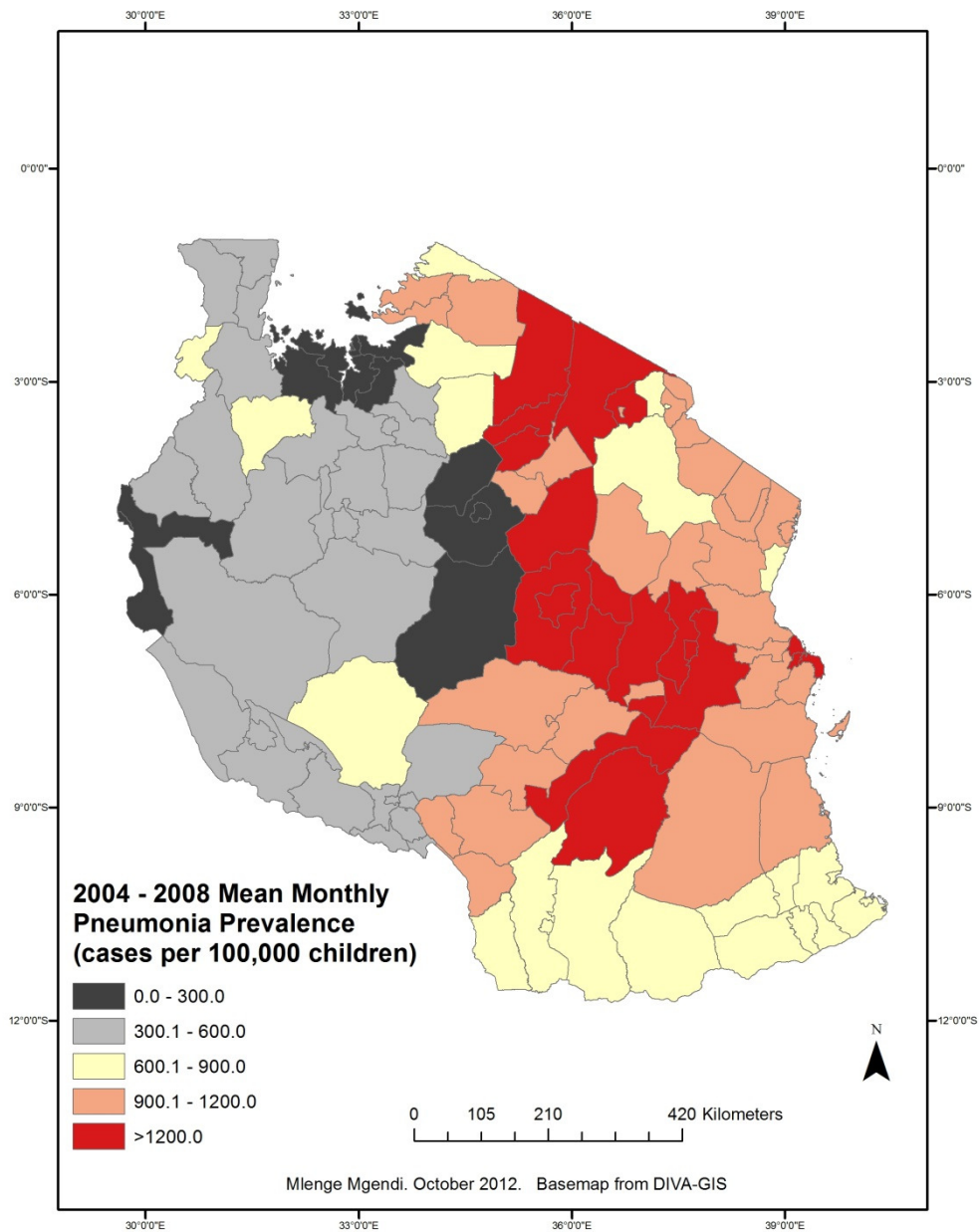


Figure 19: Mean 2004 - 2008 monthly pneumonia prevalence (N of months = 60) at district level in Tanzania. The district prevalence values were interpolated from the regional rates for statistical analysis.

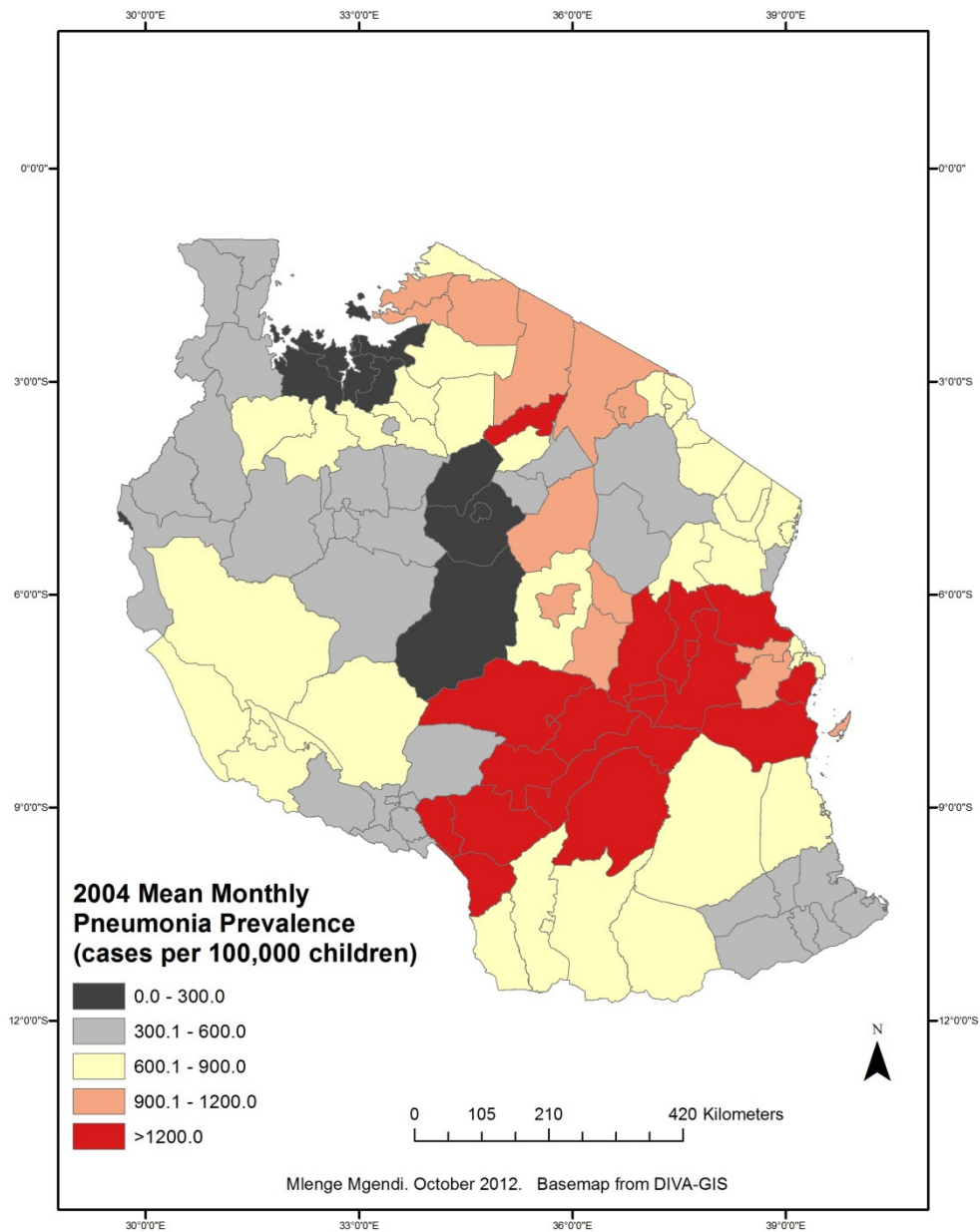


Figure 20: Mean 2004 monthly pneumonia prevalence at district level in Tanzania (N of months = 12). The district prevalence values were interpolated from the regional rates for statistical analysis.

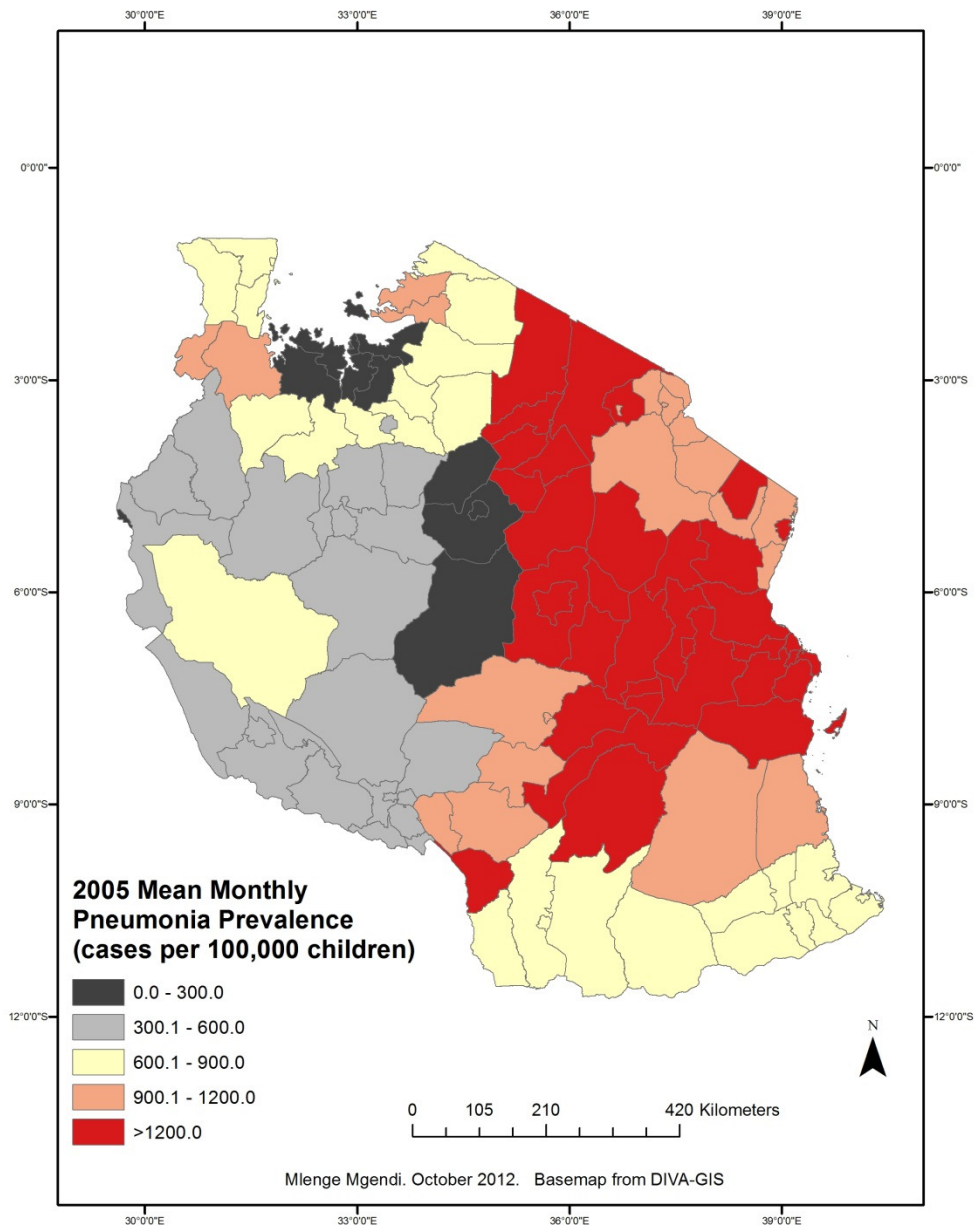


Figure 21: Mean 2005 monthly pneumonia prevalence at district level in Tanzania (N of months = 12). The district prevalence values were interpolated from the regional rates for statistical analysis.

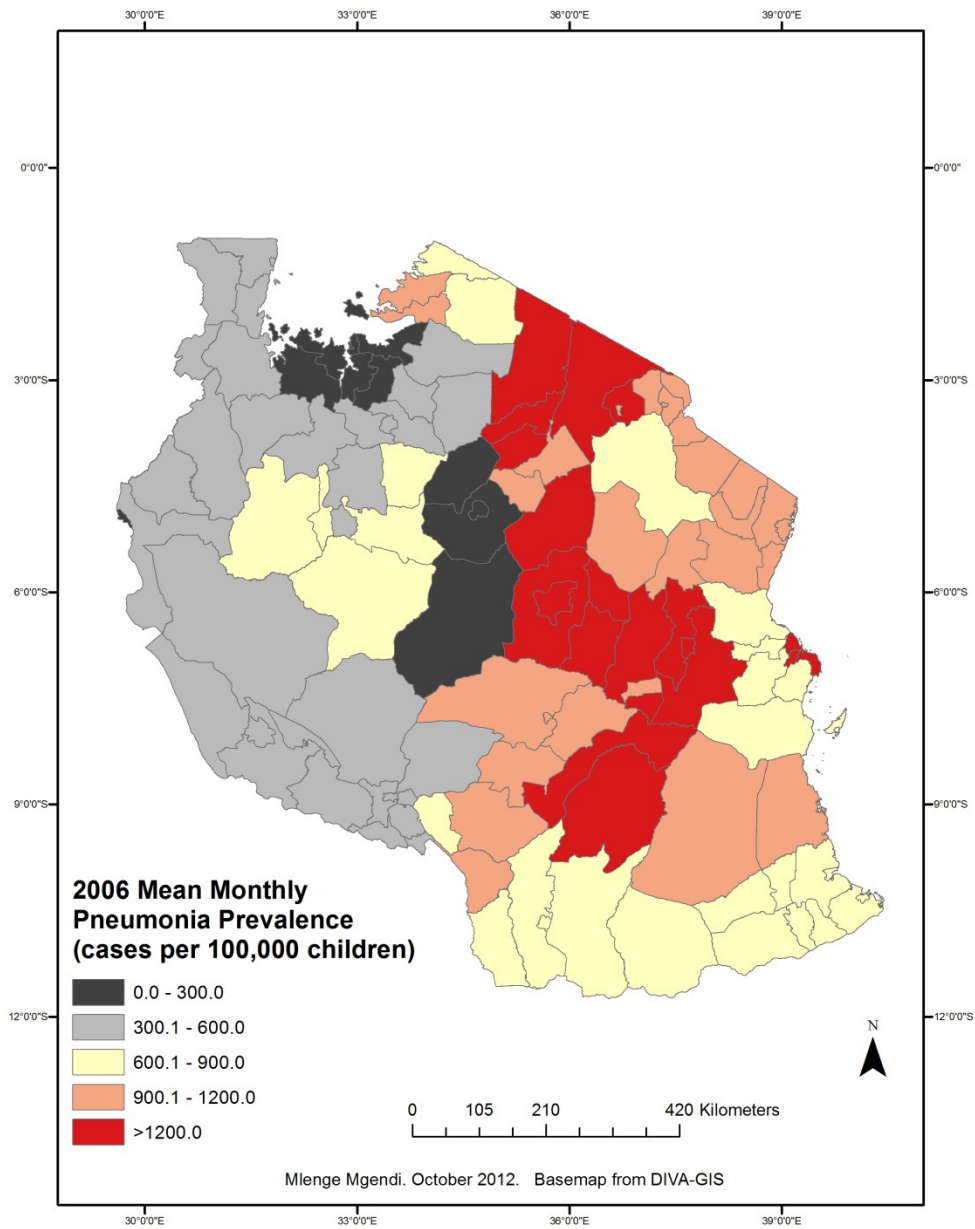


Figure 22: Mean 2006 monthly pneumonia prevalence at district level in Tanzania (N of months = 12). The district prevalence values were interpolated from the regional rates for statistical analysis.

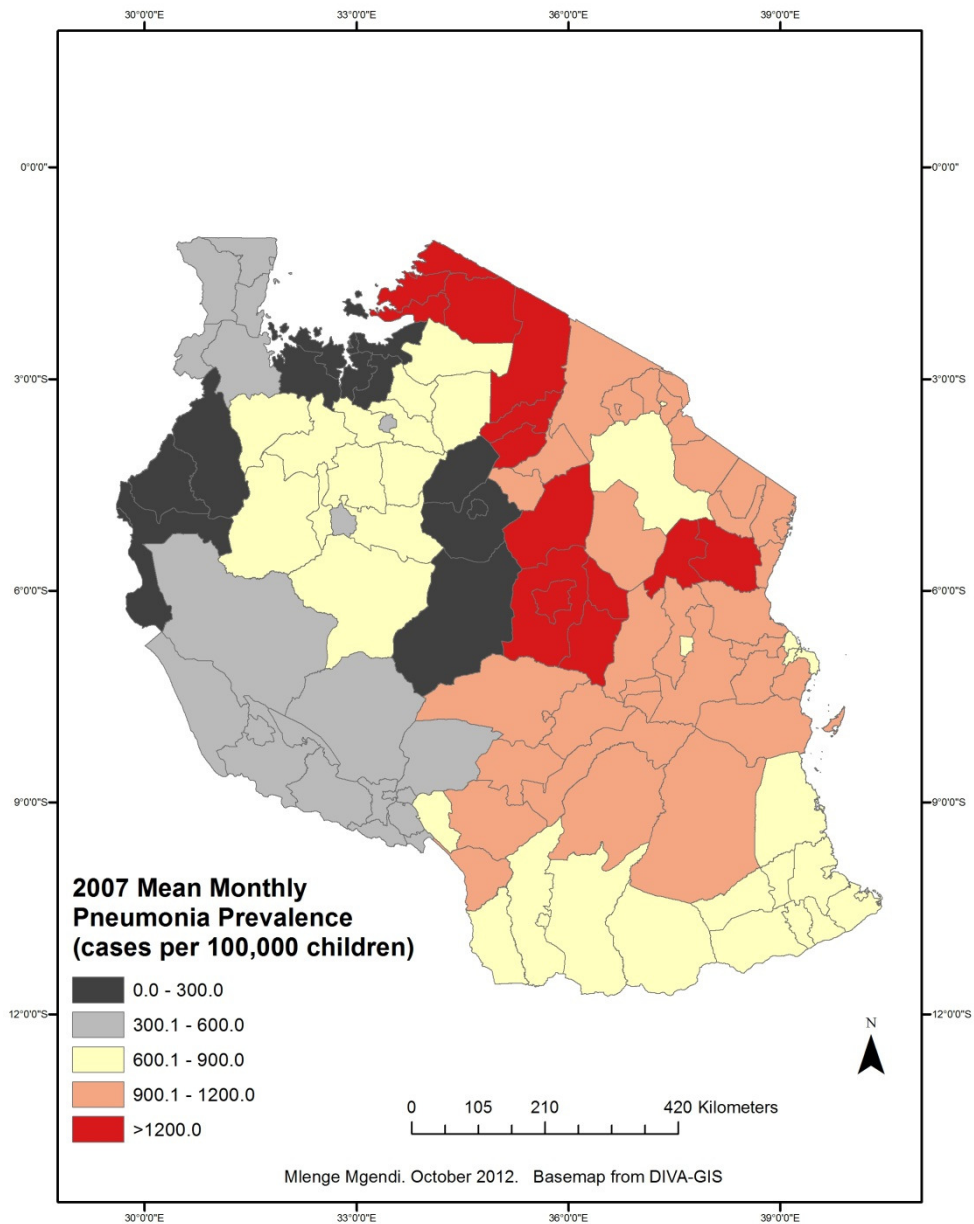


Figure 23: Mean 2007 monthly pneumonia prevalence at district level in Tanzania (N of months = 12). The district prevalence values were interpolated from the regional rates for statistical analysis.

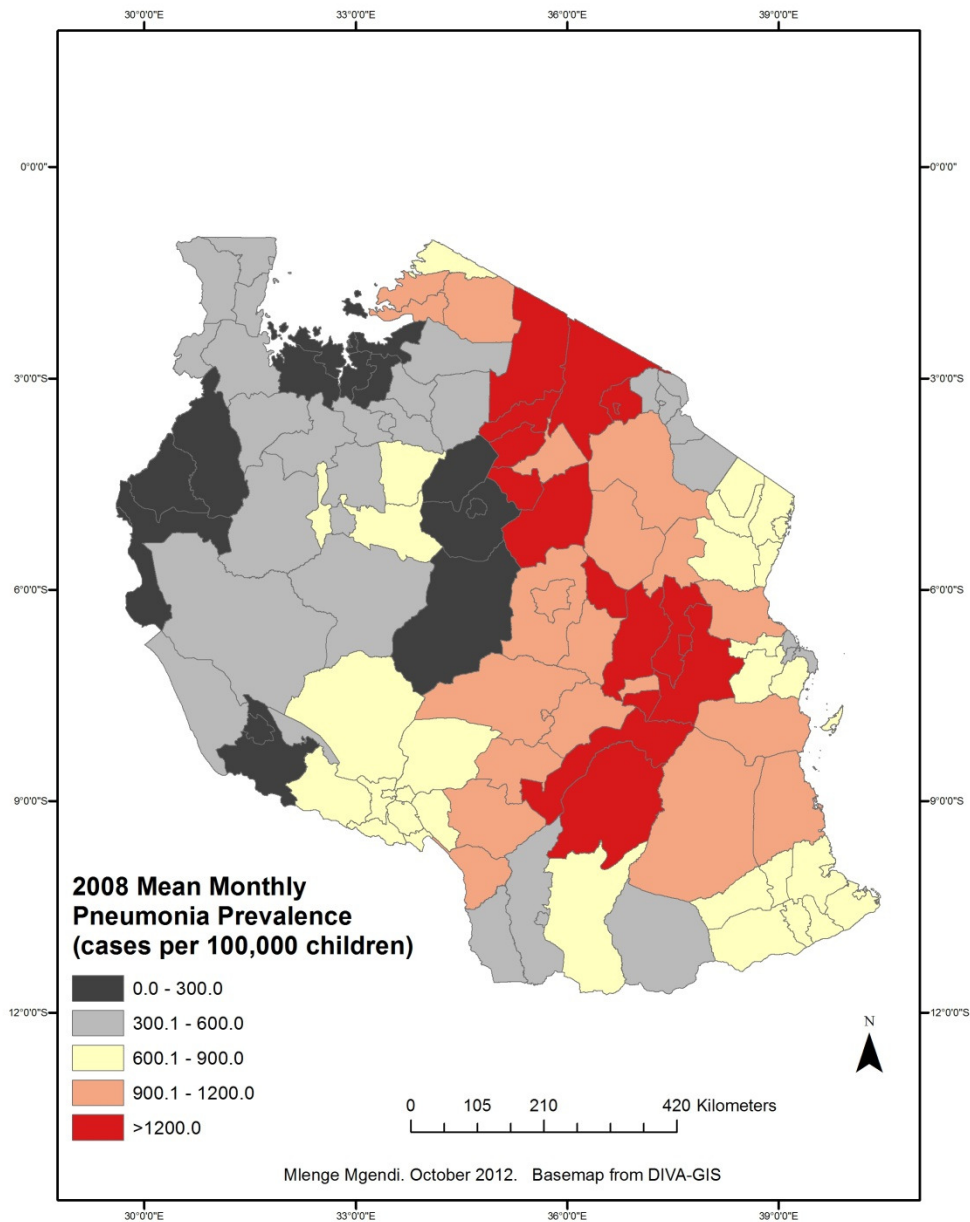


Figure 24: Mean 2008 monthly pneumonia prevalence at district level in Tanzania (N of months = 12). The district prevalence values were interpolated from the regional rates for statistical analysis.

3.7 Discussions: Pneumonia - Land Use and Land Cover in Tanzania

This chapter set out to link LULC with childhood pneumonia cases. Using Tanzania as a case study, the current dissertation processed image data and used geostatistical techniques to compare the rates of pneumonia to the LULC classes. By using these techniques, I evaluated the hypothesis that locations with higher proportions of land covers associated with production of particulate matter (sources) are likely to be more positively correlated with pneumonia prevalence than those locations with lesser proportions of the same (sinks).

Agricultural, bare soils and urban areas were the land covers considered to be sources of particulate matter based on prior research (Cheng et al. 2007; Rosa et al. 2008; Chiu et al. 2009; Halonen et al. 2009). Conversely, locations with higher proportions of natural vegetation cover were considered negatively associated with pneumonia (Beckett et al. 1998; Nowak et al. 2006). When the remote-sensing-derived land-cover types were correlated against prevalence of pneumonia, the findings showed that the link between some key land covers and pneumonia prevalence was statistically significant.

One of the notable of the findings was that places that had higher proportions of croplands also had higher rates of pneumonia. First, as the proportion of croplands increased, so did the prevalence of pneumonia. This croplands-pneumonia meant no rejection to the original hypothesis that *locations with high pneumonia prevalence will be highly correlated to proportions of land covers associated with the production of particulate matter than those locations with lesser proportions of these land cover types.*

Secondly, when urban and rural classified administrative units were compared, the urban districts had higher rates of pneumonia compared to the rural districts. The urban LULC typically includes relatively denser road networks, higher volumes of traffic, factories and less vegetation, which can be associated with higher concentrations of particulate matter and noxious gases (Bell et al. 2008; Kohlhammer et al. 2008; Chiu et al. 2009; Halonen et al. 2009; Mushtaq et al. 2011b). In Tanzania, the urban areas grow mostly in terms of residences (Lusugga Kironde 2006), and little increase in the number of factories, roads or extent of vegetation clearance. Agricultural activities can still go on in or around urban areas, especially in the mixed urban-rural locations (Flynn 2001; Howorth et al. 2001; Dongus et al. 2009).

In Tanzania's rural settings, slash-and-burn agricultural practices and wildfires are the notable LULC sources of degraded air quality (Rosa et al. 2008; Ostro et al. 2009; Rappold et al. 2011). However, the lower population density in the rural areas may serve to reduce the aggregate exposure from a single prominent source than is the case in urban settings. In the rural areas most agricultural activities are traditional, rather than modernized, there is increased likelihood of many simultaneous sources both outdoors (for instance, dust and smoke) and indoor (for example, kerosene fumes and charcoal smoke), resulting in higher exposure with less access to high quality health care. Because subsistence farming is highly seasonal, the sources of pollution are also likely to intensify seasonally, for example, during harvest or farm preparation.

Barren lands exist in both rural and urban settings and are another potential aggregated source of air pollution (Bennion et al. 2007; Bell et al. 2008; Cheng et al.

2008; Halonen et al. 2009). Bare ground that is dry provide ample opportunity for dust to be contained in air flows and be carried towards populated areas (Cheng et al. 2008). The vegetation can physically capture dust particles and hence reduce the exposure (Beckett et al. 2000). Because barren lands can be found both in urban and rural areas, degree of urbanization can be used to estimate exposure differences between rural and urban areas. Degree of urbanization will be useful because the urban areas are less vegetated compared to rural areas, despite both having barren lands. At the settings of very coarse scale like national extent in the current research, being rural or urban can produce discernible differences in exposure to pollutants, hence the differences in respiratory diseases.

Overall, particulate matter of finer or coarse sizes ($PM_{2.5}$, PM_{10}), sulfur dioxide or sulfate, nitrogen dioxide, ozone and carbon monoxide are the main pollutants of note to respiratory health (Cheng et al. 2007; Pope et al. 2007; Chiu et al. 2009). These pollutants were measured or implied in the association of LULC and respiratory outcomes; and their links to LULC sources are shown in Table 13. Most of the pollutants are linked to LULC types associated with urbanization. While both urban and rural areas are likely to have polluted air, at least at same time in the year it appears that the urban areas are the likelier due to more number of possible sources of pollution, and less seasonality in sources. In researching the link between land cover and pneumonia, it is therefore of paramount importance to seek an understanding of why and how each of the above land cover classes amplify or otherwise modify the lifecycle of pneumonia microorganisms and the other biophysical mechanisms responsible for the spread of pneumonia.

3.7.1 Characteristics of Aggregated Classes

Urban

Various characteristics of urban areas have been associated with the production of particulate matter and noxious gases (Barnett et al. 2005), exposure to which have resulted in wheezing in infants in developed countries (Ebisu et al. 2011). Urban characteristics, for example the volume of traffic and proximity to roads and factories, can be expected to correlate positively with increased pollutants and a higher occurrence of linked respiratory diseases. The urban linkage to air pollution is also likely to be the case in developing countries where proximity to busy roads has also been associated with air pollution (Jackson 2005).

Mixed Forests (all of the forest types)

Generally, the vegetated land cover classes can then be expected to lower the rates of pneumonia. Woodlands and trees in general reduce air pollution by trapping the particulate matter on the plant surfaces (Beckett et al. 1998; Nowak et al. 2006) which has been demonstrated in experimental and field studies (Pyatt & Haywood 1989; Beckett et al. 1998). The vegetated land cover classes imply less sources of pollution such as bare ground and agricultural.

Table 13: Linking air-pollutants and Land use / Land cover (LULC) in the recent studies (2007 – 2011) inquiries indexed in MEDLINE database.

Land Use / Land Cover (LULC)	Pollutants				
	PM _{2.5}	PM ₁₀	Sulfur dioxide or sulfate	Nitrogen Dioxide	Carbon Monoxide
Urban (factories, dense road network / higher volume of traffic)	road transport exhaust emission (Halonen et al. 2009), (Ostro et al. 2009), urbanization(Mushtaq et al. 2011b), (Bell et al. 2008), (Chiu et al. 2009), (Kohlhammer et al. 2008)	Urban (Chiu et al. 2009), factories and densely built (Kohlhammer et al. 2008)	Coal plants and maritime oil combustion (Halonen et al. 2009), Factory(Pope et al. 2007), Urban (Chiu et al. 2009)	Urban (Chiu et al. 2009),	Urban (Chiu et al. 2009)
Barren (desert, dried water body)	Soil dust(Halonen et al. 2009), (Bell et al. 2008), (Cheng et al. 2008), Dust from dried water bodies (Bennion et al. 2007)	Soil dust (Bell et al. 2008)			
Rural (agricultural, biomasses)	Slash and burn agricultural practices (Rosa et al. 2008), (Rappold et al. 2011), Potassium in the fine particles from : burning biomass(Ostro et al. 2009)				

PM_{2.5} and PM₁₀ respectively refer to particulate matter of diameter less than or equal to 2.5 and 10 µm

The presence of trees therefore serves as a filter to clean the air off the airborne particles most of which are of anthropogenic origins (Beckett et al. 1998). Vegetation land cover influences microclimates (Oke et al. 1989), for example by ameliorating heat stress (Lafortezza et al. 2009). Long-term heat stress is known to compromise immunity against pneumonia (Tulapurkar et al. 2011). Additionally, pneumonia-causing bacteria have been linked with the atmospheric conditions such as ambient temperature (Kim et al. 1996; Watson et al. 2006).

Agricultural and Barren Lands

Agricultural, barren land cover classes and smoke are other main sources of particulate matter in form of dust. The dust from the barren and agricultural land types present a threat to respiratory health of individuals and communities (Schenker et al. 2009; Morain et al. 2010). These types of land covers are dominant in the rural areas and possibly are the main sources of particulate matter in Tanzania

3.7.2 Air Quality and Land Cover

In Tanzania, the particulate matter in the air are from various sources and their concentrations can be on the higher side similar to the developed countries (Mkoma et al. 2011). Agriculture, biomass fuel and road traffic have all been identified as sources of air pollution from particles (Jackson 2005; Kilabuko et al. 2007).

Review of literature shows a number of confounding factors that might limit (or undermine) the correlations between LULC and pneumonia. Indoor sources of pollution (Esplugues et al. 2011), weather (Chiu et al. 2009), and constituents of the pollution (Knox 2008; Ostro et al. 2009) can confound determination of the LULC-pneumonia

association. For example, indoor burning of biomass can also produce pollutants harmful to respiratory health (Esplugues et al. 2011). Wind can exacerbate the levels of pollution (Cheng et al. 2008), while rain can dampen the amounts pollution (Rosa et al. 2008). It is unlikely that these factors appreciably affected the current study because most households still use biomasses as source of fuel, hence no differences geographically. In addition, the coarse spatial and temporal resolutions potentially masked differences due to short-term weather.

However, there are limitations to this study. The original data used in this study was available at different scales. For example, the land cover data were available at comparatively finer scale compared to the coarser scaled pneumonia data. In addition, the pneumonia data were not available at the different levels of administrative units. These limitations forced interpolation to finer scales when needed or aggregation to coarser scales in order to enable comparisons of the different data. While interpolation is a standard practice, it might not be the same as using the original data, were they available at the appropriate scales.

Another limitation is the nature of design of the current investigation. This research used ecological study design to evaluate how land cover and pneumonia relate. In ecological study designs, researchers use data on group of people instead of using data of individuals. For that matter, the findings at group scales cannot reliably be inferred to individuals, because doing so will be committing what is known in epidemiology as 'ecological fallacy' (Schwartz 1994).

However, ecological study design is also useful. By using ecological design, it is one way researchers can justify findings to test by using resource-intensive health study designs(Schwartz 1994). In the current research, for example, findings point out croplands and urbanization as predictors of pneumonia. Other researchers can then design follow-up studies at finer spatial and temporal scales, using individual human subjects and deploying air quality monitoring instruments to measure the exposure to the individual subjects.

Despite the limitations pointed out above, this study has several strengths. It is the first study to investigate specifically LULC-pneumonia relationships at a national extent. Most of the previous research used LULC only implicitly as an aid in the air-pollution disease inquiries, overwhelmingly related to road transport in developed nations.

4 POLITICS AND CHILDHOOD PNEUMONIA IN POST-INDEPENDENCE AFRICA: A CASE OF TANZANIA

“Politics: who gets what, when, and how”

- H. D. Lasswell, 1936, referred to by Davis (2012)

In this chapter, I seek to explore effects politics has on the geographical distribution of childhood pneumonia in Tanzania. As the H. D. Lasswell’s definition of politics quoted above goes, I use the framework of distributive politics (Brown & Staeheli 2003; Donovan & Duncan 2009) to explore effects on the prevalence of childhood pneumonia from a post-colonial (Young 2004) hegemonic party’s (Magaloni 2006) budget allocation practices.

A hegemonic party is a dominant ruling party which gets re-elected through elections it cannot possibly lose (Hyde & Marinov 2011). Such dominant parties always strive to have formidable victories to portray an image of invincibility (Magaloni 2006). The Tanzania’s ruling party, *Chama cha Mapinduzi*, CCM (‘The Party of Revolution’) is also described as a hegemonic party (Weinstein 2011), at worst, or as ambiguous (Diamond 2002), at best. After the previous general elections, CCM reduced financial allocations as punishment for places that did not vote for CCM, and financially rewarded the places that did vote overwhelmingly for CCM (Weinstein 2011).

Linking politics to the geography of health can help uncover winners and losers in society’s seemingly apolitical themes (O’Brien & Leichenko 2003), an example of

which is the topic of human health. In the situation of human health, investigating politics can reveal historical, social, economic and political factors embedded in an epidemiology of (Mayer 1996), say, pneumonia, a respiratory disease that can be devastating to children. For instance, on the outset, childhood pneumonia may seem to be an apolitical subject entirely explained through biophysical mechanisms. A child gets exposed to air pollution (Ilabaca et al. 1999; Morgenstern et al. 2007) or severe weather (Haspil-Corgan et al. 2004; du Prel et al. 2009; Young 2009), and the child is sick with pneumonia. Then, the child is brought to a hospital, gets prescription, and returns home. Germ theory is in operation. Nevertheless, in real life, it is not that simple. There are more things that can alter the course of childhood pneumonia than the exposure to germs alone (Turshen 1977).

Take the quality of healthcare for example. A parent may take the sick child might to a health facility that has no medicines or trained personnel due to small budget caused a government that sees pneumonia is less of a priority. A 2006 joint UNICEF/WHO report laments that pneumonia is ‘the forgotten killer of children’; forgotten despite the fact that pneumonia kills under-five children more than malaria, AIDS and measles combined do (Wardlaw et al. 2006). If only governments financed the universal access to prevention and treatment, the lives of 1.3 million children will be spared yearly, the UNICEF/WHO report emphasizes. Other researchers also suggest that health budget is an important variable in determining the quality of healthcare accessible to the public (Meadowcroft 2008; Tediosi et al. 2009; Jarris et al. 2012). Apparently, many governments give budgetary consideration to priorities other than pneumonia. There is a

need to attract the attention of the governments and other stakeholders back to childhood pneumonia.

Therefore, this chapter attempts to attract the attention to childhood pneumonia in Tanzania, one of the 15 nations with the highest number of new cases of childhood pneumonia in the world (Rudan et al. 2008). Pneumonia, also known as Acute Respiratory Infection (ARI) or Lower Respiratory Tract Infection (LRTI), affects lungs which become inflamed, resulting in to fever, difficulty of breathing and death if left untreated (Scott et al. 2008). Pneumonia is responsible for 11.2% of under-five mortality in Tanzania (Samarasekera 2008), or in other words, an estimated 1.9 million cases per year or 0.33 cases per child per year (Rudan et al. 2008).

In sum, I demonstrate exploration of politics in understanding the factors other than germs that affect the epidemiology of childhood pneumonia in post-independence African nation. In so doing, I give examples of budget allocation practices and general-election politics in Tanzania. In the following sections, I discuss the importance of politics in health geography while I revisit previous research on politics of health. Furthermore, I argue for contemporary approach in politics of health, demonstrate an empirical example of contemporary effects of distributive politics on health, and discuss the findings.

4.1 Importance of Politics in Health Geography

Politics in health geography allows researchers to observe how power relations determine or shape health outcomes (Donovan & Duncan 2009), especially through distributive, antagonistic and constitutive politics (Brown & Staeheli 2003). According to

Brown and Staeheli, distributive politics refers to the power to allocate and distribute resources, together with controlling people and institutions. Constitutive politics connects the concerns for identity, inclusion and normative assertions. Then, antagonistic politics refers to the conflicts, contests and resistances against, for example, the “power of the state through planning policy to perpetuate spatial inequality” (Brown & Staeheli 2003).

Engaging politics in health geography in the realms of post-medical geography provide an opportunity to broaden the perspectives of understanding human health (Kearns 1993). In turn, the complexity of health geography justifies the multiple-perspectives and methods (Kwan 2012). Andrews et al. (2012) summarize the three main application areas of health geography as being health care settings, public health, and environmental health, which is a special case of public health. In addition to the much-used quantitative analysis, health geographers also query the political and economic factors that affect the settings of health care. In his own words, “health care settings are increasingly contested domains, competed over and influenced at the macro-scale by political and economic interests, at the meso-scale by professional interests and at the micro-scale on a day-to-day basis by the people who frequent them” (Andrews et al. 2012). What Andrews et al. (2012) argue is that, these applications of health geography converge on policy and practice, for example, as revealed through decentralization processes.

Political squabbling around processes like decentralization which are inherently political, can then end up amplifying inequalities in health between different local systems (Atkinson 2002). According to Atkinson (2002), the goodwill of intentions to

decentralize are transmitted from central to local through operationalization procedures which brings the policy into contact with social and cultural factors that may impede smooth transmission. “Without addressing the influence of the wider context, decentralised health systems run the very real risk of increasing inequity between districts rather than the intended opposite”(Atkinson 2002), with the unintended consequences hampering designated implementation of what on paper appears to be good plan to decentralize.

Distribution of resources is one of the issues that can affect the intended outcomes of decentralization. Even what appears to be an objective formula for distributing the resources can be inherently biased. For example, rural areas which have higher operating costs and lower metrics used in the allocation formulas (Asthana et al. 2003). Researchers need to uncover the unintended consequences, especially against the vulnerable populations.

In uncovering the consequences of politics to human health, researchers have engaged in debates over what is the political. In one extreme, the arguments are about evaluating biochemical processes that happen within the human body itself, .i.e., ‘political ecology of the body’ (Guthman 2012). In another extreme, researchers such as King (2010) debate about ‘political ecologies of health’ which deal with economic, historic and social factors distantly located from the bio-mechanisms of the body itself. The overarching theme in the incorporation of politics in health geography is to seek social justice in the community, whereby no group of people faces undue risks and exposures to disease and death (Beauchamp 1976).

Social justice is one of the main substantive topics in which health geography can engage in research that is useful to the public, particularly to the groups whose health suffers from situations “associated with where they live, and the political regimes in power there, or unfolding events that impact upon them (such as conflict)” (Andrews et al. 2012). Budgetary distribution that is influenced by voting patterns may put the populations that depend on the distributed finances to undue inequalities of health outcomes. By facing potentially different outcomes based on where they live, social justice for children at risk to pneumonia will be breached.

Previous research on the politics of health shows an evolving discipline of political geography over time, how political geographers explored the politics of health, mostly by using political ecology approaches. First, I start by discussing what political ecology is.

The ‘what is political ecology?’ question has caused debates within and outside political ecology field itself (for example, Forsyth 2008; Escobar 1996; Paulson, Gezon, and M. Watts 2003; Rocheleau 2008; Vayda and Walters 1999; Walker 2006, 2007; Michael Watts and Peet 2004; Turner 2009). The contentious point in these debates is about which and how much dosages of politics and of ecology political ecology studies should use. However, the debating political ecology scholars agree to the fact that political ecology is too broad a field to uniformly be fitted with an all-encompassing, definite theoretical framework. ‘Political ecology’ is more than a mere expedient truncation of ‘politics of ecology’. Political ecology is a tool and a way to learn how the human beings interact with the biophysical

portion of the environment. However, I think a modern definition to broadly capture the essence of political ecology. Turner (2009) describes political ecology as “analyses of society-environment relations, contextualised by history and place, with a particular emphasis on environmental and social justice implications of broader political economic change of social and environmental change”. While acknowledging that the definition emphasizes the compartmentalization between humans and the biophysical, Turner (2009) argues that the political ecology studies understand complexity of (the apolitical) ecology, but differ on the extent political ecologists engage with ecology. That is, different political ecology researchers delve into the biophysical world differently depending on the complexity of the relations they seek to understand. The level of involvement ranges from more emphasis on the social (less biophysical) to the more biophysical (less social).

The flexibility of political ecology means its main theoretical concepts are in constant scrutiny that helps it evolve to maturity (Watts & Peet 2004). Key debates in the contemporary political ecology therefore lean on theorizing politics tailored to knowledge of the biophysical environment; identifying and fitting in relevant research methods to suit conceptual understanding of politics and environment; and, to find ways to actually change the human society and the biophysical environment for the better (Paulson et al. 2003).

The theoretical developments have therefore allowed intellectual turns within the genealogy of political ecology towards epistemologies of post-structuralist, non-equilibrium ecology and questioning environmental truths from politicized measurements of the biophysical environment (Forsyth 2008). Such questioning enabled

a detailed analysis of production of power, knowledge and practice through discourse (Escobar 1996). The maturing political ecology academic discipline thus involves several methods and theoretical underpinnings in human-environment relationship (Rocheleau 2008). Because political ecology concerns itself in understanding how unequal power relations and knowledge claims are tied to the environment (for example Bryant 1998; Greenberg and Park 1994; Muldavin 2008), such concern is one of the distinguishing features between political and apolitical ecology. The evolution of political ecology over time is highlighted next with respect to human health.

4.2 Political Ecology and Health

Over the past four decades, political ecologists have tied human health colonial, post-colonial and capitalist aspects of economy and history. In “The Political Ecology of Disease” article published in the 1970s, which is the earliest political ecology of health reference I could find, Turshen (1977) discerns differences between clinical medicine and political ecology approaches. Turshen opined that clinical medicine is subjective, affected by history, and not neutral as it claims to be. “Expressed differently, a body of scientific knowledge such as medicine is a systematic approximation of reality, but neither equivalent to nor the same as reality itself” (Turshen 1977). What Turshen is arguing is, clinical medicine does not consider everything such as social relations; hence clinical medicine is unfit to be the same as reality. By selecting what to systematically represent, clinical medicine also loses the claims to objectivity. Turshen declares that clinical medicine is tied to economic structure through three main factors, namely: prevailing

social relations, values, and the medical model. The three factors are based on the dominant mode of production, which varies historically.

Turshen (1977) then uses history of the nineteenth century Europe to establish the links between capitalism and clinical medicine. In the nineteenth century Europe, clinical medicine focused on returning the sick body to what was thought to be its normal equilibrium, whereas health was defined as an absence of disease. Clinical medicine avoided dealing with collective groups of people, instead concentrated on the individual, who is the fundamental in capitalist society. At the same time, clinical medicine hid its ideology - capitalism - and the power clinical medicine held, in order to maintain appearing objective and apolitical. Even when clinical medicine extends to medical ecology, clinical medicine only considers biological and socio-cultural factors of public health.

The dominant classes of capitalist society wanted to avoid the development of public health because collective action on health problems could strengthen political resistance. The corollary is that clinical medical practice, by situating the diagnosis and treatment of disease at the level of the individual, provided the ruling classes with a means of social control: patients would fail to make common cause with each other or to protest the external, underlying conditions that make them ill. The effect is to depoliticize malnutrition, alcoholism, drug addiction and mental illness by defining them as medical problems. The medical profession - made up predominantly of members of the ruling classes - is thus invested with

power in order to control the behavior of the working class. Especially in the field of psychiatry, this aspect of social control is very clear.”

(Turshen 1977)

What Turshen is arguing is that even in the case of medical ecology which is supposed to look at factors beyond an individual, medical ecology deliberately avoids politics and economics in order to hide the ideological biases of clinical medicine. Using history of developments in public health during the changes in nineteenth century Europe, Turshen argues that the capitalists blocked the public health profession attempts to put health concerns into the collective. The capitalists then co-opted public health as an extension of clinical medicine.

Having characterized clinical medicine as capitalist, Turshen (1977) concluded that it is preferable to use Marxist approach to understand health of groups of human. “A truly political ecology of disease recognizes the determinant influence of the mode of production on health status” (Turshen 1977), showing preference for political ecology approach which focuses on classes and means of production as a lens through which to view human health, instead of using the existing capitalist, individualistic clinical medicine. One criticism that can be levied is that Turshen’s argument did not use the concept of hegemony to understand human health. However, without Gramscian hegemony, it is far-fetched to apply political ecology, for it “is hard to imagine contemporary political ecology without hegemony as a central conceptual resource” (Mann 2009). Despite the dearth of the concept of hegemony, Turshen’s theorization of political ecology of health still provides strong historical background, debunks the

assertion of clinical medicine of being apolitical, and lays out a foundation for Turshen's further analysis of the political ecology of health using Tanzania as a case study.

Years later in "*The Political Ecology of Disease in Tanzania*" book, Turshen (1984) argues that capitalism causes poverty in the working-class, whereas poverty is, in turn, the root cause of diseases in Tanzania. Turshen assigns blame to colonialism for the woes of health care in Tanzania after independence. Turshen sees colonialism as "shorthand for the very complex economic, social and political processes" (Turshen 1984). Turshen though concedes that there is only so much that can be attributed to the colonialism, because there has to be alternative or complementary analysis in post-colonial Tanzania. Turshen still does not support this alternative analysis with the same vigor as she does with colonialism.

In my opinion, up until 1984, the time of the publication of Turshen's book, two main processes contributed appreciably to the conditions of Tanzania's then health system. The first process is Arusha Declaration that ushered in the era of *Ujamaa* in Tanzania in 1967. Forced movement of people, the second process, was an extension of the *Ujamaa* policies put forward through the Arusha Declaration. Turshen also acknowledges these two processes, but does not assign their importance to affect poverty the way I think she should.

In the 1967's "Arusha Declaration", Tanzania introduced *Ujamaa* ideology, a variety of "African" socialism that saw nationalization of major means of production and more government involvement in social programs. Education, health and poverty alleviation were set to be the priority of the country having declared ignorance, disease

and poverty “the national enemies”. The government-run health and educational facilities were noted. The facilities provided free services to the masses. Privately-run educational and health facilities were restricted. The *Ujamaa* era also witnessed the ruling party banning all other political parties. For decades the ruling party remained the only political organization allowed in the country.

The Arusha Declaration was a direct attack to capitalism, and brought about rapid changes in production. I posit that Arusha Declaration had some benefits mixed with unintended negative consequences. For example, following the Arusha Declaration, the Tanzania government was able to control all means of production, hence, the economy. With that control, the Tanzania government was available to provide universal health care, education and other social goodies. But at the same time the government was ill-prepared to manage the production sectors. There was less number of qualified employees than required to manage the unexpected responsibilities to manage the economy. Nepotism, corruption and government involvement in the day to day running of production did not go well with the industries and other production sectors either. This led to failure of production, and Tanzania government reduced to begging for some handouts from the Western capitalist nations, the nations which the Arusha Declaration was demonizing in the first place.

The second process of forced movement of populations towards collective *ujamaa* villages, was known as “Operation *vijiji*”. People were forced from their ancestral lands towards collective villages (*vijiji*), with disastrous consequences. Tanzania has never been

the same again since. The effects of forced movement on land tenure are still felt presently.

I argue that these two factors were important in post-independence Tanzania until President Julius Nyerere, the architect of the *Ujamaa* policies, decided to step aside in 1985, to let someone else to do some corrective measures. Despite the negative consequences and pressure from international organizations, still Tanzania went on with *ujamaa* policies. Nyerere had refused to accept loan conditions from the international financial organizations. There was no turning back from *ujamaa*, at least for him, for he was popularly known to maintain that turning back would make him turn into stone.

Ali Hassan Mwinyi became the next president of Tanzania after Nyerere retired from the government, but remained in the ruling political party. President Mwinyi introduced many changes. He allowed free press, private business enterprise and more liberty to the people. For that he became fondly known as “*Mzee Ruksa*” (‘The Old Libertian’). In 1991 Mwinyi’s government officially buried the Arusha Declaration with the ‘Zanzibar Declaration’. Nyerere resigned from being the Chairman of the ruling party CCM. Tanzania underwent so many changes in the 1985 to 1999 time-period in which Nyerere was still alive, but outside the government.

In December 2011, Tanzania celebrated 50th anniversary of Tanganyika’s independence. Surely by now, it should make more sense, to assign blame for the bad, and shower accolades for the good, to post-independence Tanzanians. For this reason, Turshen’s work on the political ecology of Tanzania serves as a good historical record for

the prior and the first 20 years of Tanzania independence. For the time period after 1985, alternative analysis is certainly warranted.

A decade later following Turshen's 1984 book on political ecology of disease in Tanzania, Mayer (1996) built on the earlier works on political ecology of health. Arguing that political ecology should deal with local outcomes of wider phenomena, Mayer opined that "political ecology of disease, like political ecology in general, should demonstrate how large-scale social, economic and political influences help to shape the structures and events of local areas" (Mayer 1996). Mayer introduces a framework for political ecology of disease that combines social and environmental causes that have implications to disease. This framework is captured in one sentence: "How have politics, power and human-environment interactions shaped disease emergence in specific locations and places?" (Mayer 1996). Mayer's political ecology of disease framework integrates the concept of power into development theory to apply political ecology on understanding disease dynamics.

In any case, using political ecology to investigate disease provides distinct difference from clinical medicine and other apolitical approaches. Harper (2004) provides an excellent synthesis of what sets apart political from apolitical ecology. Political ecologists view ecosystems and social systems as intersecting, but not towards a particular idealized equilibrium, though ending up with winners who benefit from the change and losers who do not. Political ecology researchers use multi-scalar methods to compare local and wider concerns, while at the same time they agree that each case-study is of specific context that may not be generalizable to other locations.

Political ecologists are reflexive: they tend to admit having, or even promoting, a particular political view in their study of human-environment interactions, without the pretense of neutrality (Harper 2004). Harper uses critical medical anthropological approach to combine political ecology and health, whereas critical medical anthropology may not be applicable in every case. For instance, I consider critical medical anthropology is not applicable in this dissertation.

“Political ecologies of health” (King 2010), which is recent theorization on politics pertaining human health, summarizes what politics adds to health geography. King (2010) enlists three main possible contributions of political ecology to geographies of human health. First, political ecology of health is multi-scalar analytical framework that links disease with the society over space and time. This framework entails inclusion of history, economy and power into consideration. Second, is to show the underlying socio-economic factors that make individuals exposed or susceptible to acquiring disease. Third, political ecology contributes to establish interplay between human and non-human environment as two-way effects. This way, political ecology shows how human health both affects and is affected by the environment. In so doing, political ecology contributes to clearly show that health is not mere absence of disease, but that health is a process that endears itself amenable to the social processes over a time period. According to King,

... there are important contributions that political ecology can make to studies on human health... political ecology provides a theoretical framework that makes political economy and power central to its analysis

of the relationships between social and environmental systems. Additionally, political ecology would assist in illustrating how these relationships shape the transmission of disease and ability of institutions to provide effective treatment.

(King 2010).

The essence of King's argument is that, political economy and power are the main focus of political ecology in exploring the spatial aspects of population's health.

4.3 Post-Colonial Politics

Notwithstanding the King's (2010) convincing arguments, I disagree with the way King apportioned less responsibility to the contemporary African regimes. In order to illustrate the benefits of using political ecology, King chose to examine HIV/AIDS in South Africa as a case study. In his discussion, King blames the colonial and apartheid past policies for the current dire state of HIV/AIDS, as he provides brief commentary about the current government. After free elections in 1994, the new South African government was slow to deliver ARVs to the people. ARVs are medicines used by people infected with HIV / AIDS in order to reduce suffering from AIDS. King then quotes a study that blames the previous governments for what the current government of ANC, the South Africa ruling party, was doing. Though he includes other studies with views critical to the ANC government, he does not appear to do so with the same vigor as he did when he quoted previous studies with the views blaming the apartheid regime for present day HIV / AIDS.

Despite the now many years since the new ANC government took power, King still refuses to explicitly express his own opinion on whom to blame for the delay of South African government in responding to HIV/AIDS. In my opinion, King would like to blame the current government, but is too frightened to lay the blame where he should. Nevertheless, he also appears he does not see it fair to blame the previous governments of the Republic of South Africa, and I say, justly so. Apparently most of King's research is done in South Africa. The affiliation shown in King's article puts him to be a scholar in a Western nation. He might then want to tread South African politics carefully, lest he burns the metaphorical bridges with the South African host government. Hence he decides to metaphorically sit on the fence in this matter, though tacitly insinuates if anything, a reader may want to blame the past governments as a politically-correct safe bet.

While I acknowledge position of researchers who argue for effects of colonial legacy on the present day Africa (Van de Walle 2009; Hillbom 2012), I argue that modern African governments have more impact to the present human-environment interactions in Africa than the colonial actions that happened in the distant past. Historical changes in the colonial times are used to deflect attention from the current shortfalls in African leaderships. For example, while there might be remnants of effects of actions colonialism or apartheid in South Africa, these actions are now quite in distant past and continued attention to those misses out an opportunity to criticize the continuing wrong doings. This blame-shifting to colonial times, provides an excuse which the African bureaucracy love, because the flaws in their leadership go un-criticized.

Young (2009) provides an excellent argument to stop blaming the colonial past for the wrong-doings of the current African rulers. Young suggests that it around the year 1990 when it was the last time the remnants of colonial effects in Africa could be justified. The basis for early 1990s being the cutoff point is that neoliberal policies after the collapse of the Soviet Union brought about the huge changes in the African politics around that time.

I also agree with Young (2009) on his portrayal of post-independence African rulers. Young portray African rulers as a replacement of the colonial rulers, as far as the rest of the population was concerned. The few educated Africans behaved as if they were the new colonial masters, thinking it was the “prerogative of the youthful educated nationalist generation to exercise tutelage over an unlettered citizenry” (Young 2009). The new elite Africans did not want to change the colonial laws and policies, as they wanted to expand the power of the state in the name of ‘nation-building’. Early in 1960s, when the African nations were getting independence, it was at the height of the Cold War, which the elite exploited in pledging allegiances to the Cold-War parties. In the meantime, the African ruling elites consolidated power, banning the rest of political parties, except the ruling party. In effect, the African rulers oppressed the citizens more than the colonialists did. According to Young,

whereas the colonial state asked only obedience, the post-colonial polity demanded affection. Mere submission did not suffice; active participation in rituals of loyalty (support marches, assemblies to applaud touring

dignitaries, purchase of party cards, display of the presidential portrait, participation in plebiscitary elections) was mandatory.

(Young 2009).

In other words, Young believes the African rulers were the worse oppressors of the Africans, way more than the colonial administrations were. With the expanding state, these rulers developed cults of personalities and networks of patronage, with the state control of economy the masses were at the mercy of the whims and wishes of the ruling elite. Young himself writes:

Whatever the divergent forms taken by African states, most have long ceased to resemble the colonial state. The time elapsed since African independence now begins to approximate the time period during which African subjects experienced a consolidated colonial regime... Certainly, survivals of the colonial legacy are still apparent... However, these are progressively overwritten by new defining events, political practices and agendas. The tides of globalization wash over the continent, depositing sedimentary layers of social exposure and economic impact. The rise of significant diaspora populations from many countries produces novel forms of international linkage. As these many processes work their way into institutional forms, political patterns, and social memory, the explanatory power of the post-colonial label erodes. In short, the post-colonial moment appears to have passed.

(Young 2009)

The essence of Young's argument is that we should pay attention to what happens in Africa now, if we need to explain the political, economic and social determinants of environmental phenomena. What happens now is more important than whatever had happened in the distant past in shaping the outcomes of interest in the lives of Africans today. Contemporary researchers will do well to determine what happens now rather than seeking a safe scapegoat in colonialist past. In demonstrating politics of childhood pneumonia in post-independence Tanzania, I use contemporary budget allocation practices and general-election politics because current budget allocations and election politics are hardly affected by the Tanzania colonial past, if at all. Before discussing political ecology of childhood pneumonia in Tanzania, I first explain my ontological and epistemological positions.

I used the scientific (positivist) methods in the earlier chapters of this dissertation too. In the preceding chapters, I explored the roles of weather and land cover to the distribution of pneumonia in Tanzania through implementation of geographical information systems (GIS) and statistical approaches. However, the preceding sections were also scarce in depth for the political, economic and social aspects. The political, economic and social aspects of disease are part of the reality of childhood pneumonia in Tanzania which also deserves addressing. Therefore, by exploring distributive politics, this chapter illustrates the importance of human-dimension to the geography of pneumonia, by highlighting relevant political, economic and social aspects of pneumonia in

Tanzania. In this chapter I combine both the positivist (empirical) and interpretive (political) approaches.

The preceding discussion shows that integrating politics in health geography, is an approach that can successfully interrogate the political, economic and social aspects of a disease (Richmond et al. 2005). Politics is an important part of understanding the spread of diseases, and usually requires deployment of approaches other than positivism alone. While empirical studies are useful, they usually miss out on the social-economic aspects of the disease phenomena. For example, the linkage between politics, economics and other social factors are often missing in the bio-physical empirical studies. The roles of the socio-economic factors remain by and large undetermined. To illustrate effectiveness of politics to investigate childhood pneumonia in Tanzania, I provide the historical background of the multi-party politics in Tanzania, budget allocations for health, prevalence of childhood pneumonia, and discuss how pneumonia prevalence and politics relate.

4.4 Historical Background

The Tanzania Government play an important role in the provision of care to the children because the majority workers in the health sector are employed by the government (World Health Organization 2007). Although there are alternatives to the government-funded health care, most population have limited access to it due to financial limitations. For example, 94% and 93% of Tanzanian women and men respectively are not insured (National Bureau of Statistics & ORC Macro 2011). Thus, anything that interferes with the government capacity to provide the resources for health

care can have more impact to the majority of people, compared with the interruptions in the private sector, which handles smaller portion of healthcare. This reliance on the government-owned facilities arises historically from policies by the first governments after independence.

A change of Tanzania presidential leadership, pressures by the international finance organizations and the fall of the Iron Curtain, precipitated the end of *Ujamaa* policies in Tanzania. By 1992, Tanzania officially abandoned *Ujamaa* ideology through “Zanzibar Declaration” and ushered in a new era of unfettered privatization of public entities and other liberalized undertakings such as decentralization and reduced government spending in the social programs. The free government-run programs ended while the era of multi-party politics was ushered in.

The first Tanzanian multi-party elections were held in 1995. The presidential term is five years. There are four general elections held so far in the multi-party environment, each won by the ruling party. The ruling party, CCM, have won all the presidential, majority of the parliamentary and local government elections. The opposition parties are fragmented, and are alternating in being the main challenger to the ruling party. In each losing general election, the main challenging party ended up complaining of voting irregularity and casted doubts as to the freeness and fairness of the entire general election process.

The ruling party, in turn, celebrated each victory by reminding the voters that not only does CCM win, but also it wins by overwhelming majority. This showing-off by the ruling party is typical of hegemonic ruling parties which seek formidable victories to

send voters a message of invincibility (Magaloni 2006). For CCM, they named winning against the opposition parties as *ushindi wa kishindo* ('thunderous victory'), *ushindi wa sunami* ('tsunami-like victory'), *ushindi wa kimbunga* ('whirlwind victory'), and *kuwagaragaza wapinzani* ('to floor the opposition') to remind the voters of how invincible CCM is.

Based on observations in Mexico, Magaloni (2006) describes behavior expected of hegemonic ruling parties. One of things typical of hegemonic parties is to use distribution of favors to the faithful and meting out punishment to the opposing through selective distribution of public resources. Budget allocation is one of the public goods that hegemonic ruling parties leverage for political favors from the voters (Magaloni 2006). So, because CCM, the Tanzania's ruling party is hegemonic (Weinstein 2011), researchers have documented strategies similar to the Mexican hegemonic party.

4.5 Budget Allocation as a Link between Health and Politics

Recent research has linked funds distribution according to the loyalty measured through voting for the Tanzania's ruling party (Weinstein 2011). Weinstein evaluated the strategies the Tanzania's ruling party used to deliver finances to the local governments in the year 2004 and 2005. The budget allocations showed that not only did the ruling party rewarded the most loyal voting jurisdictions; CCM government also punished the lukewarm loyal and the outright opposition by reducing the disbursed funds. According to Weinstein (2011), "CCM's goal is not only to win outright, but also to maximize electoral returns, and it does so by decreasing expenditures and punishing slight defection, even in loyal areas." What Weinstein is arguing is that the ruling party wants

to stay winning for a long period of time in future, nipping in the bud the idea that CCM is expendable.

Weinstein (2011) also argues that because the budgets allocations are generally discretionary, the ruling party uses the discretion loophole to punish the less-than-loyal districts. Apparently, the budget allocation formulas do not contain the ruling party from playing politics with the budget allocation processes. The government overrules the grant allocation formula in delivery of finances to local governments “because politicians have the power to overrule the formulas” (Allers & Ishemoi 2011). In 2004 the government had introduced resource allocation formulas to allay the political tinkering concerns (Semali & Minja 2005). However, up to the fiscal year 2007/08, the government did not fully implement the formula, despite later on the government conceding not implementing allocation formula was one of “weaknesses” of the budgeting processes (United Republic of Tanzania 2008).

4.6 Effects of Contemporary Distributive Politics on Health

In this section I demonstrate an empirical example of the effects of contemporary distributive politics on childhood pneumonia. The Tanzania health care national budget of about \$11 per capita is below the recommended value of \$34 per capita (Mboera 2012). The low budget makes it important it is even more effectively used to deal with the threats such as childhood pneumonia.

Pneumonia is responsible for 11.2% of under-five mortality in Tanzania (Samarasekera 2008). There are estimated 1.9 million new cases of clinical pneumonia in Tanzania; that is, 0.33 cases per child per year (Rudan et al. 2008). The death rates are

comparatively lower in the Tanzanian older populations. For example, the records from the main hospital of Temeke Municipality in Dar es Salaam Region (Mayo 2007), show that under-five children were 53% of all pneumonia cases for the 2000 - 2002 time-period. The under-five children are the subjects of interest in the current research.

Tanzania's Ministry of Health & Social Welfare (MoH&SW) provided data on monthly cases of childhood pneumonia covering the 2004 - 2008 time periods at the level of administrative regions. I calculated monthly pneumonia prevalence as cases per 100,000 children by combining the pneumonia data with the corresponding under-five projected yearly population from Tanzania's National Bureau of Statistics (NBS)(National Bureau of Statistics 2006), because the latest census was in 2002. The map of the 2004 - 2008 regional mean monthly pneumonia prevalence is shown in section 2.4.2, which clearly shows non-uniform spread of pneumonia cases in Tanzania.

Tanzania demographic and health survey 2010 (National Bureau of Statistics & ORC Macro 2011) provides further understanding of the state of health in Tanzania. Three-quarters of all children aged between 12 to 23 months were fully immunized. Overall majority (97%) of the children were vaccinated at least against one disease. Four percent of children under age five had suffered from acute respiratory infection (ARI) within two weeks preceding the survey, while majority (71%) of the children was taken to a health facility. The infant and the Under-5 mortality rates of 51 and 81 per 1,000 live births respectively are still on the higher side, though the trend is on the reduction of the mortality rates.

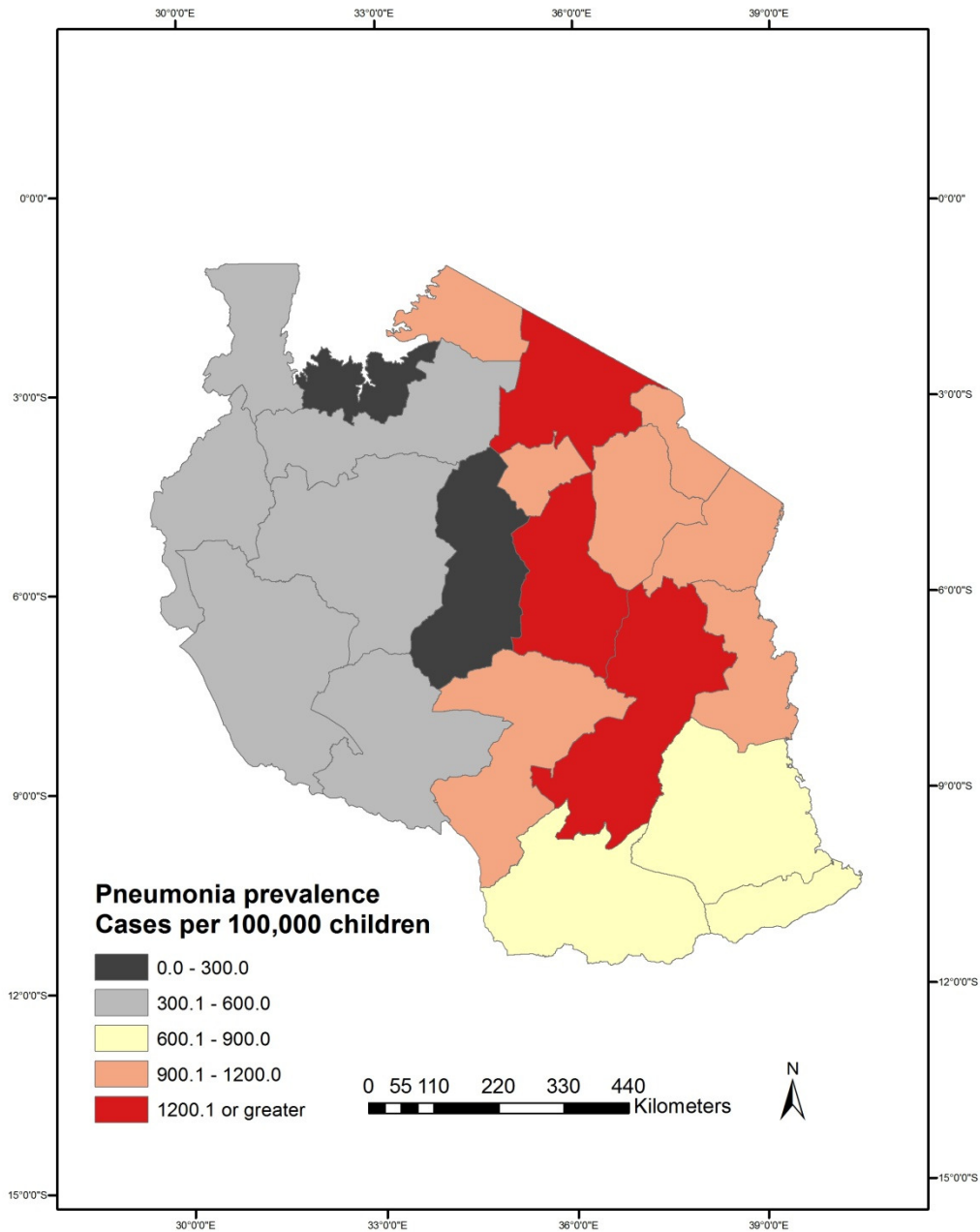


Figure 25: Mean 2004 – 2008 monthly childhood pneumonia prevalence in Tanzania, represented as cases per 100,000 in the administrative regions. The distribution of pneumonia is not even.

4.6.1 Material and Methods

I used the findings from Weinstein (2011) who identified the districts (*wilaya*) which were financially punished for voting for the opposition. Weinstein (2011) argues that because the budgets allocations are usually discretionary, the ruling party uses the discretion loophole to punish the less-than-loyal districts. Apparently, the budget allocation formulas do not constrain the ruling party from playing politics with the budget allocation processes. Following the general election in year 2000, and the subsequent transfer of funds from the central to the local governments, Weinstein (2011) evaluated the transfer of funds in the financial year 2004 – 2005 compared to previous years.

Weinstein (2011) found that some districts had significant change in the finances received from the central government. In Tanzania there are 21 administrative units known as “regions” (*mikoa*), which are in turn sub-divided into “districts” (*wilaya*). Some of the regions did not have any district with significant change in the disbursement. Other regions had at least one district which was either punished with bursary decreases or rewarded with money increases. Other regions had both: at least a district that was punished, and at least a district that was rewarded. The reward or punishment was expedient to the proportion of the votes a district provided to the ruling party.

I grouped the Tanzania regions according to the presence of districts within the region which experienced budget cuts, budget increases, presence of both budget cuts and budget increases in different districts in the region, and the rest of the regions with

districts without significant changes in budget allocations. The groupings are based on the financial disbursements in the year 2004-2005. The punishment or reward was based on how the district voted for the ruling party in the year 2000 general elections. In this map I aggregate the findings reported by Weinstein (2011). Table 14 shows the disbursements in the 2005/06 financial year. The proportion of the local government authorities (LGA) budget funded by the central government's disbursement vary between the LGAs, similar to Weinstein (2011) findings for 2004/05 financial year. The rewarded LGAs had greater proportion of their budgets funded by the central government, while the punished LGAs had funded proportions lower than the mean. The absolute amounts of funds disbursed are, however, higher in the punished LGAs than in the rewarded LGAs. The amounts, however, are incomparable because of the differences in the sizes of budgets of the LGAs.

Table 14: Disbursement to the local government authorities (LGA) in 2005 – 2006 financial year

Local Government Authority (LGA)	Region	Changes observed in 2004_2005 Budget (Weinstein 2011)	2005_2006 budget transfers (TShs)	% of LGA budget
Arumeru	Arusha	Increased	12,463,933,854	96.8
Arusha City Council	Arusha	Decreased	6,733,252,401	77.7
Biharamuro	Kagera	Increased	7,712,863,855	98.2
Bukoba Municipal Council	Kagera	Decreased	2,766,644,132	88.8
Ilala	Dar es Salaam	Decreased	15,702,993,500	71.6
Temeke	Dar es Salaam	Decreased	15,106,040,342	80.6
Kinondoni	Dar es Salaam	Decreased	16,361,064,782	78.5
Moshi	Kilimanjaro	Decreased	5,429,594,383	83.9
Liwale	Lindi	Decreased	2,522,342,256	92
Musoma Municipal Council	Mara	Decreased	5,429,594,383	89.9
Mwanza City Council	Mwanza	Decreased	9,691,246,950	77.8
Kisarawe	Pwani	Decreased	2,649,340,380	93.2

Table 14: Continued

Local Government Authority (LGA)	Region	Changes observed in 2004_2005 Budget (Weinstein 2011)	2005_2006 budget transfers (TShs)	% of LGA budget
Mafia	Pwani	Decreased	1,439,127,100	89.9
Rufiji	Pwani	Decreased	3,765,467,120	92.7
Ileje	Mbeya	Increased	2,500,804,470	98.2
Mbarali	Mbeya	Increased	4,835,835,295	96.4
Masasi	Mtwara	Increased	8,710,556,297	84.9
Mtwara Municipal Council	Mtwara	Increased	2,335,400,200	88.2
Average in Rewarded LGAs			6,426,565,662	93.6
Average in Punished LGAs			7,299,725,644	84.7
LGA's Average			7,008,672,317	87.7

Data obtained from <http://www.logintanzania.net/>

The group of regions that were financially punished seemed to have better health metrics compared to the rest. The number of health facilities (Figure 26) and the percent of mothers who give birth at the health facilities (Figure 27) shows that the punished regions are comparatively better-off compared to the rest of regions. Because typically it is the mothers who take sick children to hospitals when the mothers perceive children fevers to be high, and the hospital is expected to provide correct diagnosis and treatment (Kamat 2006), the differences in pneumonia prevalence between these groups are therefore likely to be due to the actual differences in the number of children who fall sick, and not due to the differences in the number or usage of health facilities.

I then compared the rates of childhood pneumonia between the four groups of regions. The pneumonia data I received from the Tanzania's ministry of health, were made available at regional level at which I made the comparisons. I wanted to find the answer to question: are there differences in the rates of pneumonia between the groups of Tanzania's administrative regions, arranged according to the financial punishment hypothesis as put forward by Weinstein (2011)?

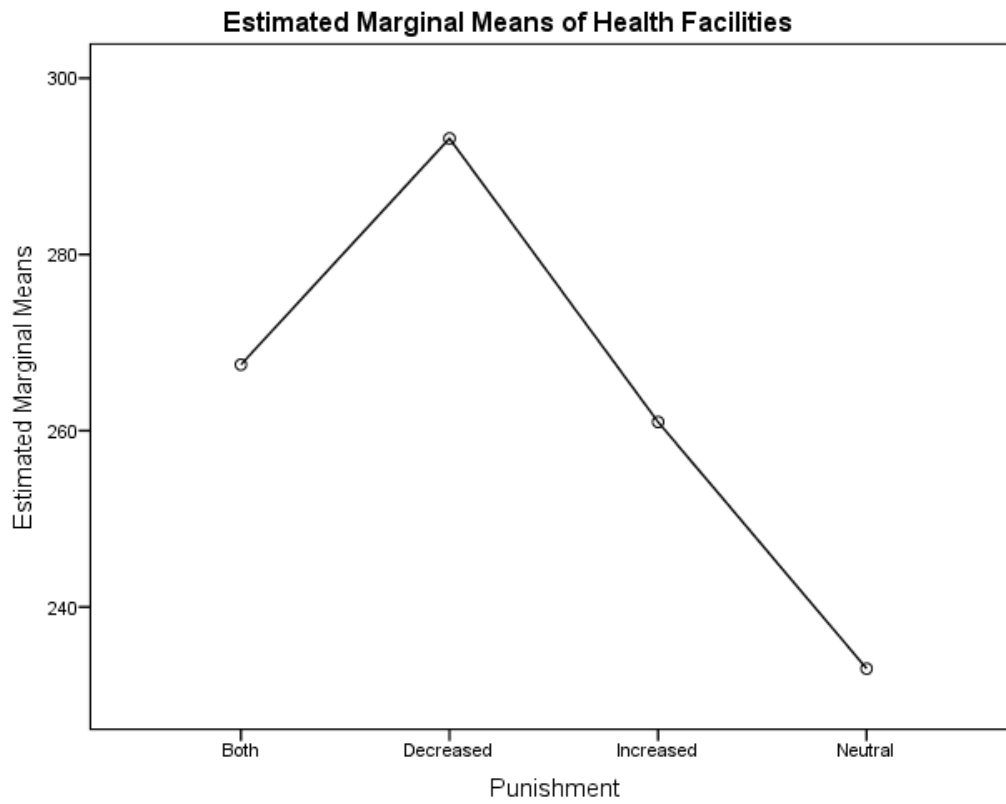


Figure 26: Mean number of health facilities per region belonging to the groupings based on financial punishment as described by Weinstein (2011).

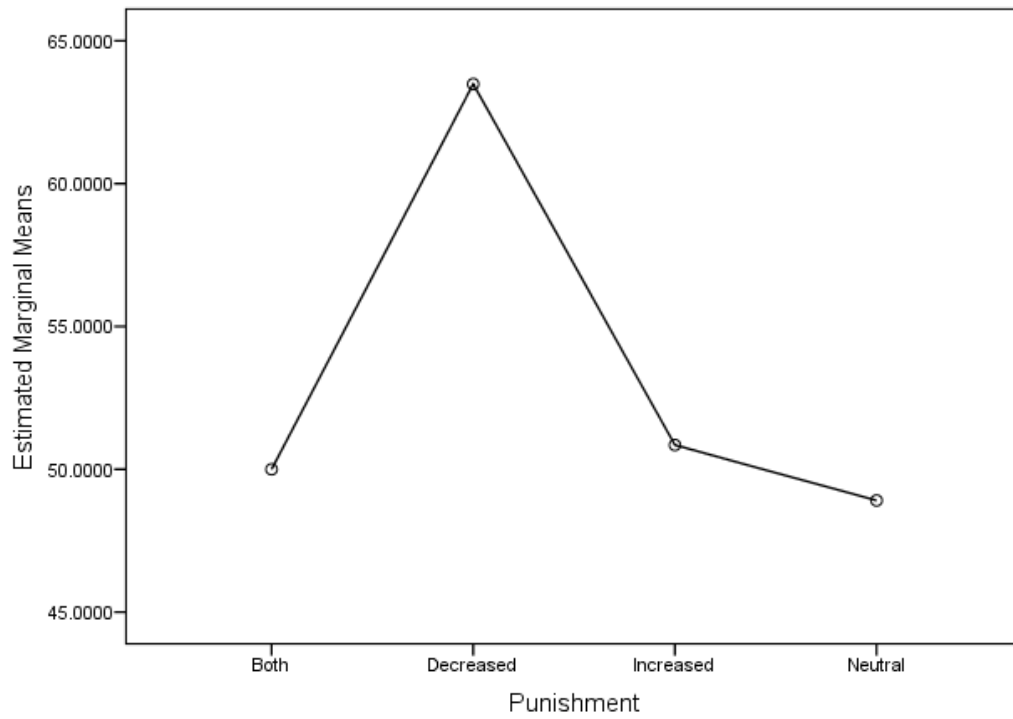


Figure 27: Percentage of mothers who delivered at health a health facility per region belonging to the groupings. The groupings are based on financial punishment as described by Weinstein (2011).

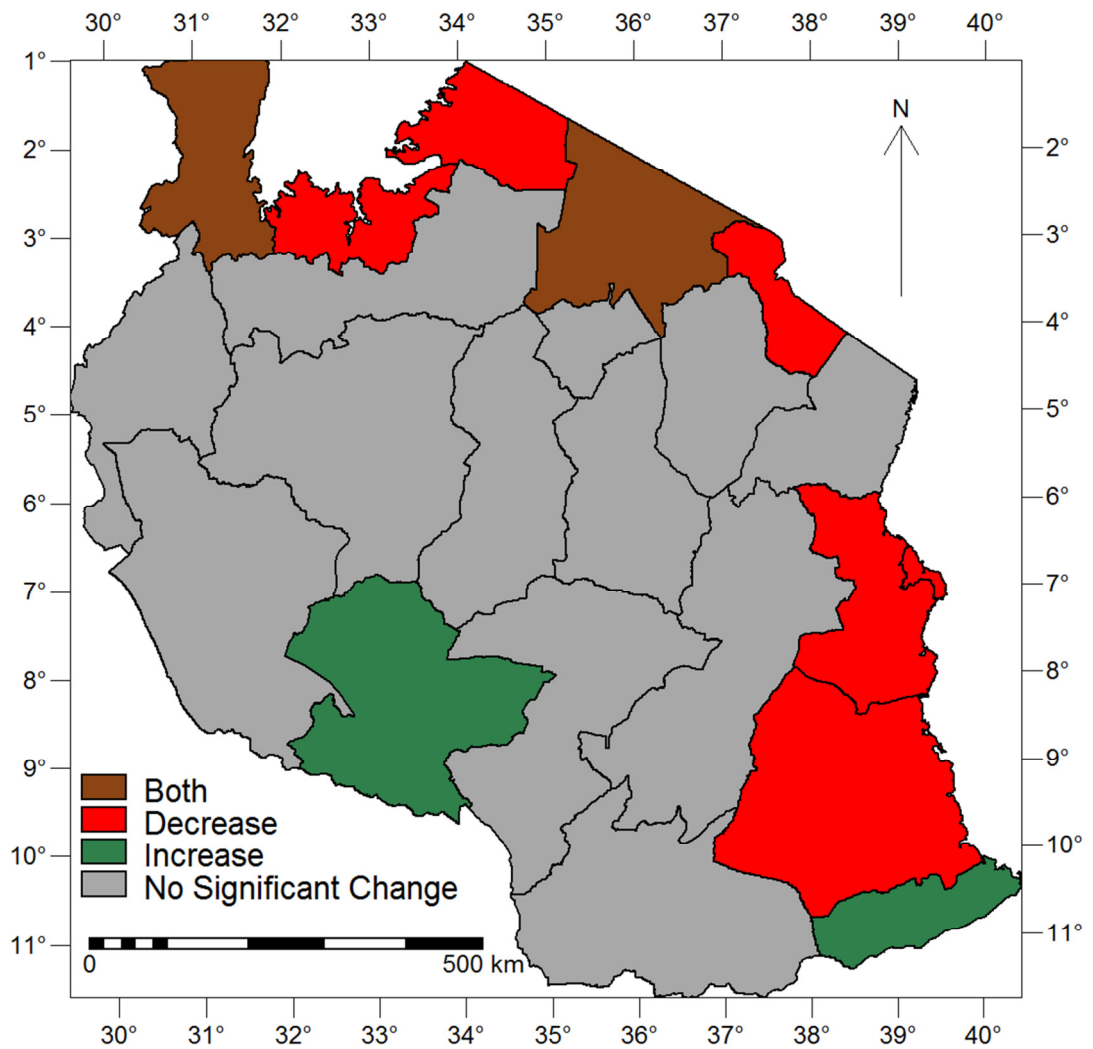


Figure 28: Tanzania regions grouped according to the presence of districts within the region which experienced budget changes.

I used PASW version 18 (IBM) to perform the statistical analyses. I also used univariate analysis of variance with pneumonia childhood prevalence as the dependent variable. I then made multiple-comparisons of childhood pneumonia between the groups of regions shown in Figure 28 for the 2004 - 2005 time period.

4.6.2 Results

This study set out to examine the relationship between childhood pneumonia and politics. Specifically, compare the groupings of administrative regions of Tanzania as defined by the penalty of underfinancing due to voting for the opposition party. The mean monthly childhood pneumonia prevalence varied between the groups of regions as shown in Table 15. The regions were grouped based on financial punishment for voting for the opposition parties, as reported by Weinstein (2011). The prevalence is expressed as number of cases per 100,000 under-five children.

What that table shows is the 2004 - 2005 mean pneumonia prevalence in the groups of Tanzania's administrative regions. The prevalence is expressed as number of cases per 100,000 under-five children. In order to be sure that the differences between the groups were not due to chance, I undertook univariate analysis of variance. Table 16 shows the pairwise comparison of differences between the groups of regions. Pairwise comparison shows there was only one pair with statistically-significant difference. That is, the regions which were punished with decreased budget had 444.6 more pneumonia cases per 100,000 children compared to the regions which were financially rewarded for loyalty to the ruling party. There was no difference between other pairs of comparison. That is, the regions that had experienced both the punishment and reward, showed no difference

to the regions that were punished or rewarded only. There was no difference also between the regions that were neither rewarded nor punished with the regions that had rewards, punishment or both. These results require further discussions.

Table 15: The 2004 - 2005 mean pneumonia prevalence in the groups of Tanzania's administrative regions.

Punishment	Std.		N
	Mean	Deviation	
Both	864.0	482.4	48
Decrease	997.3	1038.9	144
Increase	552.7	250.9	48
Insignificant Change	835.5	724.6	264
Total	857.5	789.8	504

Table 16: The differences between years 2004 - 2005 mean pneumonia prevalence in the groups of Tanzania's administrative regions.

YearGroups	(I) Punishment	(J) Punishment	Mean Difference (I- J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
2004_05	Both	Decrease	-133.4	130.5	0.7	-469.6	202.9	
		Increase	311.3	159.8	0.2	-100.6	723.1	
		InsignificantChange	28.5	122.8	1.0	-288.1	345.0	
	Decrease	Both	133.4	130.5	0.7	-202.9	469.6	
		Increase	444.6*	130.5	0.0	108.4	780.9	
		InsignificantChange	161.8	81.1	0.2	-47.2	370.8	
	Increase	Both	-311.3	159.8	0.2	-723.1	100.6	
		Decrease	-444.6*	130.5	0.0	-780.9	-108.4	
		InsignificantChange	-282.8	122.8	0.1	-599.4	33.8	
	InsignificantChange	Both	-28.5	122.8	1.0	-345.0	288.1	
		Decrease	-161.8	81.1	0.2	-370.8	47.2	
		Increase	282.8	122.8	0.1	-33.8	599.4	
	2006_08	Both	Decrease	15.4	91.9	1.0	-221.4	252.1
			Increase	199.0	112.6	0.3	-91.0	488.9
			InsignificantChange	96.1	86.6	0.7	-126.7	319.0
Decrease		Both	-15.4	91.9	1.0	-252.1	221.4	
		Increase	183.6	91.9	0.2	-53.1	420.3	
		InsignificantChange	80.8	57.1	0.5	-66.4	227.9	
Increase		Both	-199.0	112.6	0.3	-488.9	91.0	
		Decrease	-183.6	91.9	0.2	-420.3	53.1	
		InsignificantChange	-102.8	86.6	0.6	-325.7	120.0	
InsignificantChange		Both	-96.1	86.6	0.7	-319.0	126.7	
		Decrease	-80.8	57.1	0.5	-227.9	66.4	
		Increase	102.8	86.6	0.6	-120.0	325.7	

Based on observed means.

The error term is Mean Square(Error) = 456487.065.

*. The mean difference is significant at the .05 level.

Controlling for mean temperature covariate, the difference between rewarded regions, and the rest is clearly shown in Table 17. The rest of regions have no statistical significant difference in the year 2004 to 2005. No any difference is seen among these groups in the years from 2006 to 2008. This suggests the punishment effects identified in 2004 - 2005 did not carry-over to 2006-2008 in the same way. There was another general election in the end of 2005. Also, weather effects confounded the differences. Punished regions are only different from the rewarded, and not statistically different from the rest of regions. These findings imply rewarding the regions reduced the pneumonia rates. This suggest scenario B, i.e., CCM punished the regions that were already with higher rates of pneumonia, is the likelier than the scenario A that higher rates of pneumonia resulted from financial punishment.

The grouping of regions resulted in too few data points to have enough statistical power to compare the effects of land cover had on the punishment hypothesis at the regional level. However, using the projected pneumonia rates at ward - level, it was possible to compare directly the pneumonia rates between the districts that were penalized, and those which were financially rewarded. The rates of pneumonia in wards which were punished still were higher than the prevalence in the rest of the groups (Table 18). It should be noted, however, that the pneumonia rates at the ward level were interpolated from the regional level prevalence data. The interpolation used the overall 2002 population in the wards. Nevertheless, the interpolation was robust, and likely to represent the number of pneumonia cases on ground.

Table 17: Univariate analysis and pairwise comparison of pneumonia in the regions arranged according to financial punishment, controlling for mean temperature covariate.

YearGroups	(I) Punishment	(J) Punishment	95% Confidence Interval for					
			Mean			Difference ^a		
			Difference (I-J)	Std. Error	Sig. ^a	Lower Bound	Upper Bound	
2004_05	Both	Decrease	47.8	136.6	1.0	-314.1	409.6	
		Increase	499.9*	164.6	0.0	63.8	936.0	
		InsignificantChange	111.8	122.9	1.0	-213.8	437.4	
	Decrease	Both	-47.8	136.6	1.0	-409.6	314.1	
		Increase	452.2*	128.6	0.0	111.5	792.8	
		InsignificantChange	64.0	83.7	1.0	-157.7	285.8	
	Increase	Both	-499.9*	164.6	0.0	-936.0	-63.8	
		Decrease	-452.2*	128.6	0.0	-792.8	-111.5	
		InsignificantChange	-388.1*	124.0	0.0	-716.6	-59.7	
	InsignificantChan ge ^e	Both	-111.8	122.9	1.0	-437.4	213.8	
		Decrease	-64.0	83.7	1.0	-285.8	157.7	
		Increase	388.1*	124.0	0.0	59.7	716.6	
	2006_08	Both	Decrease	95.8	98.2	1.0	-163.9	355.5
			Increase	288.9	119.0	0.1	-25.7	603.6
			InsignificantChange	138.4	88.3	0.7	-95.1	371.8
Decrease		Both	-95.8	98.2	1.0	-355.5	163.9	
		Increase	193.1	91.8	0.2	-49.7	435.9	
		InsignificantChange	42.6	59.4	1.0	-114.5	199.6	
Increase		Both	-288.9	119.0	0.1	-603.6	25.7	
		Decrease	-193.1	91.8	0.2	-435.9	49.7	
		InsignificantChange	-150.6	88.8	0.5	-385.5	84.3	
InsignificantChan ge ^e		Both	-138.4	88.3	0.7	-371.8	95.1	
		Decrease	-42.6	59.4	1.0	-199.6	114.5	
		Increase	150.6	88.8	0.5	-84.3	385.5	

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

Table 18: Multiple comparison of pneumonia rates between wards (*kata*) in the districts according to financial punishment or reward.

YearGroup	(I) BudgetChange	(J) BudgetChange	Mean Difference			95% Confidence Interval	
			(I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
2004_05	Decreased	Increased	300.1*	20.6	0.000	251.7	348.5
		Neutral	482.2*	14.3	0.000	448.7	515.7
	Increased	Decreased	-300.1*	20.6	0.000	-348.5	-251.7
		Neutral	182.1*	17.2	0.000	141.9	222.3
	Neutral	Decreased	-482.2*	14.3	0.000	-515.7	-448.7
		Increased	-182.1*	17.2	0.000	-222.3	-141.9
2006_08	Decreased	Increased	-68.2*	15.0	0.000	-103.3	-33.0
		Neutral	163.2*	10.4	0.000	138.9	187.5
	Increased	Decreased	68.2*	15.0	0.000	33.0	103.3
		Neutral	231.4*	12.5	0.000	202.2	260.6
	Neutral	Decreased	-163.2*	10.4	0.000	-187.5	-138.9
		Increased	-231.4*	12.5	0.000	-260.6	-202.2

Based on observed means.

The error term is Mean Square(Error) = 783755.251.

*. The mean difference is significant at the .05 level.

The data on neutral districts exclude Mafia and Ukerewe island districts.

4.7 Discussions and Conclusions

The administrative regions (*'miko'*) that were financially punished were observed to have higher childhood pneumonia rates than the administrative regions which were financially rewarded for voting for CCM, the Tanzania's ruling party. These differences in childhood pneumonia prevalence are statistically unlikely to happen by chance. The findings offer a number of implications.

First implication is the question whether the childhood pneumonia is higher because of low finances disbursed to the region or not. While it may as well be the case low finances resulted into higher prevalence, the reader may also disagree, providing an alternate explanation. Alternatively, the locations that for some reason happen to have higher rates of pneumonia, voted for the opposition, while the areas happened to be with lower pneumonia rates voted for the ruling party. People vote for the opposition because of the misgivings they have about the contemporary politics and bad governance affecting their lives. For example at Mbande, a village near Dar es Salaam, citizens voted for the opposition during the year 2000 election, as a symbolic protest on the way contemporary politics have affected their village (Kamat 2008).

From the point of view of addressing the scourge of childhood pneumonia, though, it may not matter which is the cause and which is the effect. The locations voting for the opposition, are financially punished (Weinstein 2011), despite having higher rates of pneumonia. Conversely, the locations which vote for the ruling party have *relatively* lower rates of childhood pneumonia, *yet* they are receiving bigger budgetary allocations as a reward for their apparent loyalty to the ruling party. In my opinion, the

budget should be distributed according to the needs. Granted, the budgetary funds were not distributed on the basis of pneumonia prevalence, nevertheless it is not morally and ethically right to distribute the symbolic national cake based on votes to the ruling party. The nation belongs to every citizen; it is not fair to put other citizens to disadvantage just because the ruling party wants to keep getting more votes. According to Weinstein (Weinstein 2011), the financial penalty is unsuited in Tanzania where “a low level of economic development compounds the effectiveness of the punishment strategy because poor constituents rely exclusively on government resources for their livelihood.”. That is, most people who are affected by the reduced budgets are poor, who depend on the social services paid for by the government from taxes the government collects from the people. Interventions to reduce the suffering from pneumonia result in to also reducing child mortality rates from pneumonia (Sazawal & Black 2003). This is another good reason for the government to target the locations with higher rates of pneumonia, regardless of the voting patterns.

While the cause and effects association of the budget-prevalence association require further investigation, it is possible to speculate what might be the underlying factors. One likely factor is that most people who live in less urbanized places tend to vote for the ruling party, because the opposition parties hardly reach the rural areas due to financial and other limitations (Babeiya 2011). These rural areas are less developed relatively to the more urbanized locations in Tanzania, as far as social services are concerned. The majority (74.2%) of Mainland Tanzania population lives in rural areas (National Bureau of Statistics 2011), and depend on the public-funded primary healthcare

facilities for their healthcare needs (Castro-Leal et al. 2000). Therefore, if the healthcare budget is not objectively allocated, there is a greater likelihood of undue inequity in health outcomes.

Croplands represent another link to the rural-urban differences. In the previous chapters, I also found out that croplands were associated with increased rates of pneumonia. Cultivation is the main activity in most rural areas. These same rural areas may be also more likely to get the rewards, and less likely to be punished, due to the loyalty to the ruling party. Agricultural activities can confound the budget-pneumonia link.

Conversely, another possibility is that *actually* lower budgets *do* result into poorer health and worsening healthcare to the people. Research has shown that the quality of care depends on the budgetary allocations as further explained below. The availability of medicines and qualified personnel are partly determined by the existing budgetary constraints. These factors affect the health of populations.

For instance, healthcare workers can be directly affected by inequality of health budget allocations in Tanzania. Urban areas have more health personnel per capita compared with the rural area (Munga & Maestad 2009). When Munga and Maestad (2009) statistically compared the effects of the number of health care personnel on the under-five children, they found that the inequality of number of health care workers explained about 20% of under-five mortality. Elsewhere, it has been shown that a relationship exists between attending to the health workers well-being and reduction of children suffering from pneumonia. When the community health care workers were

trained and their concerns attended to in a trial project to combat pneumonia in Gadchiroli, India, it resulted in reduced case-fatality rates (Bang et al. 1990). Employees of under-funded local authorities can have hard time to be content with their working environments, and thus render poor service. Manongi et al. (2006) show how the institutional problems affect the health care workers individually as follows. The lack of adequate facilities such as a laboratory or even microscopes makes the workers “gamble” the cause of illness. They are forced to prescribe treatment in a trial and error mode. Eventually the personnel get depressed in addition to harming the patients. Moreover, the health personnel lament the absence of training opportunities, delayed salary increments and little appreciation for working in hard environment, which have demotivating effects on the health workers. It can be seen from the Manongi et al. (2006) discussion of what the health workers face, that the quality of care to the children is intertwined with the enthusiasm and qualifications of the health care personnel.

Up to the year 2006 when hiring of healthcare staff was recentralized, the remote, poorer local authorities had trouble in attracting and retaining qualified healthcare personnel (Munga et al. 2009). With the recentralized hiring of healthcare personnel, there may be increased opportunity for the ruling party to silently further punish what CCM sees as insolent locations that vote for the opposition. This is another area that requires further exploration.

On the theoretical front, this study have demonstrated how the Tanzania’s ruling party, by wanting to maintain its dominance, it ends up financially punishing regions which are either with pre-existing higher rates of pneumonia, or they eventually become

plagued with higher rates. According to King (2010), one of the advantages of including politics in health geography is to show the link between the society and biophysical environment through inclusion of history, economy and power. This study contributes to illustrate how *power* (hegemonic party wanting to perpetually get reelected), *history* (how past general poll votes are having effects on the government actions) and *economy* (budget distribution from the central to the local governments) are intersecting with the *biophysical environment* (childhood pneumonia) in Tanzania.

Moreover, this dissertation contributes to the post-independence literature that does not blame the past colonial events for the today's actions in African countries. For example, the tendency of an African ruling party of clinging to power by manipulating public finances can hardly be blamed on to the colonial past. If anything, the financial punishment of people who voted for the legally recognized political parties is solely the works of CCM and its bureaucratic apparatuses and nothing to do the over a half-century past events. I recommend contemporary political ecology research in Africa and other developing nations to start holding the current regimes responsible. Such an approach will present practical solutions to existing problems. It is not warranted to blame the colonial history for what happens now.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Background

Until recently, researchers have paid less attention to what drives in-country geographical differences in children's health within a (developing) nation than they have to the differences between nations at a global scale. For example, a WHO / UNICEF report shows that 95% of pneumonia cases are in developing countries, with 74% of the new cases concentrated in only 15 countries (Wardlaw et al. 2006). While the international differences in the rates of pneumonia are notable, the within-nation differences which Rudan et al. (2008, 410) describe as "critical inequities" deserve equally close evaluation and scrutiny.

Studies that have investigated within-nation health outcomes show the need for targeted response policies. Researching inequalities of maternal and child health (MCH) in the Sub-Saharan African countries, Hosseinpoor et al. (2011) showed that mean national data contrasted sharply with variations within the countries. Populations in these countries were at high risk to poor health outcomes because of the inequalities in health provision and coverage due to socio-economic factors. Similar observations have been seen in other developing nations, (Barros et al. 2012; Bauze et al. 2012).

Exploration of within-nation health inequalities has mostly emphasized underlying socio-economic factors such as the wealth and poverty of citizens (Boerma et al. 2008; Sousa et al. 2010), with little consideration being paid to bio-physical factors such as weather and land cover. Weather is known to influence the geographical spread of

pneumonia (Fuhrmann 2010; Murray et al. 2012), cholera (Mhalu et al. 1987; Muruke et al. 2008) and malaria (Lindsay et al. 2000). Some researchers have associated land cover with infectious diseases and other ailments (Curran et al. 2000; Lo & Quattrochi 2003; Ezenwa et al. 2007; Pradier et al. 2008; Wagner et al. 2008). Their research has associated changing rates of disease prevalence to (planned and unplanned) urbanization, expansion of agriculture, and removal of forest (Patz et al. 2008). Still, these factors seldom feature in health inequality research. The current research addressed has this addressed this knowledge gap by evaluating associations of weather and land-cover change with childhood pneumonia.

A further knowledge gap in existing within-nation health inequality literature is the lack of temporal dimensions in research into inequality and disease distribution. The absence is consistent with the assumption of a static state of inequalities, with strong emphasis being given to locational differences. Seasonal differences in the prevalence of diseases are conspicuously absent in the health inequalities research. This absence arises from the exclusion of the seasonal biophysical factors from covariates in the disparity of sub-national health outcomes as discussed above. In this dissertation I evaluated the assumption of temporal homogeneity of childhood pneumonia. The temporal non-homogeneity of childhood pneumonia brings resource allocation challenges similar to locational inequalities.

The allocation of financial and other resources to the health sector at all levels of government is complicated, mainly because allocations are biased regardless of the prevailing rates of disease (Sridhar & Gómez 2011). While policy-makers and the

bureaucrats may feel they make objective considerations in allocating resources, such considerations are difficult in constrained finance situations and are therefore highly prone to political influence (Jarris et al. 2012). It is therefore important to consider the politics around health resource allocations because, “a better understanding of how and why politics interacts with the budget- and priority-setting processes is critical to a sustainable public health system” (Jarris et al. 2012).

This dissertation therefore explored differentials in the spatial and temporal patterns of the spread of pneumonia within Tanzania by evaluating climatic and land change factors, together with the politics of budget allocations for the health sector which are spatially unequal. This dissertation contributes to the understanding of within-nation pneumonia distribution in developing nations. It is the first in Tanzania to evaluate the impact of weather, land cover and politics on childhood pneumonia. By evaluating the impact of weather and land cover, this dissertation also provides an example of non socio-economic factors affecting health inequalities. By analyzing a large landmass of two main climatic types, this dissertation also contributes appreciation of non-stationarity of temporal variations of childhood pneumonia, in addition to the commonly-evaluated spatial variations.

The next section summarizes the main findings of this dissertation, and is followed by a discussion around policy and the implications for future research.

5.2 Summary

5.2.1 Brief Summary

This study investigated the association between childhood pneumonia and weather, land cover, and politics. Tanzania, a country with high rates of childhood pneumonia, was chosen because I am from Tanzania, familiar with the politics, and health aspects of the country. Research and general literature on childhood pneumonia is inconclusive about what factors drive the differences in the rates of pneumonia, especially in the context of a high-incidence like Tanzania. Therefore, this dissertation specifically sought to explore how weather variables, land cover classes, and politics were linked to the geographical incidence of pneumonia in Tanzania in order to answer the main research question posed in section 1.2.

Precipitation amounts and seasonality define the major climate zones of Tanzania, with two main zones dominating, subsequently, so do the other climate parameters such as temperature, sea level pressure, wind speed and relative humidity. The literature on weather-pneumonia links is contradicting on how weather, and which climate variables, influence the spatial and temporal distribution of pneumonia. In this dissertation I have evaluated whether weather, and which climate variables in particular, can be used to predict spatial and temporal patterns of childhood pneumonia across the country. In so doing, I have also explored whether the climate zones had any influence in the weather-pneumonia association. After applying a set of quantitative analyses, I then applied Geographically Weighted Regression (GWR) methods to evaluate the spatial variations in the associations between pneumonia prevalence and climate parameters.

Tanzania has a variety of land use (LU) and land cover (LC) types within its borders. Natural forests, grasslands and croplands form the largest proportion of land cover. Urban and semi-urban land cover types are of smaller proportions in terms of area compared to the rural land cover types. Research literature implies direct and indirect associations between land cover types and the occurrence of pneumonia. This dissertation explored those relationships for Tanzania.

Finally, this dissertation researched the political dimensions of childhood pneumonia in Tanzania. Contemporary African health-geography is mostly concerned with linking present patterns of health to colonial (historical) events. The focus on the colonial past misses out the effects of contemporary politics on health patterns. For example, recent decisions about distribution of resources are determined by contemporary politics more than the events that happened during colonization over five decades ago. Recent research has suggested that governments distribute financial resources based on the votes the ruling parties received in the previous general election (Weinstein 2011). In this dissertation I have investigated how the politics around distribution of health budgets is associated with the patterns of distribution of pneumonia in Tanzania.

5.2.2 Empirical Findings

The main empirical findings are described below under chapter-specific arrangement.

1. Does weather affect the distribution of pneumonia in Tanzania, if so, how?

Climate variables were associated with the prevalence childhood pneumonia. Moreover, there were notable differences in the types and strengths of the association

between the two broad rainfall regimes that comprise Tanzania. The associations also varied seasonally (i.e., between wet and dry seasons), thereby emphasizing the effects of weather on the spatial and temporal patterns of childhood pneumonia. For example, in the regions with bimodal rainfall, weather was more strongly associated with pneumonia compared to the unimodal regions.

2. Do land use types affect the distribution of pneumonia in Tanzania, if so, how?

Using Tanzania as a case study, the current dissertation processed image data and used geostatistical techniques to compare the rates of pneumonia to the LULC classes. By using these techniques, I evaluated the hypothesis that locations with higher proportions of land covers associated with production of particulate matter (sources) are likely to be more positively correlated with pneumonia prevalence than those locations with lesser proportions of the same (sinks).

Land use types were also associated with the geographical patterns of childhood pneumonia. Croplands, together with the urban-rural divide were the main land cover predictors of pneumonia distribution. Mixed rural-urban locations had higher rates of pneumonia compared to the urban and rural locations.

3. What is the association between politically-influenced health budget distribution with pneumonia distribution Tanzania?

The administrative regions that received lower budget allocations had higher rates of pneumonia. However, I was unable to ascertain whether the lower budget allocations caused higher pneumonia rates or if the regions that happened to have higher rates of

pneumonia were more likely to vote against the ruling party, and hence receive lower budget allocations.

5.2.3 Implications

This dissertation was conducted at a coarse, national scale, and it shows variations in the types of association between weather, climate, land cover, politics and pneumonia, and variations in the strengths of those associations. By analyzing the national distribution of pneumonia instead of a single city or district, the nationwide ‘big picture’ of the factors influencing pneumonia distribution can be revealed. This leads to a different type of understanding. Nationwide studies are important in large nations with their heterogeneous climates, land uses and levels of development. By being nationwide, this study follows some of the research conducted in the continental United States on weather-pneumonia research (Doshi 2008; Shaman et al. 2011). Therefore, instead of using case studies of small areas, whose results may not be transferrable to the rest of the nation (as in Mäkinen et al. 2009; Oluleye and Akinbobola 2010; Onozuka et al. 2009), pneumonia research at the national scale can elucidate more understanding of the complex patterns of childhood pneumonia.

At this point it is important to address concerns about the interaction of weather, land cover and political factors in affecting childhood pneumonia in Tanzania. For example, it can be argued that observed differences attributed to weather are due to land cover or politics, and vice versa. Nonetheless, the findings from this dissertation are highly unlikely to be influenced by the interaction between the three main influences because (a) The temporal scales used in evaluating the three main factors were different,

thereby reducing the confounding effects between variables. For example, while the current study did not evaluate the mechanisms through which weather and land cover had an effect on pneumonia, the findings from the current study make it feasible to hypothesize why weather and land cover are independently important. This is because different temporal scales were used for weather and for land cover. Weather data was of higher frequency (monthly resolution), whereby land cover data were explored annually. The monthly differences between land cover were assumed to be a negligible contribution compared to the observed differences in weather. On the other hand, monthly weather changes were assumed to have little influence on the year-to-year land cover changes. There was therefore no need to combine land cover with weather data.

Nevertheless, land cover, weather and politics can and do interact and influence each other, especially over the long term. While land cover and weather each separately has mechanisms associated with pneumonia, land cover and weather affect each other. As an illustration, urbanization tend to reduce the diurnal temperature range, while the rural areas have higher temperature ranges (Gallo et al. 1996, 1999; Kalnay et al. 2003). In addition, anthropogenic land cover changes are implicit in changing precipitation patterns (Marshall et al. 2004), and croplands have been observed to have cooling effects in the United States (Bonan 2001).

In designing research about and interventions against childhood pneumonia, special attention needs to be paid to the allocation of resources, and how the existing allocations relate to the risk of childhood pneumonia. Research shows there is a link between resource allocation and health care delivery. For example, Tanzania's rural areas

are facing a shortage of the basic healthcare personnel with lower than the national averages which are themselves lower than needed levels of staffing. A significant proportion of the rural healthcare employees are not permanently employed, while some of those who are employed, are either absent from their workplace or perennially underproductive by engaging with other activities at the employer's time (Manzi et al. 2012). Distribution of health resources is an important consideration across the developing nations (Ottersen et al. 2008; Youngkong et al. 2009). That is, because of extreme resource scarcity in Tanzania, choices have to be made based on the general outcome such as life expectancy. Decisions on distribution of health resources have ethical dimension with tangible implications to human life because:

Policymakers in resource-scarce settings balance thousands of lives when choosing between urban versus rural treatment roll-out, treatment versus prevention, children versus adults, and low-cost versus high-cost treatment. (Johansson & Norheim 2011)

Put simply, deciding on the allocation of healthcare resources is a process that can mean loss of life, and impacts some segments of society more than others.. For example, health budgets in a Tanzanian administrative region of Mtwara is less than the internationally recommended \$12 per capita (Flessa 2003). Flessa demonstrates that allocating such low budgets has a direct relationship to deaths, disease incidence and prevalence, and the loss of quality of life. Part of the reason is that health care personnel are likely to face the effects of unsatisfactory resource allocation. Human resources in healthcare are important to meet up the national health goals, more so in the low-income

nations, because perceived unfairness and dissatisfaction brings about demoralization and low productivity (Kurowski et al. 2004; Songstad et al. 2011). History and politics shape the health workers experiences, even at a health-facility level when justice is not seen to be done, health workers become demoralized. In their own words, “Working conditions are vital for health worker motivation and ultimately for the quality of the health care delivered”(Songstad et al. 2011). That is, the quality of health care depends, at least in part, on motivating health workers.

Therefore, in a low resource setting like Tanzania, there is practically no room for political manipulation of budgetary resources, without the effects directly impacting people’s health.

In addition, the Tanzania government promises to distribute future funds by using “an objective, equitable, efficient and transparent allocation formula.” (United Republic of Tanzania 2008). However, evidence from previous studies, including Allers and Ishemoi (2011) and Weinstein (2011) show that the allocation formula is not implemented. Moreover, this study has demonstrated that the locations that happened to receive less budget money also had higher prevalence of childhood pneumonia. These findings add to the importance of the Tanzania government to keep good its promise to adhere to the formula when allocating health resources. Likewise, if the Tanzania government acknowledges the seriousness of childhood pneumonia, it may as well include pneumonia incidence as one of the variables in the budget allocation formula.

5.2.4 Public Health Implications

The factors discussed in this dissertation partly explain the variance of pneumonia distribution in Tanzania. The partial predictability of pneumonia prevalence suggests the importance of considering these geographical factors when making decisions that impact public health of pneumonia. Although other researchers suggest geography will be more important in the future due to mass rollout of pneumonia vaccines (Scott & English 2008), importance of consideration the spatio-temporal variations pneumonia can also play a part in saving lives and reducing suffering from pneumonia. This dissertation has important implications for the dynamic distribution of the within-country variations of pneumonia, especially in the less developed nations.

Moreover, this dissertation has shown that the rural-urban divide and other land cover characteristics, existing weather and projected climate change, together with politics of resource allocation play a role in shaping or describing the distribution of differentials of pneumonia within a nation. However, most of these factors are not directly falling under the health-sector policy-making. Therefore, researchers and policy makers will need to pay more attention to the creation of health-friendly policies and practice to further our understanding of pneumonia distribution and protecting the public. Such actions include resource allocation strategies that are informed of regional and seasonal specificities (Crighton et al. 2008).

5.3 Recommendations for Future Studies

Based on the experiences from this dissertation, I recommend more detailed record keeping and availability about childhood pneumonia cases in Tanzania. The

population-level records starting at smaller administrative units, when timely released, will enable discernment of the spatial and temporal dynamics of pneumonia prevalence. This will be applicable not only for pneumonia but also to other diseases. Development of an interactive Internet GIS portal with frequently updated information will be useful to both researchers and practitioners. An improved availability of data will enable research on future disease scenarios such as those based on climate change projections, anticipated land use and political changes.

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APPENDIX

A: BASELINE / DESCRIPTIVE TABLES

Units, unless otherwise specified, are:

Temperature (°C)

Mean Minimum Temperature (°C)

Mean Maximum Temperature (°C)

Rainfall (mm)

Relative Humidity (%)

Wind Speed (m/s)

Sea Level Pressure (mb)

Aggregate Regional Monthly Pneumonia Prevalence and Weather for 2004 – 2008

Region	N	Mean Minimum Temperature	Mean Maximum Temperature	Mean Temperature	Mean Windspeed	Mean Sea level pressure	Mean Rainfall l	Mean Prevalence
Arusha	60	15.8	23.8	19.2	2.8	1013.7	65.3	1226.2
Dar es Salaam	60	28.1	31.1	26.5	4.9	1013.2	49.6	1640.3
Dodoma	60	17.0	25.4	20.5	4.0	1013.9	44.5	1351.7
Iringa	60	16.6	24.8	20.7	4.5	1014.2	46.3	1110.8
Kagera	60	14.0	18.8	20.4	2.5	1012.6	100.1	492.3
Kigoma	60	13.7	19.7	21.3	3.1	1012.4	101.4	300.2
Kilimanjaro	60	19.0	27.1	20.9	3.6	1013.9	40.3	906.6
Lindi	60	23.7	31.3	24.8	3.6	1013.5	56.6	787.9
Manyara	60	18.5	26.1	21.1	3.9	1013.8	44.9	1026.1
Mara	60	14.7	21.7	19.1	2.5	1013.4	90.8	955.3
Mbeya	60	14.9	22.9	20.6	4.5	1013.7	48.1	550.5
Morogoro	60	20.6	28.6	23.0	3.8	1013.7	44.2	1449.4
Mtwara	60	25.6	32.3	25.7	3.9	1013.6	60.9	680.2
Mwanza	60	16.1	21.4	21.4	2.7	1012.1	102.0	80.3
Pwani	60	24.4	30.1	24.4	4.3	1013.4	51.9	1049.6
Rukwa	60	14.2	21.5	21.5	3.9	1012.7	69.9	522.1
Ruvuma	60	19.3	27.5	22.5	3.7	1014.1	61.4	683.4
Shinyanga	60	15.2	21.8	20.4	2.9	1012.9	91.6	595.1
Singida	60	15.1	23.7	19.9	4.1	1013.9	52.9	139.1
Tabora	60	15.6	23.2	21.6	3.7	1012.7	70.0	521.0
Tanga	60	22.0	28.0	22.4	4.2	1013.7	42.2	992.8
National	1260	18.3	25.3	21.8	3.7	1013.4	63.6	812.4

Aggregate Monthly Pneumonia Prevalence and Weather for 2004 - 2008

Month	N	Mean			Mean Maximum Temperature	Mean Temperature	Mean Windspeed	Mean Sea level pressure	Mean Rainfall	Mean Prevalence
		Minimum Temperature	Temperature	Temperature						
January	105	19.4	25.0	22.4	2.8	1011.6	126.7	706.9		
February	105	19.3	24.6	22.2	2.6	1011.6	127.7	753.3		
March	105	19.1	24.5	21.9	2.8	1011.9	115.0	887.5		
April	105	18.3	24.5	21.2	3.5	1012.8	63.6	1019.8		
May	105	17.7	24.9	21.1	4.0	1014.4	20.6	931.6		
June	105	16.6	24.3	20.3	4.2	1016.2	8.5	906.8		
July	105	16.1	24.3	20.2	4.3	1016.5	8.6	825.3		
August	105	17.1	25.5	21.4	4.3	1015.2	12.6	712.8		
September	105	18.1	26.5	22.4	4.3	1014.2	22.7	866.4		
October	105	18.9	27.0	23.0	4.4	1013.1	46.0	741.3		
November	105	19.3	26.6	23.0	3.9	1011.7	80.6	700.7		
December	105	19.6	25.4	22.6	3.1	1011.4	130.0	696.6		
Annual	1260	18.3	25.3	21.8	3.7	1013.4	762.8	812.4		

Aggregate long term weather variables by region

Month	N	Long term Temperature	Long term Rainfall	Long term Relative Humidity	Long term SeaLevel Pressure	Long term Windspeed
Arusha	60	18.5	75.5	76.2	1013.3	2.8
Dar es Salaam	60	26.1	79.9	77.3	1025.4	4.9
Dodoma	60	19.7	51.4	73.9	1013.5	3.9
Iringa	60	19.7	52.0	70.1	1011.0	4.4
Kagera	60	19.4	128.4	78.2	994.8	2.4
Kigoma	60	20.1	118.6	71.2	992.2	2.9
Kilimanjaro	60	20.2	55.0	79.7	1019.9	3.6
Lindi	60	24.1	64.8	72.7	1022.3	3.6
Manyara	60	20.3	57.2	78.9	1015.9	3.8
Mara	60	18.3	104.9	75.3	1007.2	2.5
Mbeya	60	19.4	57.2	67.0	1003.8	4.3
Morogoro	60	22.2	52.7	73.2	1017.4	3.7
Mtwara	60	25.1	69.3	74.1	1025.1	3.8
Mwanza	60	20.4	126.5	75.3	1000.2	2.6
Pwani	60	23.8	71.0	76.4	1023.3	4.2
Rukwa	60	20.2	83.7	66.4	995.6	3.7
Ruvuma	60	21.6	65.0	69.6	1015.0	3.7
Shinyanga	60	19.4	111.8	73.8	1002.8	2.7
Singida	60	19.0	62.4	72.3	1008.2	3.9
Tabora	60	20.5	85.6	69.1	1000.9	3.4
Tanga	60	21.9	66.5	81.4	1022.1	4.1
National	1260	20.9	78.1	73.9	1010.9	3.6

Aggregate long term weather variables by month

Month	N	Long term Temperature	Long term Rainfall	Long term Relative Humidity	Long term SeaLevel Pressure	Long term Windspeed
January	105	21.1	168.6	85.0	1009.2	2.6
February	105	21.2	148.4	86.1	1008.9	2.4
March	105	20.9	154.5	88.2	1009.3	2.5
April	105	20.3	108.0	87.7	1010.2	3.2
May	105	20.1	40.1	78.0	1011.8	3.9
June	105	19.7	13.9	68.2	1013.5	4.0
July	105	19.7	11.1	63.3	1014.0	4.2
August	105	20.5	12.3	60.6	1013.2	4.2
September	105	21.6	21.9	59.8	1011.8	4.2
October	105	22.2	52.3	63.8	1010.4	4.2
November	105	22.3	75.7	68.6	1009.7	4.0
December	105	21.7	129.9	77.8	1009.4	3.2
Annual	1260	20.9	936.7	73.9	1010.9	3.6

Yearly weather and pneumonia aggregates

Month	N	Mean Min. Temperature	Mean Max. Temperature	Mean Temperature	Wind speed	Sea level pressure	Rainfall	Mean Prevalence
2004	252	18.0	25.2	21.7	3.5	1013.7	669.4	718.5
2005	252	18.8	26.5	22.1	3.8	1013.5	453.6	996.6
2006	252	18.2	24.9	21.7	3.8	1013.4	917.4	879.5
2007	252	18.3	24.8	21.8	3.5	1013.1	947.7	760.5
2008	252	18.2	25.0	21.7	3.8	1013.1	825.7	707.0
Grand Total	1260	18.3	25.3	21.8	3.7	1013.4	63.6	812.4

B: MULTIPLE IMPUTATION

Summary of comparison between dataset with missing value, and the same dataset without missing values, filled in by using multiple imputation.

Purpose and method:

An **original** dataset without missing values had three independent variables QBO, AMO, and ENSO. Missing values were randomly introduced. The missing values were filled by using random numbers between the minimum and the maximum value of the variable and hence create another dataset '**random**'. The missing values were also filled-back by using multiple imputation method, and create the third dataset '**multiple imputation**'. The three datasets were compared by running regression analysis against radius of tropical cyclone as an independent variable in PASW version 18.

Results

All the three regression criteria were significant ($p < 0.001$). In all three the same conclusion could be reached as AMO was not statistically significant. But both the standardized and un-standardized coefficients of the randomized variables looked much different from the original or from the multiple imputation. The tables of results are shown in the following pages.

Conclusion:

Multiple Imputation method produces results that are closer to original than just replacing the missing values with random numbers

		QB													
		AMO			O		QBO		ENS		ENSO		TCav		
		AMOi		rando		imp		rando		O		Radi		Radius	
		AMO	mp	m	QBO	utd	m	O	imp	m	us	Imp	Random		
N	Valid	252	252	252	252	252	252	252	252	252	252	252	252	252	252
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean		.09	.08	.11	6.13	5.95	6.76	.15	.12	.06	41.81	42.38	51.95		
Median		.09	.08	.07	5.60	5.60	6.40	.23	.19	.14	.00	.00	.00		
Std. Deviation		.20	.21	.25	8.08	8.27	8.60	1.10	1.09	1.29	55.75	54.61	62.40		
Skewness		.09	-.12	1.40	.30	.25	.28	-.02	-.02	-.10	.94	.88	.93		
Std. Error of Skewness		.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15		
Kurtosis		-.59	-.33	3.25	-.70	-.67	-.75	-.15	-.19	-.05	-.24	-.14	.01		
Std. Error of Kurtosis		.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31		
Minimum		-.34	-.54	-.34	-9.20	-	-9.20	-3.39	-3.39	-3.39	.00	-42.91	.00		
						11.6									
						0									
Maximum		.56	.56	1.00	26.30	26.3	26.30	3.53	3.53	3.53	245.0	245.00	245.00		
						0					0				
Percentile	25	-.07	-.08	-.05	-.18	-.40	.00	-.63	-.68	-.96	.00	.00	.00		
	50	.09	.08	.07	5.60	5.60	6.40	.23	.19	.14	.00	.00	.00		
	75	.22	.22	.23	12.28	12.0	12.58	.93	.93	.95	89.43	87.39	96.62		

Coefficients^a

Model		Unstandardized		Standardize	t	Sig.	95.0% Confidence	
		Coefficients		d			Interval for B	
		B	Std. Error	Beta			Lower	Upper
						Bound	Bound	
1	(Constant)	67.428	5.432		12.414	.000	56.729	78.126
	QBOrandom	-2.181	.462	-.301	-4.717	.000	-3.092	-1.270
	AMOrandom	-2.818	15.272	-.011	-.185	.854	-32.897	27.261
	ENSOrandom	-6.543	3.055	-.136	-2.142	.033	-12.560	-.526

a. Dependent Variable: TCavRadiusRandom

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.295 ^a	.087	.076	59.96945490	.087	7.906	3	248	.000

a. Predictors: (Constant), ENSOrandom, AMOrandom, QBOrandom