PATTERNS AND DETERMINANTS OF CHOLERA OUTBREAKS IN IMBO REGION OF BURUNDI

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN EPIDEMIOLOGY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Cholera is an ancient disease but remains an important public health threat mainly in low-and-middle-income countries. The disease has been reported almost every year in Burundi. Understanding its spatial-temporal distribution and the determinants within the country contribute to early detection and quick response to contain the outbreaks. The objective of this study was to determine the patterns and factors responsible for cholera outbreaks in Imbo Region of western Burundi. Data were collected retrospectively from health districts and hospitals/dispensaries records. A structured questionnaire was administered to selected participants from affected community to get information on determinants of cholera outbreaks. The analysis was done by using R software, version 3.6.1. Temporal patterns were obtained by plotting cholera cases against time (months and weeks). Spatial patterns were established by tagging cholera cases to their locations for each year whereby Burundi provinces, communes, Collins shape files were entered in ArcGIS software, version 10.3. Frequency maps were generated, showing the spatial distribution of cholera disease in the study area. The findings indicate that most of the cholera outbreaks have occurred during dry seasons and were associated with a lack of potable water. The multivariate analysis showed that females were at risk of getting cholera than males (OR=1.85, 95% CI: 1.024 - 3.359) and source of water was a risk factor, whereby use of tap water was protective compared to use of surface water (OR=0.368, 95% CI: 0.168 - 0.740). In conclusion, most of the outbreaks in Imbo Region occur during the dry seasons when potable water is in shortage supply. Improving population access to the potable water distribution system and promoting sanitation and hygiene will likely reduce the occurrence and spread of cholera in the Region.

DECLARATION

I, LAETITIA IRAKOZE hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and it has neither been submitted nor concurrently being submitted to any other institution.

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DEDICATION

This research work is dedicated to my brother Prince Bertrand Cubahirokumana and to Pacifique Niyonizigiye’s family for their proper caring, prayers and encouragement during the period of my study

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LIST OF ABBREVIATION

BMH	Burundi Ministry of Health Report
BMWETMU	Burundi Ministry of Water, Environment, Territory Management and Urbanism
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

Cholera is a contagious human infection caused by a bacterium *Vibrio cholerae,* which colonizes the small intestines and produces an enterotoxin that causes a sudden severe watery diarrhoea, vomiting, dehydration and death if not treated timely (Harris *et al*., 2012; Lonappan *et al*., 2020). Cholera is known as a disease of poor sanitation and hygiene especially in the overcrowded areas, and its transmission is mainly through faecal contamination of food and water (Ali *et al.*, 2015; Anamzui-ya, 2012). In Sub-Saharan Africa, consumption of contaminated food and water as well as bathing in contaminated lake water have been linked to cholera epidemics (Birmingham *et al.*, 1997; Swerdlow *et al*., 1997). The disease has also been associated with eating at large funeral feasts (Gunnlaugsson *et al.*, 1998), and eating cold leftover foods (Swerdlow *et al*., 1997).

Cholera is endemic in 69 countries placing 1.3 billion people at risk of infection and 1.3 to 1.4 million cases and causing 21 000 to 143 000 deaths worldwide each year (Ali *et al.*, 2015). The disease affects mainly low-and-middle-income countries (Ali *et al*., 2015). In 2017, 14 African countries reported a total of 179 835 cases and 3220 deaths due to cholera (WHO, 2018). In the affected area, cholera outbreaks cause panic, disrupt socio-economic development activities (Anamzui-ya, 2012). Available statistics indicate that in the Africa Region, from 2005 to 2007, cholera resulted in a total economic loss of between US$39 million and US$72.7 million (Kirigia *et al*., 2009).

Since the last pandemic reached Burundi in 1987, several cholera outbreaks have been reported almost every year (Nkoko *et al*., 2011). A total of 3,414 cases and 31 deaths have been reported between 2013 and 2017 (Burundi Ministry of Health, 2017).

1.1 Problem Statement and Study Justification

In Burundi, cholera is an endemo-epidemic disease generating little interest for national scientists. Therefore, few studies are available about the disease (Ruyonga, 2001). In Burundi, Imbo Region is the most affected area characterised by frequent cholera outbreaks (Birmingham *et al*., 1997; Otto, 2013). Between 2012 and 2017, a total of 1151 cases and 47 deaths due to cholera have been reported in Imbo Region (Burundi Ministry of Health, 2012-1017). The Region is located alongside Lake Tanganyika and Rusizi River where population use water from the lake and connecting rivers for their domestic needs (Otto, 2013). Research on the patterns and determinants of the cholera outbreaks in the Region is therefore important to provide information on the burden, temporal and spatial distribution as well as factors responsible for frequent outbreaks. This information is useful in designing appropriate prevention and control strategies in Imbo Region as well as in similar areas.

1.2 Objectives

1.2.1 General objective

The general objective of this study was to determine the patterns and factors responsible for cholera outbreaks in Imbo Region of Burundi.

1.2.2 Specific objectives

i. To determine the spatial-temporal patterns of cholera in Imbo Region for the period of 2012-2017.
ii. To determine the risk factors responsible for cholera outbreaks in Imbo Region.

1.3 Research Questions

1) What is the distribution of cholera outbreaks in space and in time in Imbo Region of Burundi?
2) What are the risk factors responsible for cholera outbreaks in Imbo Region of Burundi?

1.4 List of Manuscripts

The dissertation is based on one manuscript:

i. Patterns and determinants of cholera outbreaks in Imbo Region of Burundi.

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 Study Area

This study was conducted in the Imbo Region, which is one of the natural subdivisions' Region of Burundi, located in the western part of the country. The area is located alongside Lake Tanganyika and Rusizi River at the borders with Tanzania and Democratic Republic of Congo (DRC). The Region is made up of six administrative provinces of Burundi. Imbo Region occupies 10% of the surface of Burundi with a population density of 300/km^2 (BMWETMU, 2014). The annual average temperature is 25^{o}C with 30^{o}C as maximum and 15^{o}C as the minimum (BMWETMU, 2014). Many rivers cross through the Region and the population around usually use the water from the river for their domestic needs. Imbo Region was selected for this study because of its geographical location and frequent cholera outbreaks (Nkoko *et al.*, 2011; BMWETMU, 2014).

2.2 Study Design

This was a retrospective cross-sectional study involving a review of the cholera data from 2012 to 2017 and face-to-face interviews of the affected population. The data were geo-referenced using Arc Geographical Information System (ArcGIS), and digital map files (shape files) were developed (Figure 1).

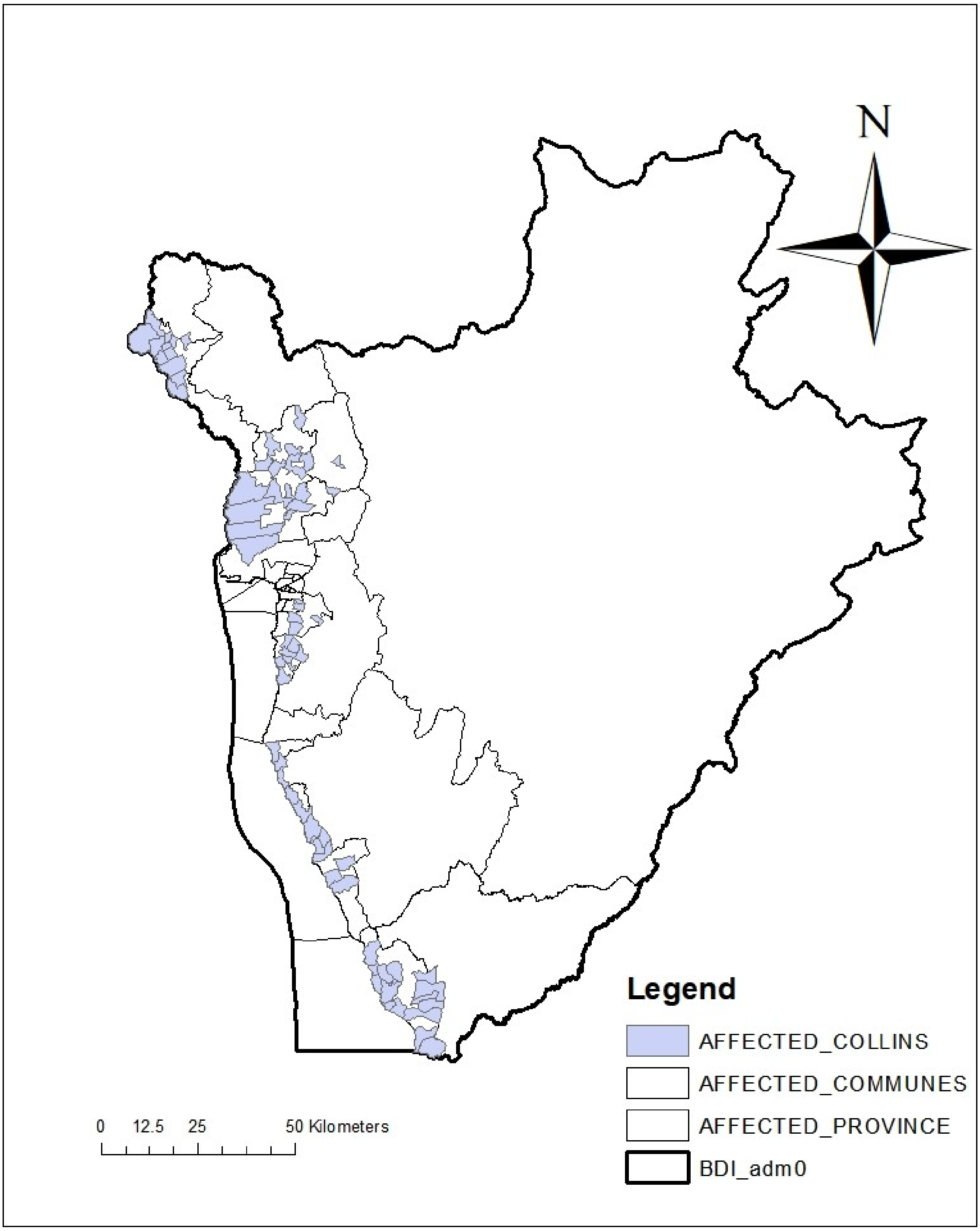


Figure 1: Map of Burundi showing study area

2.3 Sample Size

Estimation of sample size was done using a formula by Daniel (1999) with 33.7% the known prevalence of cholera in the study area (BMH, 2017). The formula is: $\mathbf{n = z^2 * p * (1-p)/d^2}$ with n = sample size, Z = confidence interval, P = expected prevalence and d = precision.

A total of 342 individuals selected randomly from the affected community were interviewed to obtain information about determinants of the disease in the study area. For the spatial-temporal distribution, all available cases from hospital/dispensary records were collected.

2.4 Data Collection

Data were collected retrospectively by reviewing the record from health districts and hospital/dispensary patient admission logbooks to identify persons admitted for acute watery diarrhoea with/without vomiting, over the period of six years (2012-2017). A cholera case was defined as any patient hospitalized for acute watery diarrhoea with/without vomiting, tested *vibrio cholerae* positive during the cholera epidemics from 2012-2017 (Hounmanou *et al.*, 2019). Socio-demographic information of the patients, time of disease occurrence and location coordinates (province, commune, wards and village/street) were retrieved from the records. Burundi provinces, communes, Collins shape files were obtained from Burundi Geographic Institute (IGEBU, 2015). The used shape files were lastly updated in 2015, currently there are some changes for Bujumbura and Bururi Province where Rumonge is now a province by itself but the updated shape files were not yet available.

Cholera cases or households which had cholera cases in 2016 or 2017 were identified, located and followed up for the interviews, using a study questionnaire. The structured questionnaire with closed-ended questions was designed for easier data collection as well as to reduce variations. It included socio-demographic characteristics (sex, age, marital status, education, occupation, household size), province, commune, ward, village/street and household facilities, knowledge of cholera and hygiene practices among respondents (source and storage of drinking water, handwashing, hygiene and sanitation, etc.). Data were collected using tablets, database was created, and one trained assistant was involved during data collection. Ethical consideration for this study was obtained from Burundi National Ethics Committee.

2.5 Data Management and Analysis

Collected data were entered in Microsoft Excel spreadsheets for cleaning. The analysis was done by using R software, version 3.6.1. Quantification of risk factors started with univariable logistic regression. The cholera variable (positive or negative)was fitted against variables on age, sex, marital status, occupation, education, household size, cholera information sources, toilet type, distance and time to health facilities, source of water, distance and time to source of water, treatment and storage of water, swimming, consumption of food leftovers, eating street foods, eating fruits, washing hands during cooking and after toilet, before and after eating. The cut-off point for qualification into multivariable logistic regression was set at 0.2. The multivariable logistic regression models were performed using generalized linear model (GLM) function and family "binomial" in R by backward stepwise procedure at the P-value of 0.05. The confounding effect was checked by assessing relative change of 25% and absolute change of 0.1 (for -0.4>0>0.4) of coefficients of remaining variables when the most insignificant variable is removed from the model. Interaction between variables in the final model was assessed. The Goodness of model fit was tested by the likelihood ratio test.

Temporal patterns were obtained by plotting cholera cases against time (months and weeks). Spatial patterns were established by tagging cholera cases to their locations for each year whereby Burundi provinces, communes, Collins shape files were entered in ArcGIS software, version 10.3. Frequency maps were generated, showing the spatial distribution of cholera disease in the study area.

CHAPTER THREE

3.0 RESULTS

3.1 Socio-demographic characteristics of participants in Imbo Region

A total of 342 participants were included in the study and for young children, their parents were interviewed on behalf. Among these participants, 55% were in the group age 6 to 18 years, 32% were under five years and 13% were above 18 years. Many of the participants (59%) were females and 41% were males. Among participants, 58% were single while 37% were married. Primary school was the education level of the majority (57%). Many of (68%) were farmers followed by student with 26%. For the majority of respondents, the household size was between five and ten (73%) (Table 1).

Table 1: Demographic characteristics of study participants (N=342)

Variables	Class	Frequency (N=342)	Percentage
Age	≤5years	109	32%
	6-18years	188	55%
	>18years	45	13%
Sex	Female	203	59%
	Male	139	41%
Marital status	Single	197	58%
	Married	125	37%
	Divorced	2	1%
	Widow	18	5%
Education level	Primary school	195	57%
	Secondary school	19	6%
	None	128	37%
Daily occupation	Farmers	232	68%
	Students	88	26%
	Business	22	6%
Number of people in the house	<5	91	27%
	between 5 and 10	251	73%

3.2 Source of Cholera Information, Household Facilities and Access to Health Care Facilities

The majority of participants (84%) obtained information about cholera outbreak through village health workers or community mobilizers, 13% through person to person communication and 3% through media (mobile phone, television). Many of the participants (95%) were using pit latrine toilet with/without cement slab, 4% were using opened defecation and 1% were using flush toilet connected to septic pits. Time to reach the health facilities was ≤30min for many of participants (69%). Distance to health facilities was ≤1.0km for 62% of participants (Table 2).

Table 2: The number and percentage of respondents with regard to source of health information, type of toilet, time and distance to health care facility

Variables	Response	Frequency (N=342)	Percentage
Getting information	Person to person	45	13%
	Village health worker/community mobilizer	287	84%
	Media	10	3%
Type of toilet	Pit latrine, with or without cement slab	325	95%
	Opened defecation	12	4%
	Flush toilet connected to septic pits	5	1%
Time to reach the health facilities	≤30min	236	69%
	31min-1hr	66	19%
	≥1hr	40	12%
Distance to health facilities	≤1km	212	62%
	1.0km-2km	22	6%
	≥1km	108	32%

3.3 Cholera Knowledge among Participants

Participants (100%) mentioned that they had heard about cholera infection. Poor hygienic practices (64%), eating unsafe food and not washing hands (21%), drinking non-potable water (8%) were reported as the way of contracting cholera, and 6% of them said that they don’t know. The majority of participants (93.86%) mentioned diarrhoea and vomiting as signs of cholera, 4.97% mentioned abdominal pain and 1.17% mentioned the cutaneous fold. Participants (100%) also mentioned that they were seeking for health care assistance when a member of the family has acute watery diarrhoea. For cholera prevention, 76.32% of participants mentioned good hygiene practices, 13.74% of participants mentioned drinking potable water, and 8.48% of participants mentioned eating safe food (Table 3). The majority of participants had good knowledge of cholera infection.

Table 3: Cholera knowledge among participants

Variables	**Response**	**Frequency (N=342)**	**Percentage**
Heard about cholera	Yes	342	100%
The way of contracting cholera	Poor hygienic practices	220	64%
	Eating unsafe food and not washing hands	73	21%
	Drinking contaminated water	27	8%
	Unknown	22	6%
Symptoms of cholera	Diarrhoea and vomit	321	94%
	Abdominal pain	17	5%
	Cutaneous fold	4	1%
Attitude when a family member has acute watery diarrhoea	Seeking for health care assistance immediately	342	100%
Cholera prevention	good hygienic practices	261	76%
	Drinking potable water	47	14%
	Eating safe food	29	8%

3.4 Source of Water and Hygiene Practices among the Participants

The majority of participants (96%) mentioned surface water as the source of water for domestic needs, and 4% mentioned tap water as the source of water for domestic purpose. Many of participants (66%) mentioned surface water as the source of drinking water and 34% mentioned tap water as the source of drinking water. The majority of participants (87%) were keeping the drinking water in a covered container and 12% in an opened container. Most participants (92%) used untreated water.

Time to access the source of water (tap water) was ≤ 30min for 64% of participants, between 31min and 1hr for 16% of participants and ≥ 1hr for 20% of participants. The distance to the source of water (tap water) was > 2km for many of participants (45%), 0-1 km for 38% of participants and 1.1km-2km for 17% of participants. The majority (99.7%) used to the eat leftover food. The majority of participants (93%) used to wash hands and fruits before eating. The majority (98%) of participants washed hands after using the toilet. Many (73%) of participants washed hands before and after cooking. The majority (96%) of participants washed hands before/after eating at home every day. Two thirds (67%) of participants washed their hands before/after eating out of the house every time (Table 4).

Table 4: Source of water and hygiene practices among the participants

Variables	Response	Frequency (N=342)	Percentage
Source of water for domestic purpose	Surface water	330	96%
	Tap water	12	4%
Source of drinking water	Surface water	227	66%
	Tap water	115	34%
Storage of drinking water	In covered container	298	87%
	In opened container	41	12%
	In tapped contained	3	1%
Treatment of drinking water	Treated with chlorine	27	8%
	Not treated	315	92%
Swimming in dams, swamps, river or lake	No	275	80%
	Yes	67	20%
Time to access the source of water (tap water)	≤30min	218	64%
	31-1hr	56	16%
	≥1hr	68	20%
Distance to the source of water (tap water)	0-1km	129	38%
	1.1km-2km	59	17%
	>2km	153	45%
Eating leftover food	Yes	341	100%
	No	1	0%
Eating street food	Yes	305	89%
	No	37	11%
Eating fruits	Washing hands and fruits	317	93%
	Eating unwashed fruits	13	4%
	Never	12	3%
Washing hands after using toilet	Yes	334	98%
	No	8	2%
Reason of washing hands after using toilet	Hygiene matters	125	37%
	To prevent disease due to lack of hygiene	209	63%
Washing hands before and after cooking	No	94	27%
	Yes	248	73%
Reason of washing hands after cooking	Hygiene matters	73	21%
	To prevent disease due to dirtiness	176	51%
Washing hands before/after eating at home	Everyday	327	96%
	Most of the time	15	4%
Washing hands before/after eating out of the house	Every time	228	67%
	Most of the time	21	6%
	Never	93	27%

3.5 Risk Factor for Cholera Outbreak in Imbo Region

In order to get information on the determinants (risk factors) of cholera outbreaks in Imbo Region of Burundi, 342 participants were chosen randomly from record to be interviewed. Among those participants, stool examination was done. A total of 282 were tested positive for *Vibrio cholerae* and 60 tested negatives.

Ten variables namely; age, sex, marital status, daily occupation, cholera information source, time to reach the health facilities, distance to health facilities, water source, time to access the source of water and water storage had p-value ≤ 0.2 and hence qualified for multivariable logistic regression.

The final logistic regression model had three variables namely sex, occupation and water source (Table 6). Females were at higher risk of getting cholera than males (OR=1.85, 95% CI: 1.024 - 3.359). Source of water was a risk factor, whereby use of tap water was protective compared to use of surface water (OR=0.368, 95% CI: 0.168 - 0.740). Individuals using surface water were at 2.7 times likely to contract cholera than individual using tap water. Occupation was maintained in the final model because it was a confounder for sex. There was no significant interaction and the likelihood ratio test yielded a p-value of (Chi-square = 17.422, df=4), indicating that the full model explained the data better than the null model (Table 5).

Table 5: Multivariable logistic regression output for cholera risk factors in Imbo Region

Variable	Response	Coefficient	Odds Ratio	95% CI
Sex	Male		1	
	Female	0.6145	1.85	1.024 - 3.359
Occupation	Farming		1	
	Studying	-0.7633	0.47	0.206 - 0.966
	Business	-0.8757	0.42	0.063 - 1.59
Water source	Surface water		1	
	Tap water	-0.9991	0.37	0.167 - 0.74

3.6 Temporal Distribution of Cholera Cases in Imbo Region of Burundi

A total of 3414 cholera cases were detected in the country during the study period. Of this, 61.3% (2,092) were reported with 0.48% (10) of deaths from Imbo Region. The temporal patterns are reported province-wise for a 2012 to 2017 using monthly distribution.

3.6.1 Makamba province

The highest numbers of cases were detected in July (2015), September (2013 and 2017), and October (2014 and 2016) (Figure 2). In 2013, the outbreak started during week 33 (2nd week of August: dry season). The highest numbers of cases were detected during week 35 (end of August: dry season) and the lowest during week 43 (3rd week of October: rainy season). In 2014, higher numbers of cases were detected at the beginning of the outbreak during week 34 (3rd week of August: dry season) and the lower numbers of cases during week 39 (3rd week of September: rainy season). In 2015, the outbreak started during week 20 (2nd week of May: dry season). The highest numbers of cases were detected during week 25 (3rd week of June: dry season) and the lowest numbers of cases during week 31 (end of July: dry season). In 2016, the outbreak started during week 37 (2nd week of September: rainy season). The highest numbers of were detected during week 38 (3rd week of September: rainy season) and the lowest numbers of cases were detected during week 39 (end of September: rainy season). In 2017 the outbreak started during week 32 (1st week of August). The highest numbers of cases were detected during week 34 (3rd week of August) and the lowest during week 37 (2nd week of September: rainy season) (Figure 3). For Makamba Province, seasonal peaks existed with most cases frequently detected during dry season (June-and July: 2013, 2014, 2015, 2017) and some during the rainy season (September 2016).

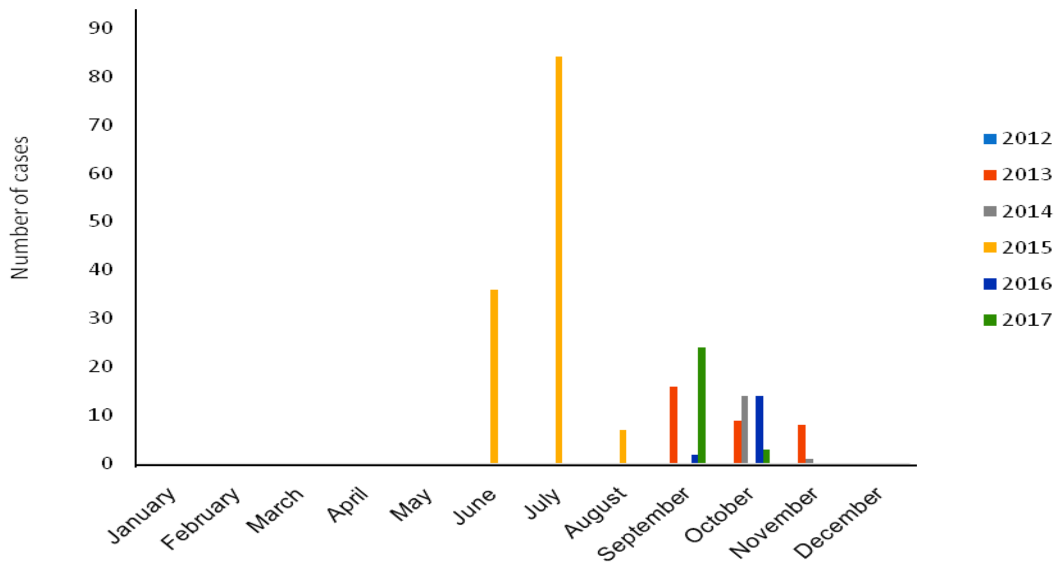


Figure 2: Monthly distribution of cholera cases in Makamba Province, 2012-2017

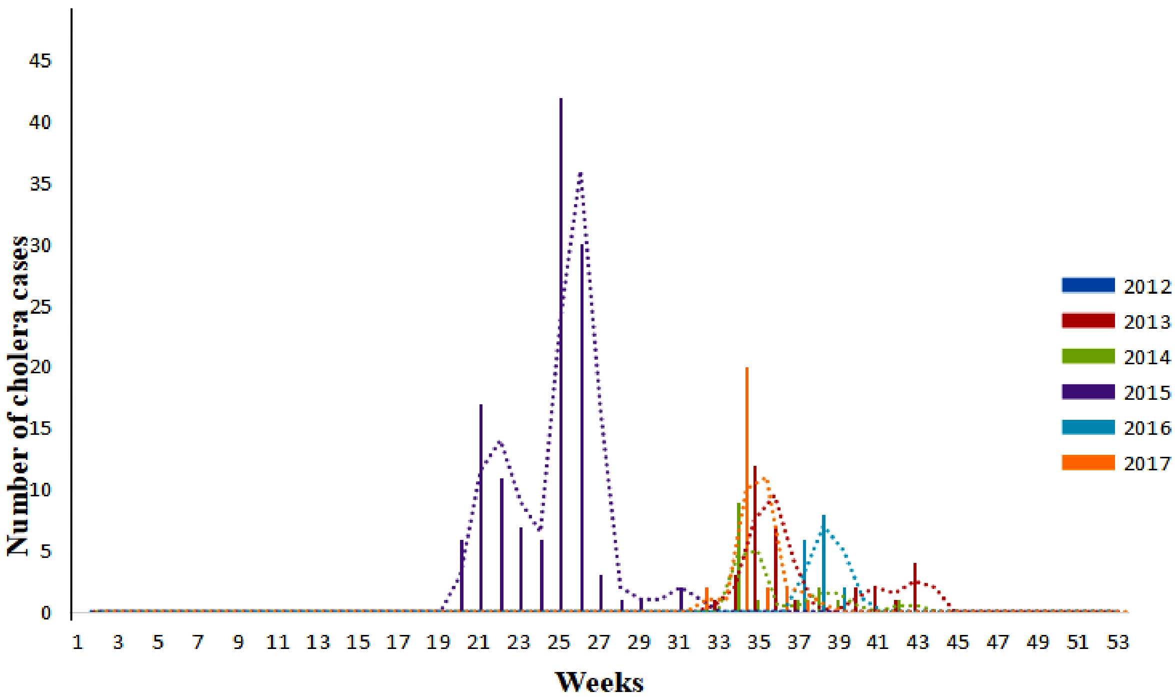


Figure 3: Weekly distribution of cholera cases in Makamba Province, 2012-2017

3.6.2 Bururi province

Majority of cases were detected in January (2013 and 2015), July (2014), October (2012), April and November (2016) (Figure 4). In 2012, the outbreak started during week 43 (3rd week of October: rainy season). The higher number of cases was detected during week 44 (end of October: rainy season) and lower number of cases was detected during week 52 (end of December: rainy season). In 2013, the higher number of cases was detected at the beginning of the outbreak during week 1 (1st week of January: rainy season) and the lower number of cases during week3 (3rd week of January: rainy season). In 2014, the outbreak started during week 30 (3rd week of July: dry season). The higher number of cases was detected during week 31 and 48 (end of July, dry season; end of November: rainy season) and the lower number of cases was detected during week 53 (end of December: rainy season). In 2015, the outbreak started during week 1 (1st week of January: rain season), with the highest number of cases detected during week 2 and 5 (2nd week and end of January: rainy season) and the lowest number of cases was detected during week 8 (2nd week of February: rainy season). In 2016, the outbreak started during week 40 (1st week of October: rainy season). The higher number of cases was detected during week 45 (1st week of November: rainy season) and the lower number of cases during week 48 (end of November: rainy season) (Figure 5). For Bururi Province, seasonal peaks existed with most cases frequently detected during the rainy season (January, October, November of 2012, 2013, 2015 and 2016) and some in dry season (June in 2014).

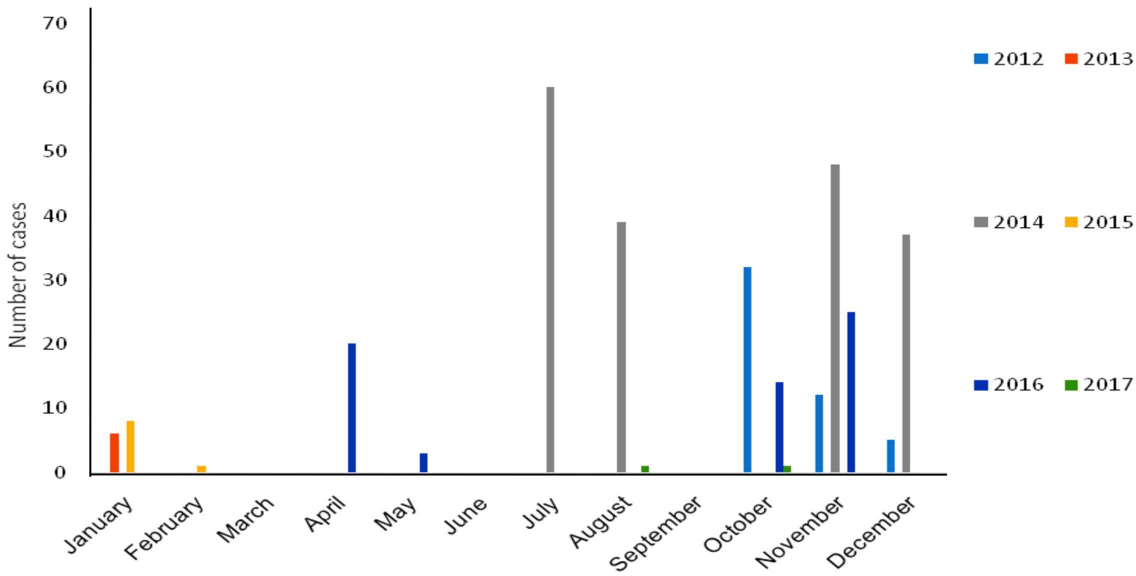


Figure 4: Monthly distribution of cholera cases in Bururi Province, 2012-2017

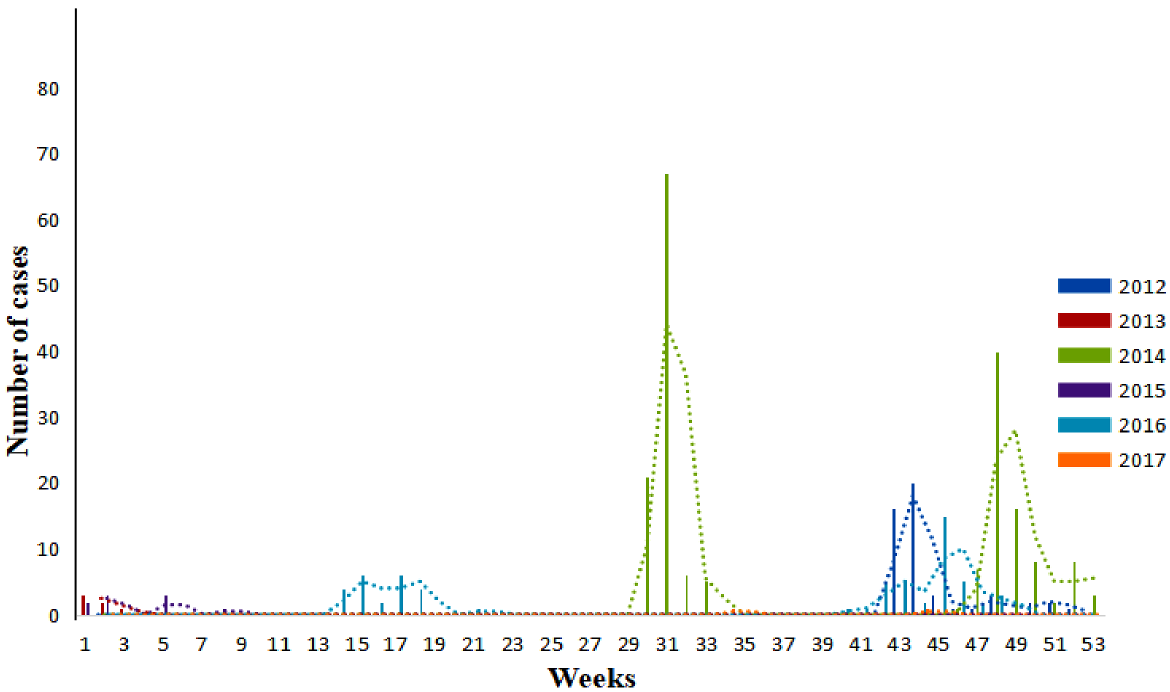


Figure 5: Weekly distribution of cholera cases in Bururi Province, 2012-2017

3.6.3 Bujumbura Mairie Province

Higher number of cases was detected in June (2015), July (2013), August (2014 and 2017) and September (2016) while the lowest numbers between January and June (Figure 6). For all six years in Bujumbura Mairie Province, lower numbers of cases were detected mostly between week 1 and 26. In 2012, higher numbers of cases were detected during week 41 (2^{nd} week of October: rainy season). In 2013, higher numbers of cases were detected during week 30 (end of July: dry season). In 2014, higher numbers of cases were detected during week 32 (1^{st} week of August: dry season). In 2015, higher numbers of cases were detected in week 27 (end of June: dry season). In 2016, higher numbers of cases were detected during week 36 (1^{st} week of September: rainy season), while in 2017 during week 42 and 47 (3^{rd} week of October and November: rainy season) (Figure 7). In Bujumbura Mairie Province, seasonal peaks were observed during dry seasons (June, July and August of 2013, 2014, 2015) and during the rain seasons (September-October of 2012, 2016, 2017).

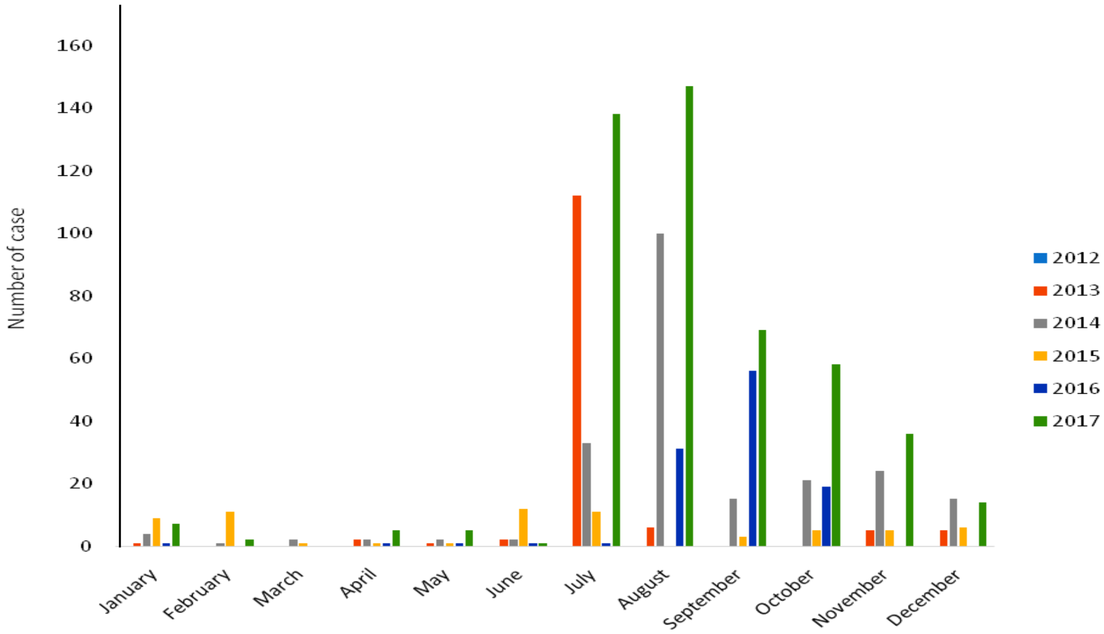


Figure 6: Monthly distribution of cholera cases in Bujumbura Mairie Province, 2012-2017

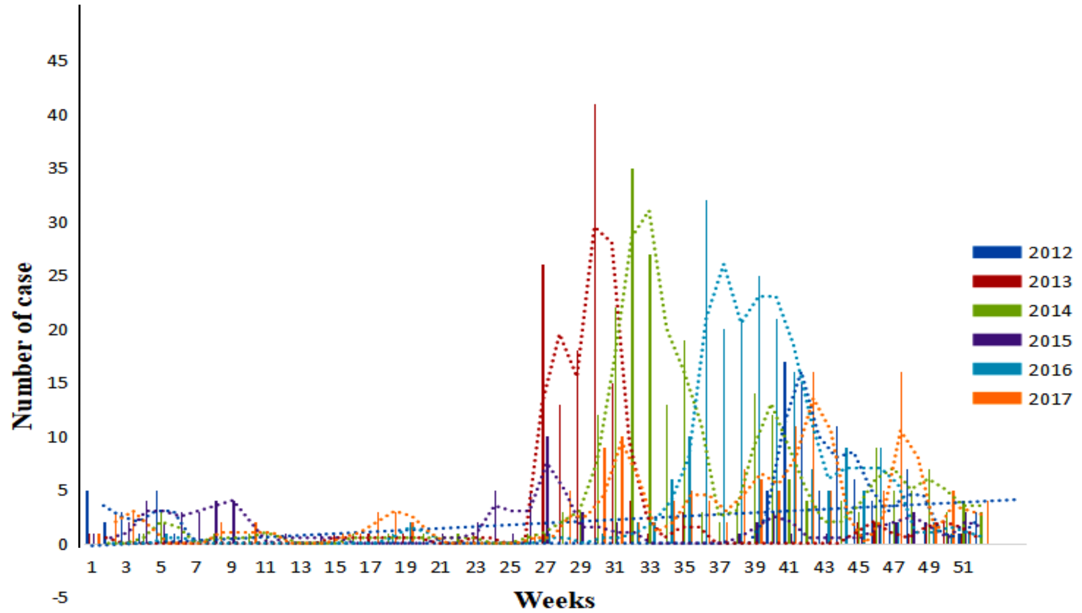


Figure 7: Weekly distribution of cholera cases in Bujumbura Mairie Province, 2012-2017

3.6.4 Bujumbura Province

Higher numbers of cases were detected in July (2016) and August (2014 and 2016) (Figure 8). In 2013, higher numbers of cases were detected during week 27 and 29 (1st and 3rd week of July: dry season). In 2014, the outbreak started during week 29 (2nd week of July: dry season). Higher numbers of cases were detected during week 32 and 33 (1st and 2nd week of August: dry season) and lower number of cases was detected during week 47 (3rd week of November: rainy season). In 2015, higher numbers of cases were detected at the beginning of the outbreak during week 9 (end of February: rainy season) while lower numbers were detected between week 23 and 29 (1st week of June and 2nd week of July: dry season). In 2016, higher number of cases were detected during week 19 (2nd week of May: dry season). In 2017, the outbreak started during week 30 (end of July: dry season) and higher numbers of cases was detected during weeks 40 and 41 (1st and 2nd week of October: rain season) (Figure 9). For Bujumbura province, seasonal peak existed with most cases frequently detected in dry seasons (May, July and August of 2013, 2014 and 2016) and some in rainy seasons (February and October of 2015 and 2016).

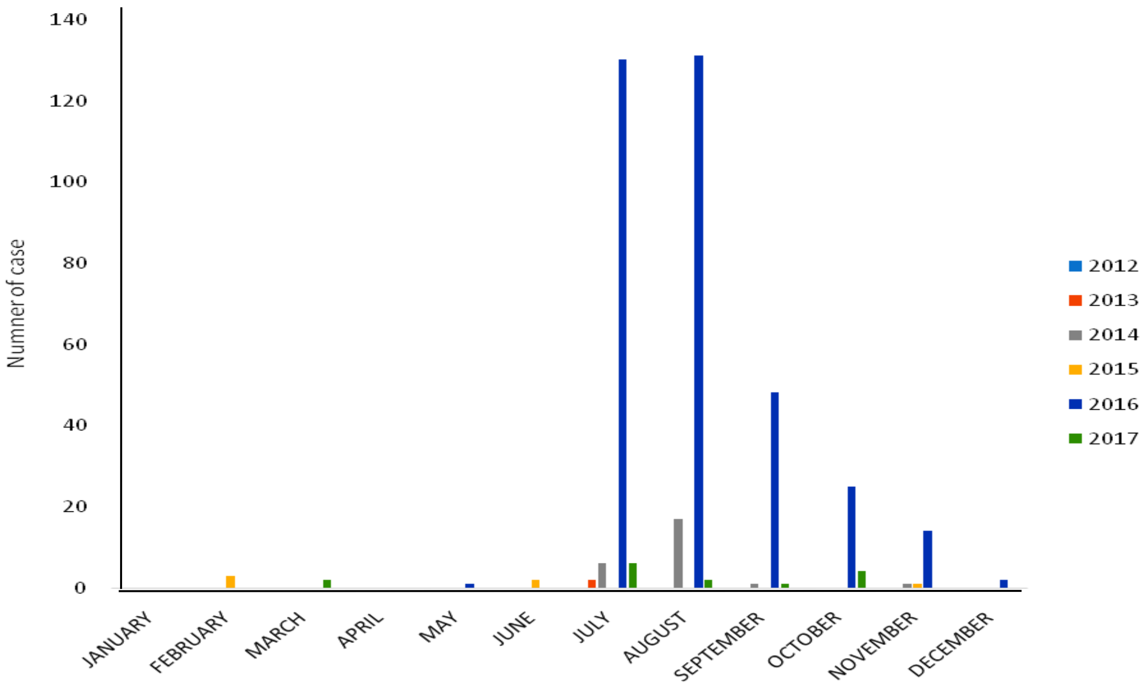


Figure 8: Monthly distribution of cholera case in Bujumbura Province, 2012-2017

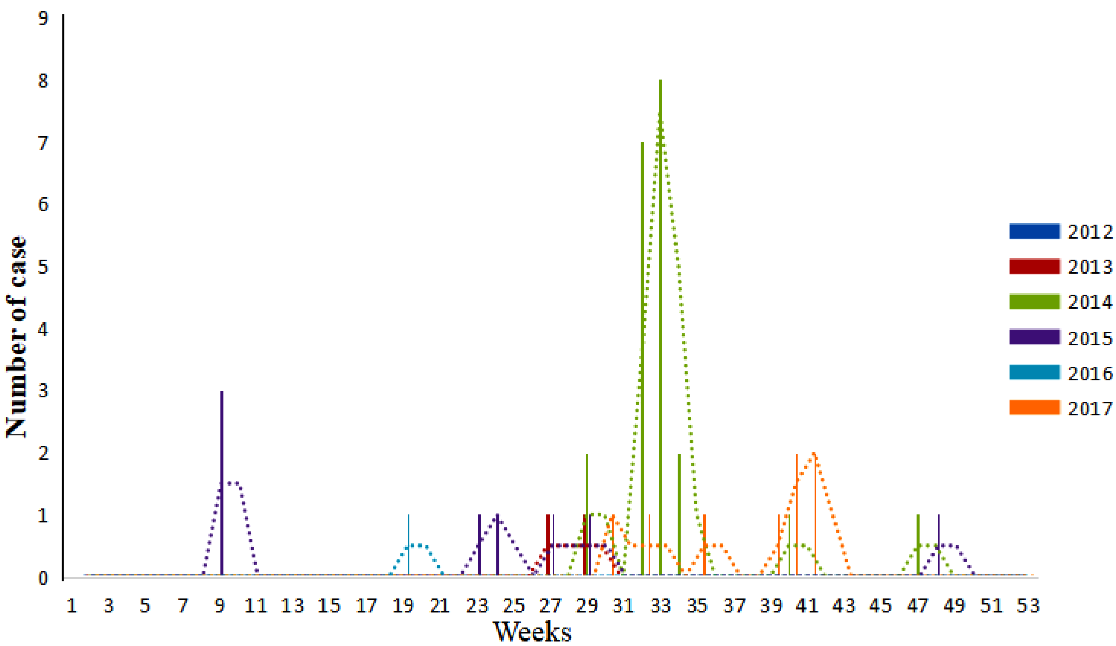


Figure 9: Weekly distribution of cholera case in Bujumbura Province, 2012-2017

3.6.5 Bubanza Province

Higher numbers of cases were detected during October (2017), and November (2014) (Figure 10). In 2014, the outbreak started during week 46 (2^{nd} week of November: rainy season), with the highest number of cases detected during week 47 (3^{rd} week of November: rainy season) and lowest number during week 48 (end of November: rainy season). In 2017, the outbreak started during week 38 (3^{rd} week of September: rainy season) with a peak observed during weeks 40 and 42 (1^{st} and 3^{rd} week of October: rainy season) and lowest number of cases during week 45 (1^{st} week of November: rainy season) (Figure 11). Seasonal peaks with most cases detected during the rainy season of November-October have been observed.

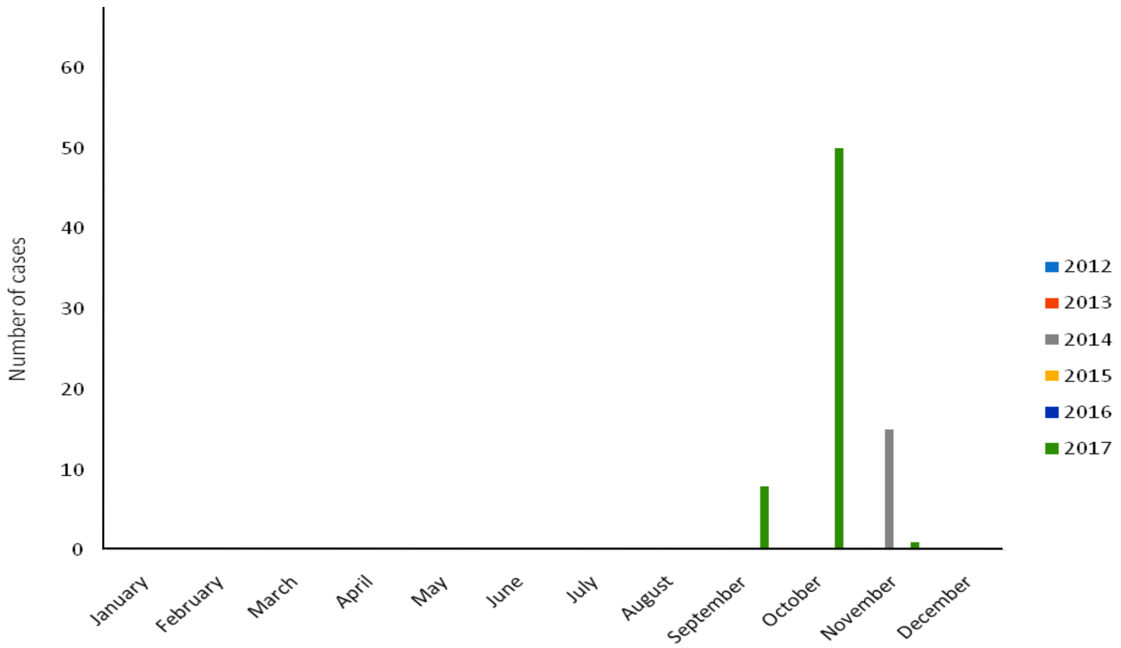


Figure 10: Monthly distribution of cholera cases in Bubanza Province, 2012-2017

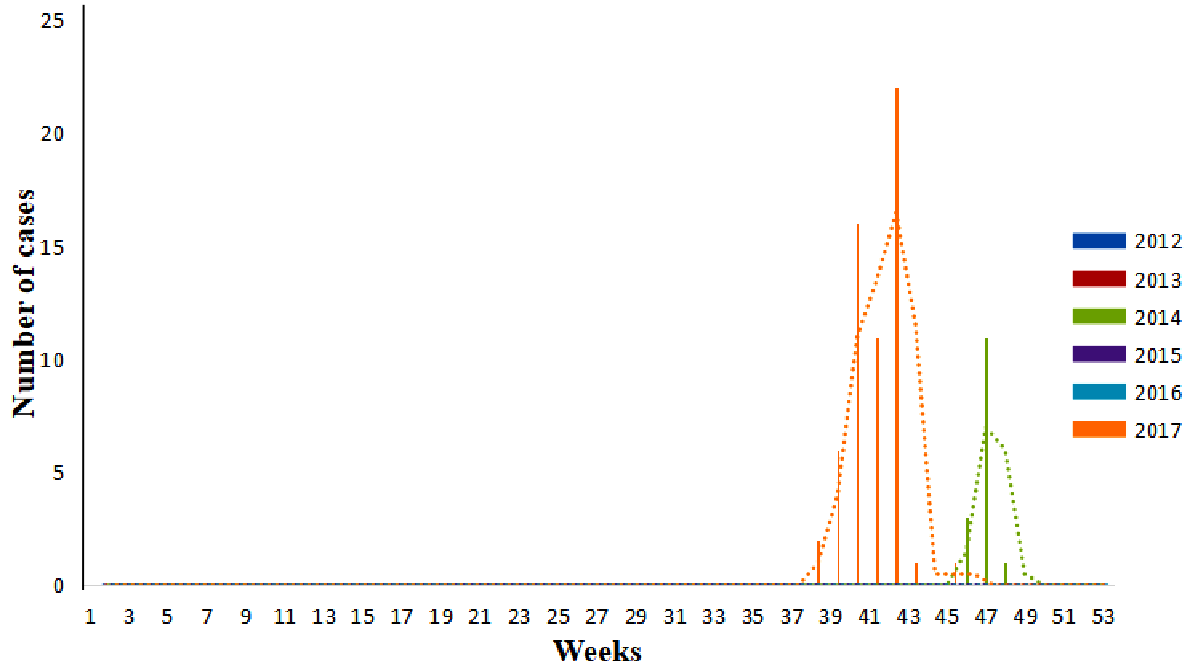


Figure 11: Weekly distribution of cholera cases in Bubanza Province, 2012-2017

3.6.6 Cibitoke province

Higher numbers of cases were detected in January (2017), August (2013), October (2012) and December (2016) (Figure12). In 2013, the outbreak started during week 1 (1st week of January: rainy season), with the lowest numbers of cases detected between week 1 (1st week of January: rainy season) and week 32 (1st week of August: dry season). The highest numbers of cases were detected during weeks 33 and 34 (2nd and3rd week of August: dry season). In 2016, higher numbers of cases were detected during week 53(end of December: rainy season). In 2017, higher case numbers were detected at the beginning of the outbreak during weeks 1 and 2 (1st and2nd week of January: rainy season) and in week 42 (3rd week of October: rainy season). The lowest numbers of cases were detected during the rest parts of the year (Figure 13). Most of the seasonal peaks in Cibitoke were recorded during the rainy season (January and December of 2016 and 2017) and some in dry season (August of 2013).

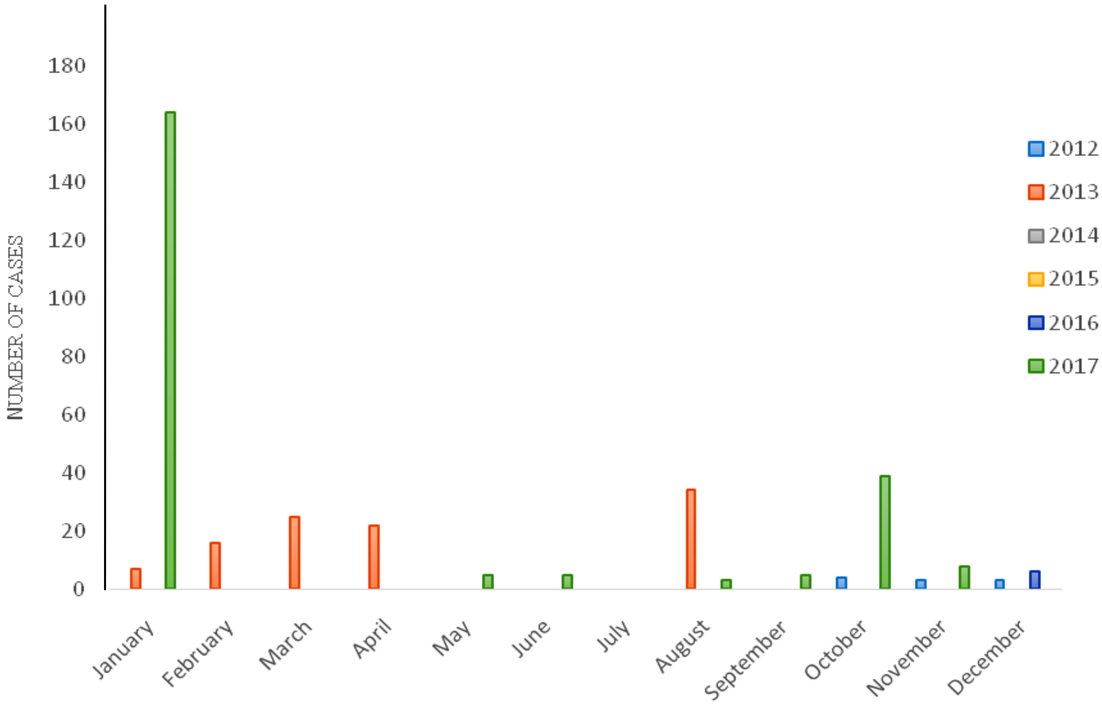


Figure 12: Monthly distribution of cholera cases in Cibitoke Province, 2012-2017

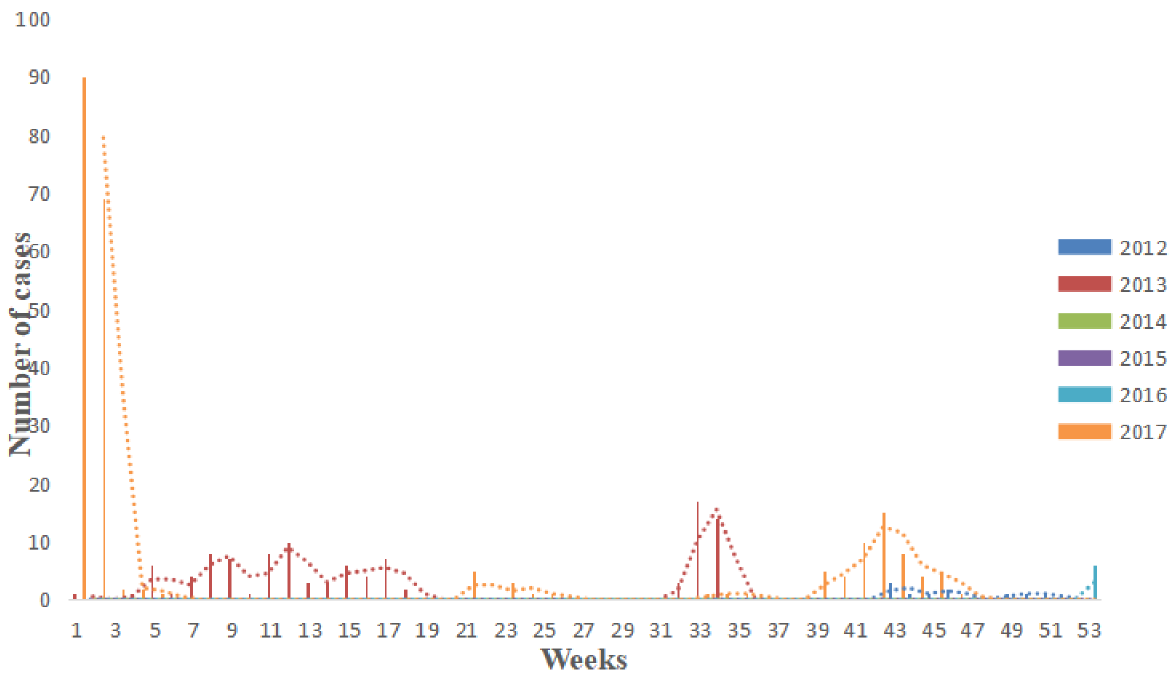


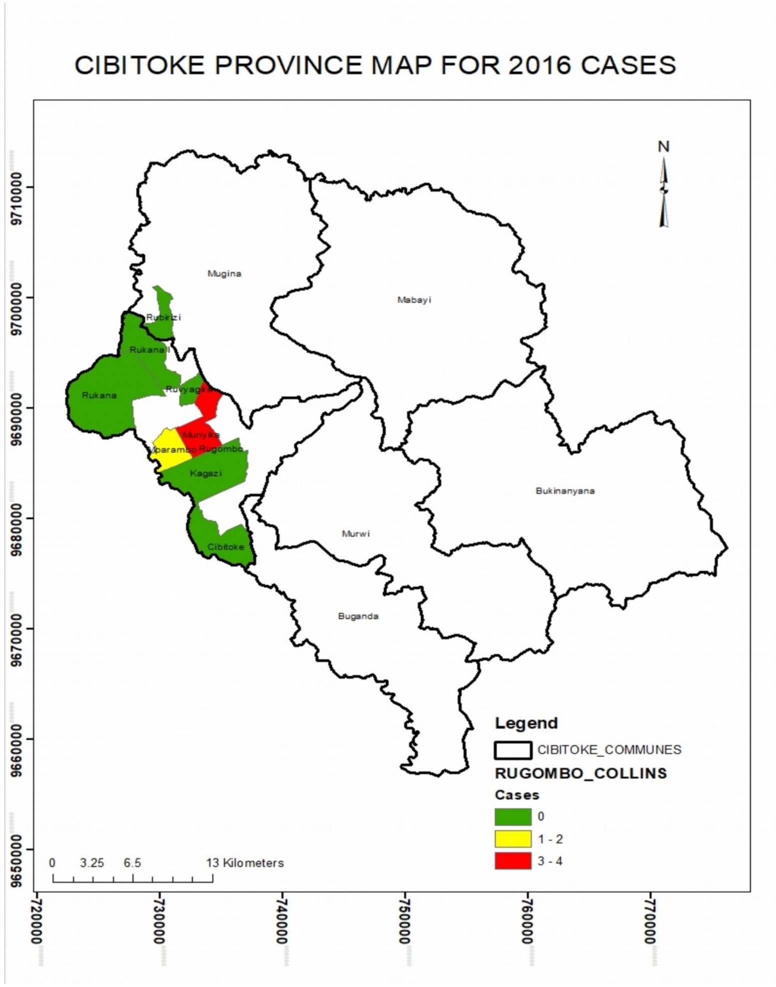
Figure 13: Weekly distribution of cholera cases in Cibitoke Province, 2012-2017

3.7 Spatial Distribution of Cholera Outbreaks in Imbo Region

The spatial distribution in study area is presented by province on the following maps.

3.7.1 Cibitoke Province

Cibitoke Province in Rugombo commune, no cholera cases were reported from 2012 to 2015. Munyika ward was the mostly affected area in 2016 while Mparambo ward in 2017 (Figure14 and Figure 15).



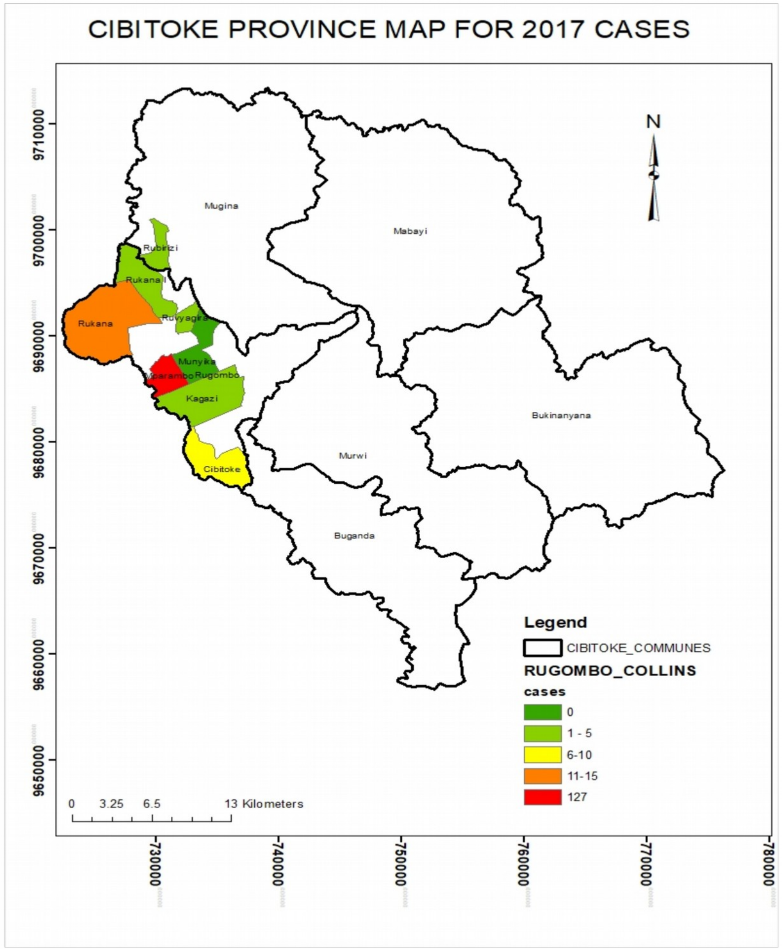


Figure 14: Cibitoke Province 2016 cases

Figure 15: Cibitoke Province 2017 case

3.7.2 Bubanza Province

In Bubanza Province, no cholera cases were reported in 2012, 2013, 2015 and 2016. The mostly affected ward in 2014 was Shari (Figure 16). In 2017; Shari, Gahwazi and Buringa wards were the mostly affected areas (Figure 17).

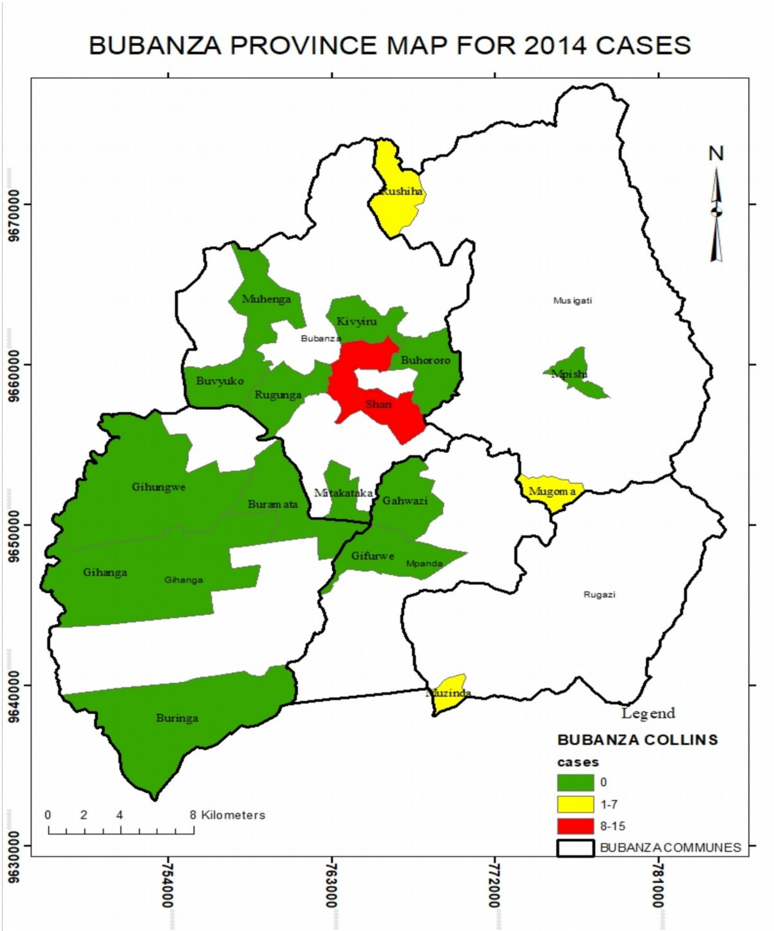


Figure 16: Bubanza Province 2014 cases

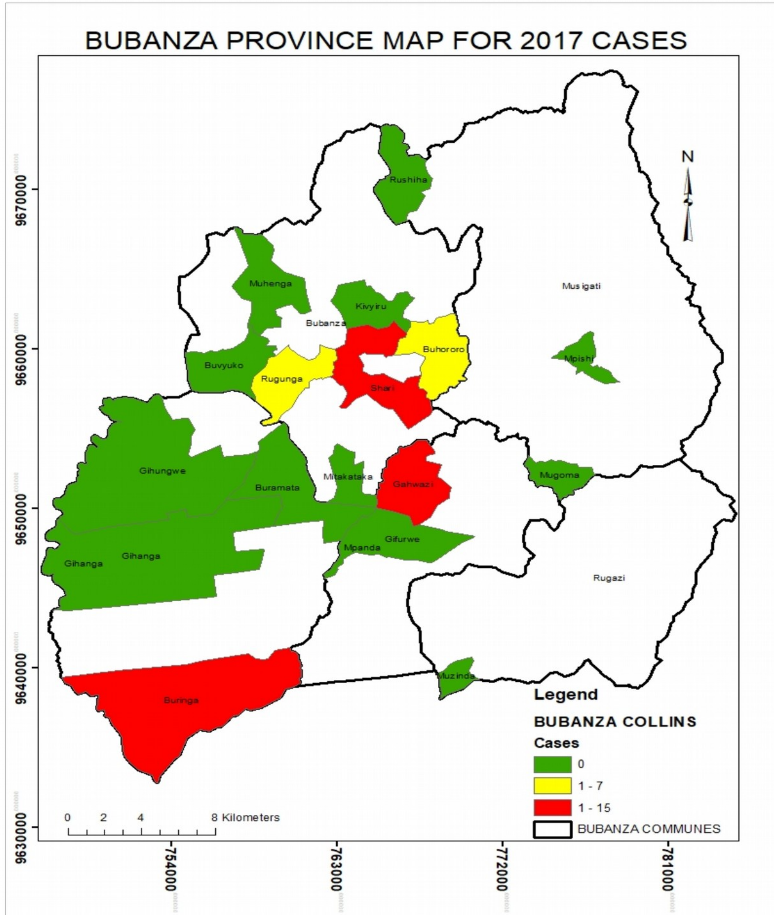
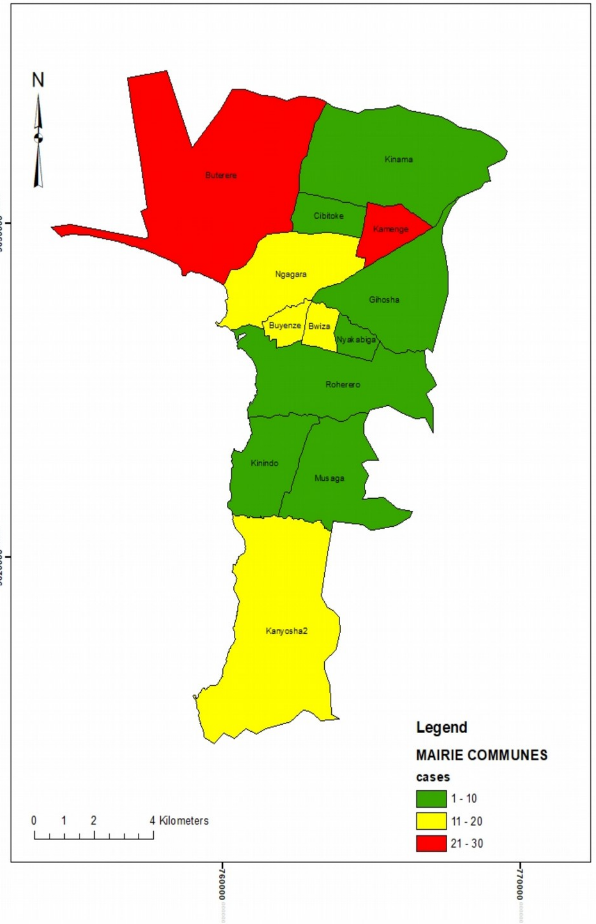


Figure 17: Bubanza Province 2017 cases

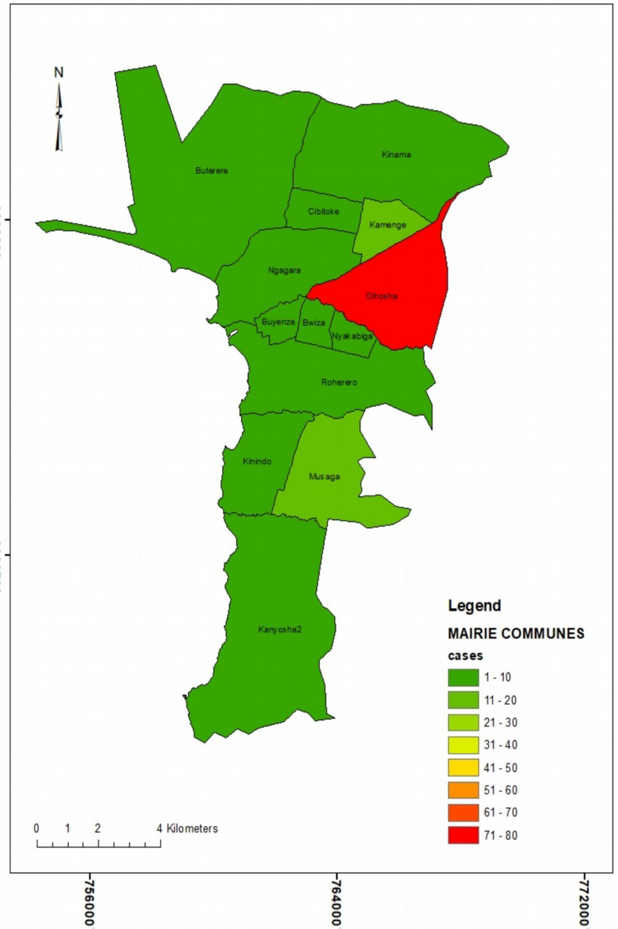
3.7.3 Bujumbura Mairie Province

In 2012, Buterere and Kamenge wards were the mostly affected areas (Figure 18). In 2013, Gihosha ward was the mostly affected area (Figure 19). In 2014 and 2015, Buterere, Kinama and Kinindo wards were the mostly affected areas (Figure 20 and Figure 21). In 2016 and 2017, Buterere ward was the mostly affected area (Figure 22 and Figure 23).

BUJUMBURA MAIRIE MAP FOR 2012 CASES



BUJUMBURA MAIRIE MAP FOR 2013 CASES



BUJUMBURA MAIRIE MAP FOR 2014 CASES

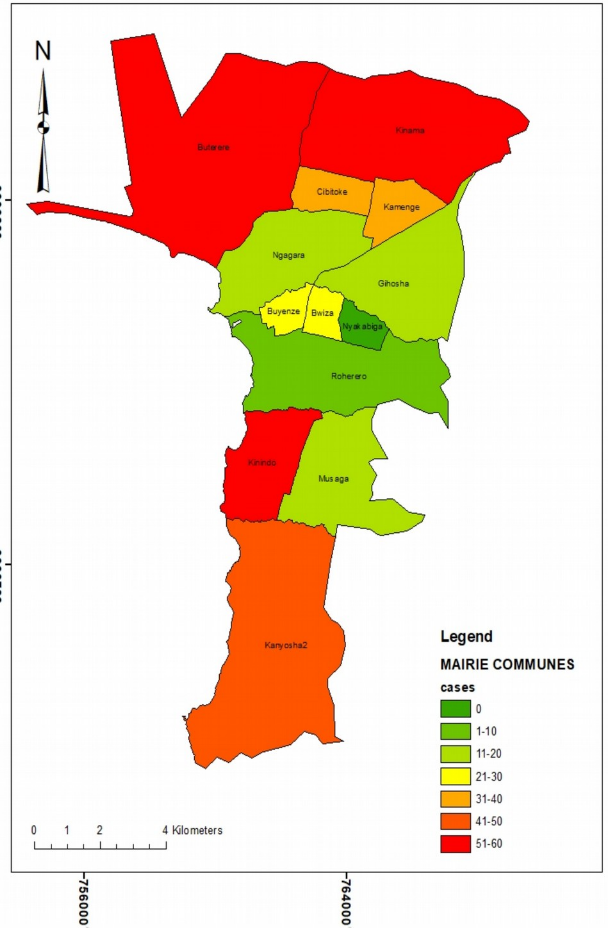


Figure 18: Bujumbura Mairie Province 2012 cases

Figure 19: Bujumbura Mairie Province 2013 cases

Figure 20: Bujumbura Mairie Province 2014 cases

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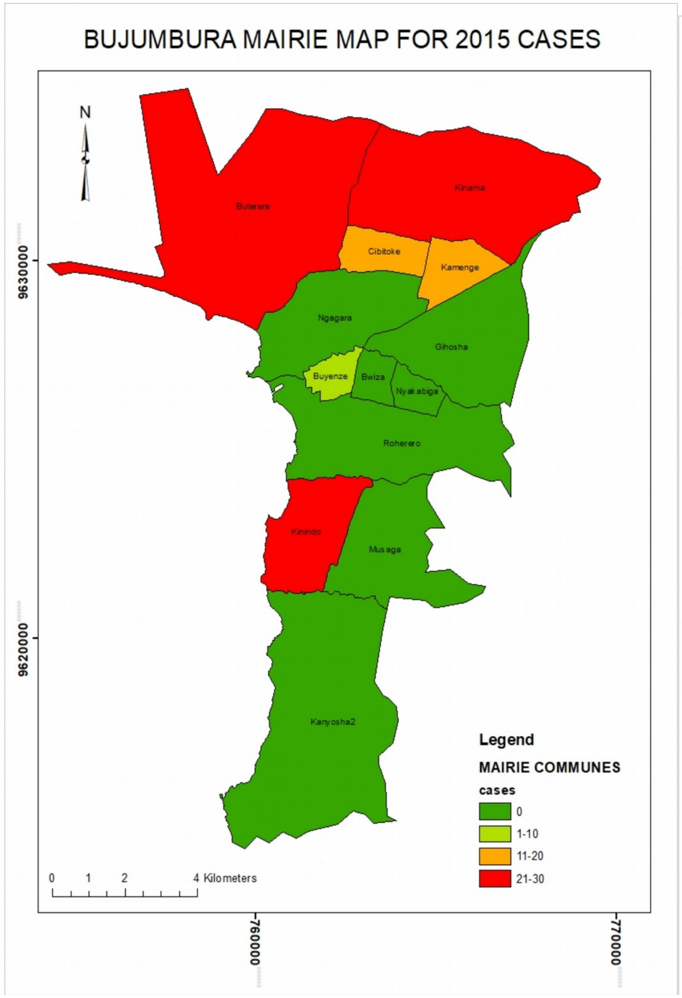


Figure 21: Bujumbura Mairie Province 2015 cases

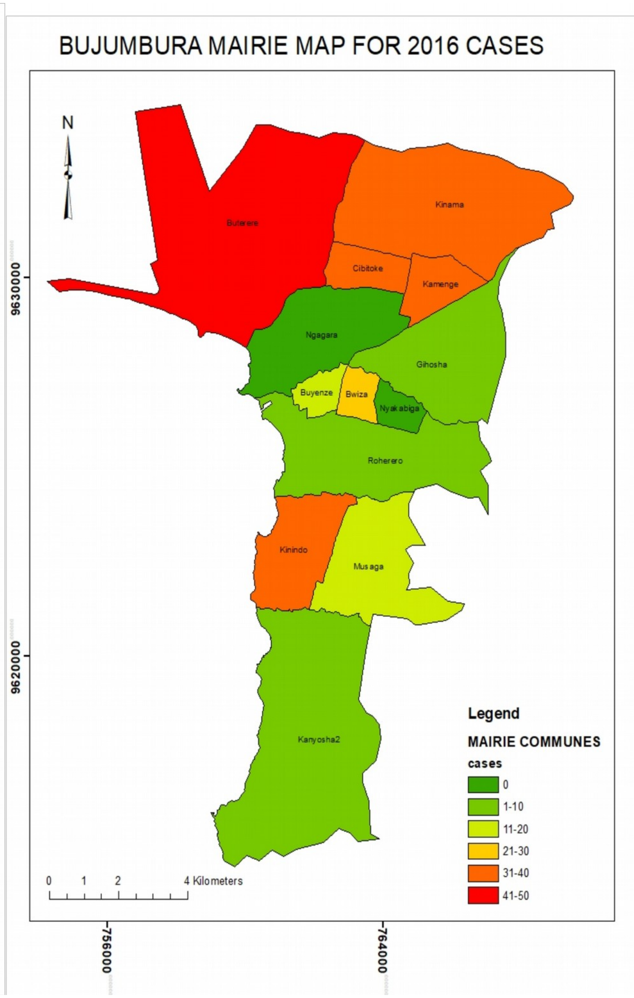


Figure 22: Bujumbura Mairie Province 2016 cases

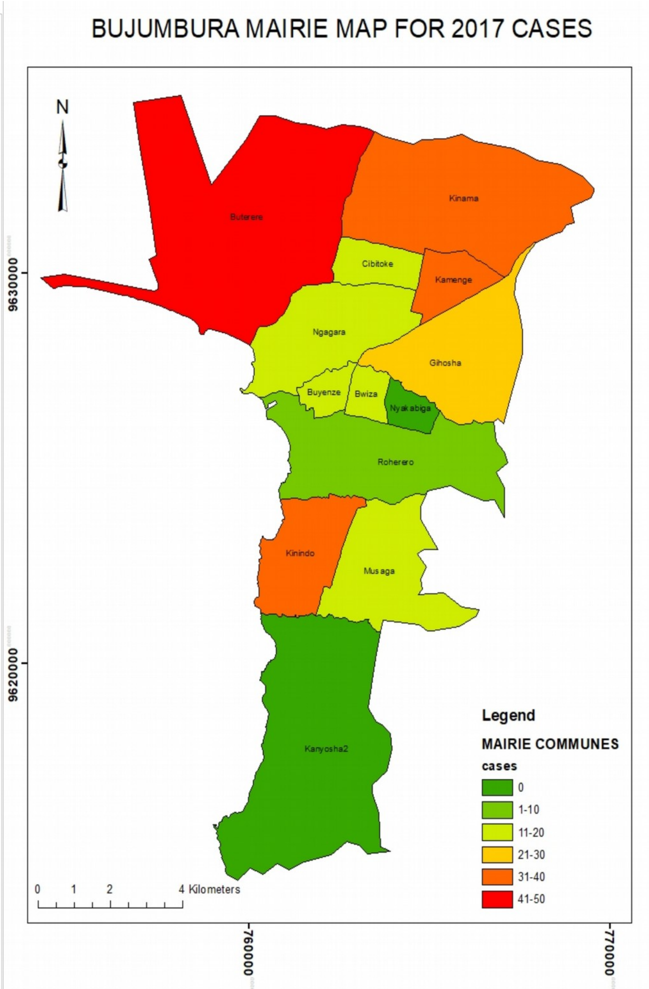


Figure 23: Bujumbura Mairie Province 2017 cases

3.7.4 Bujumbura Province

In Bujumbura Province, no cholera cases were reported in 2012. In 2013, Gomvyi ward was the mostly affected area (Figure 24). In 2014 and 2017, Gatumba ward was the mostly affected area (Figure 25 and Figure 28), while in 2015, Rukaramu and Kinyinya wards were the most affected areas (Figure 26). Nyamaboko ward was the mostly affected area in 2016 (Figure 27).

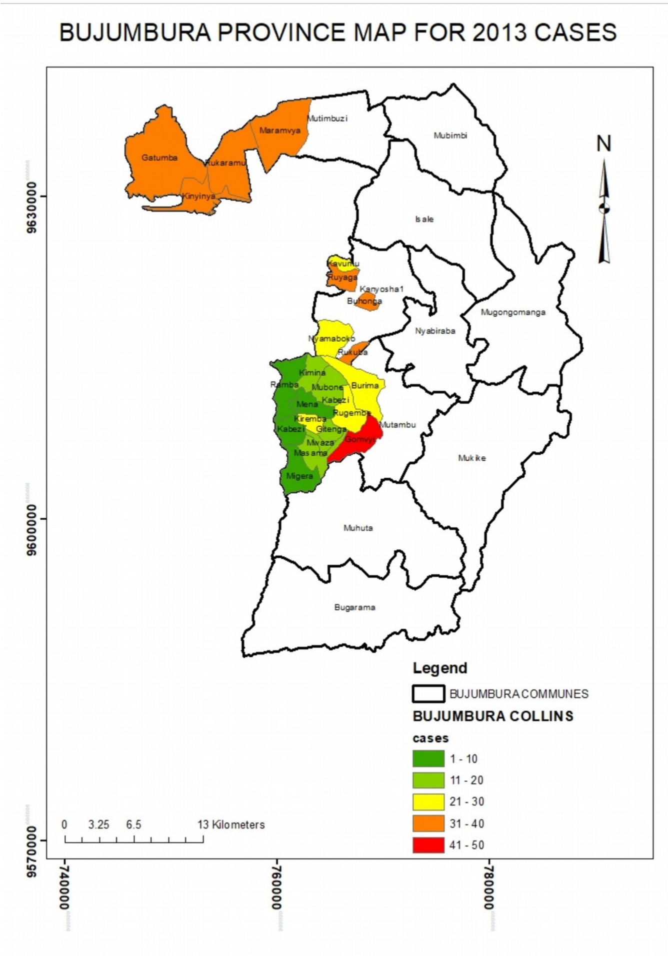


Figure 24: Bujumbura Province 2013 cases

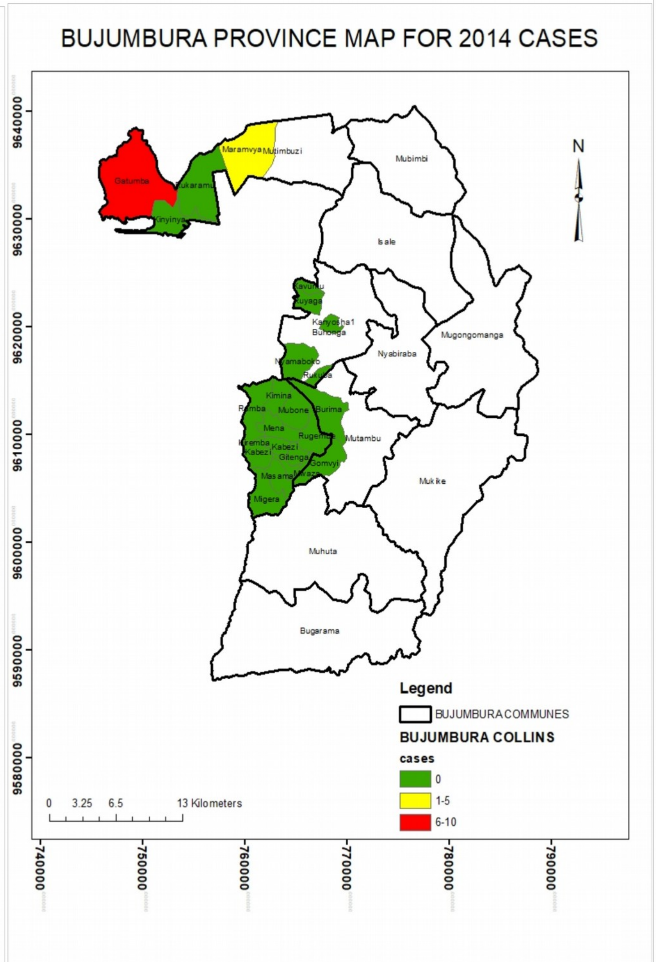


Figure 25: Bujumbura Province 2014 cases

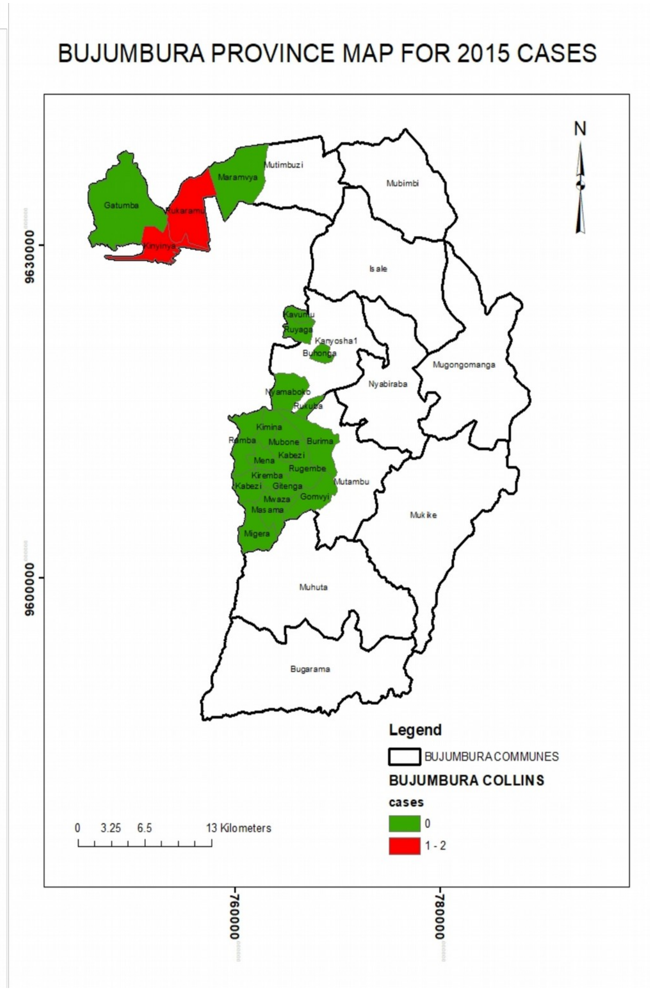


Figure 26: Bujumbura Province 2015 cases

Figure 27: Bujumbura Province 2016 cases

Figure 28: Bujumbura Province 2017 cases

3.7.5 Bururi Province

Bururi Province in Rumonge commune, the Urban center and Rukinga ward were the mostly affected areas in 2012 (Figure 29). The Urban center was also the most affected area in 2013, 2015 and 2016 (Figure 30, Figure 32 and Figure 33). In 2014, Kizuka ward was the mostly affected area (Figure 31). There were no cholera cases reported in Bururi Province in 2017.

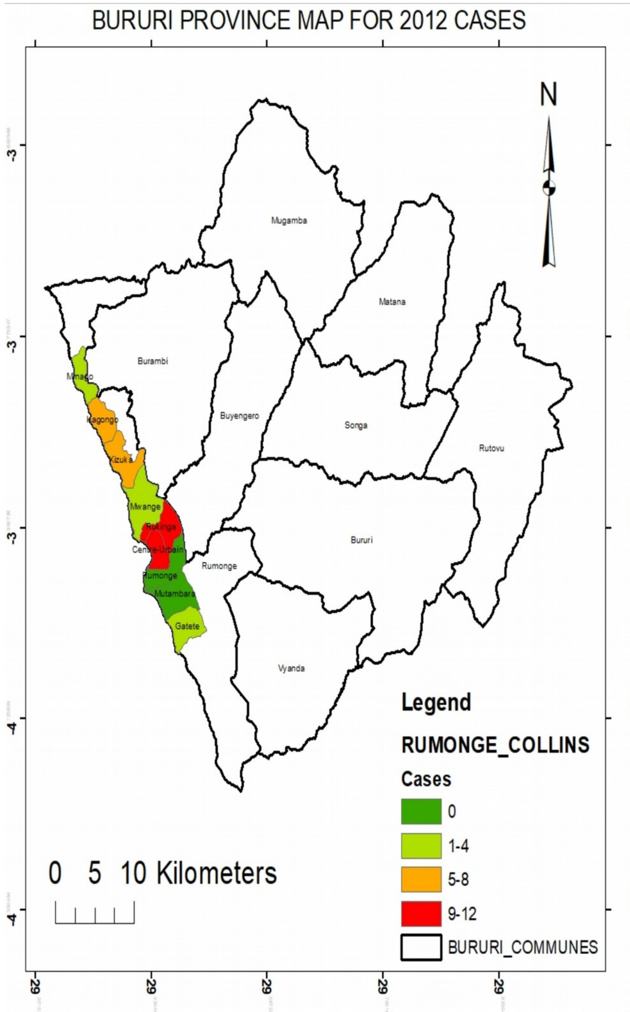


Figure 29: Bururi Province 2012 cases

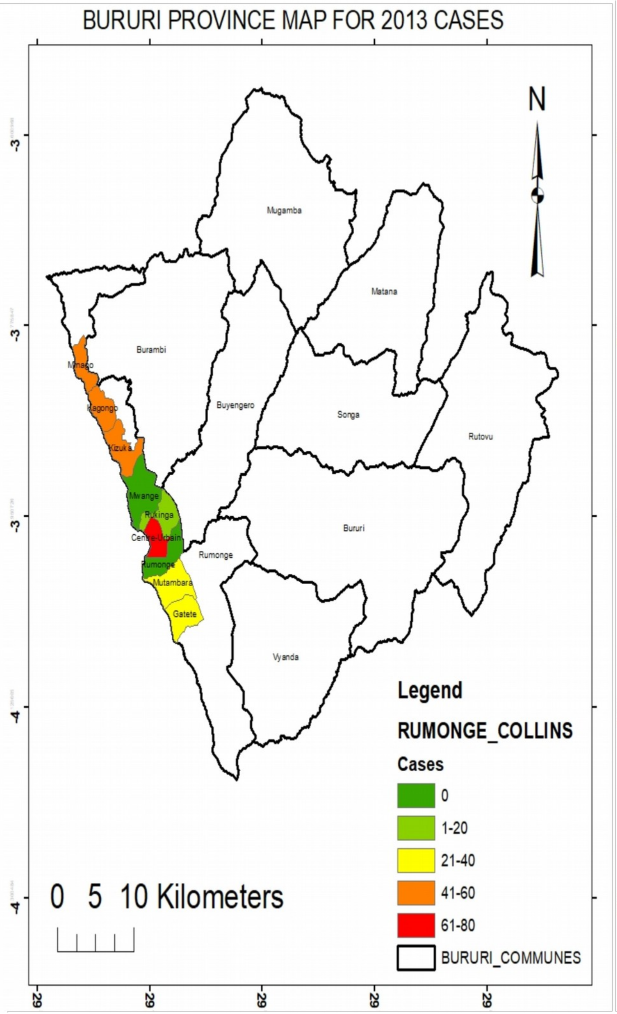


Figure 30: Bururi Province 2013 cases

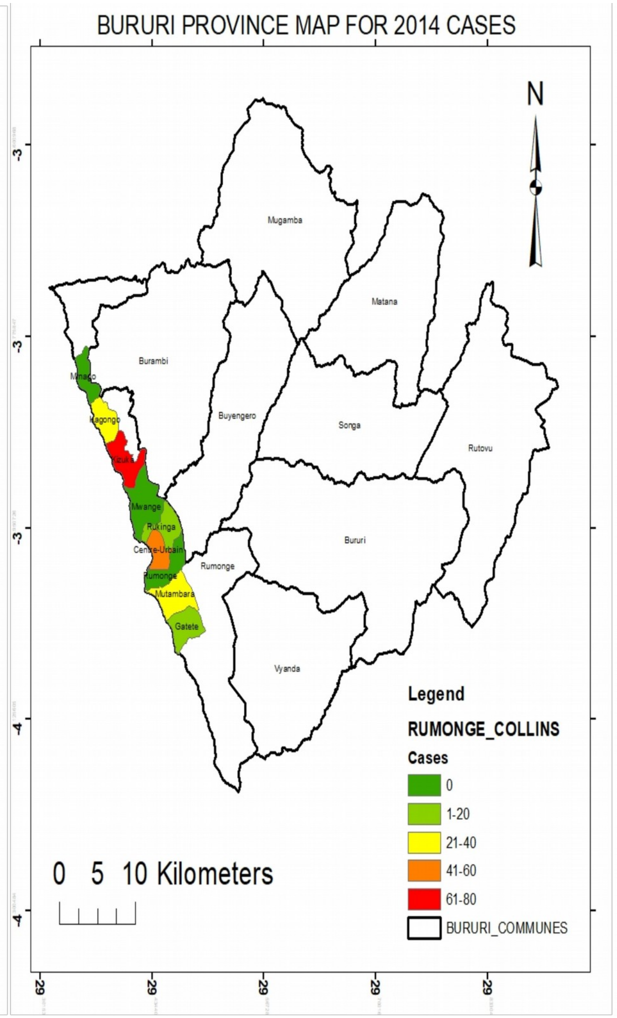


Figure 31: Bururi Province 2014 cases

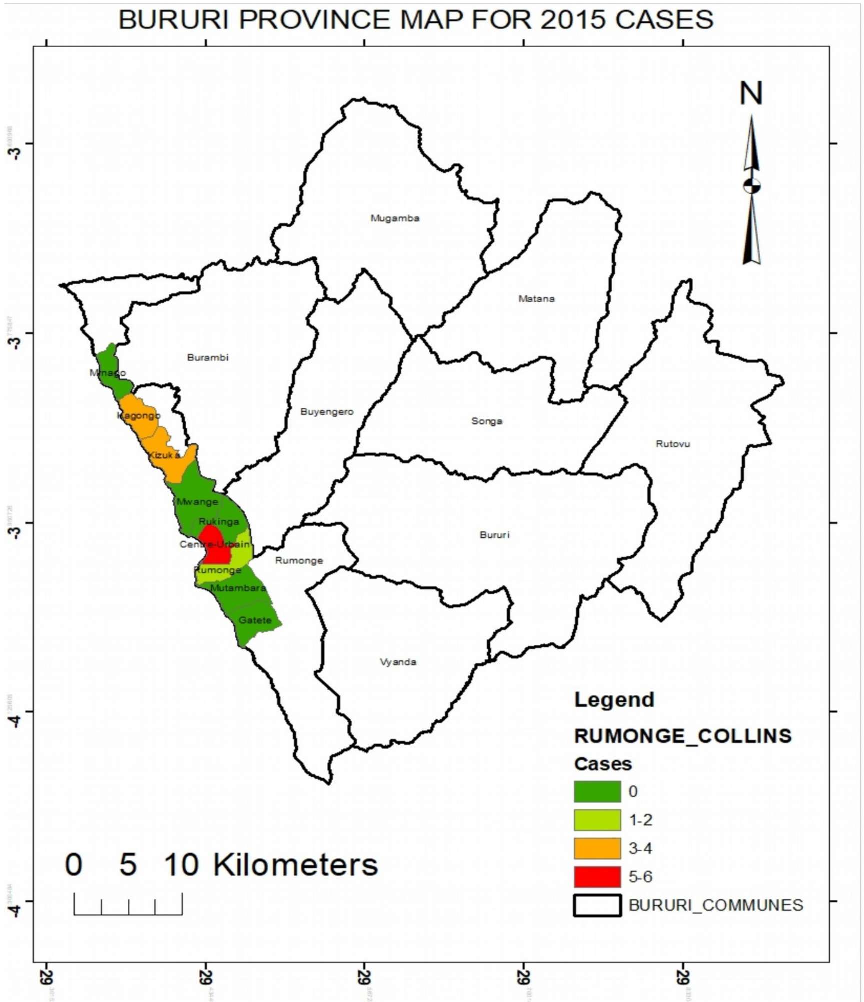


Figure 32: Bururi Province 2015 cases

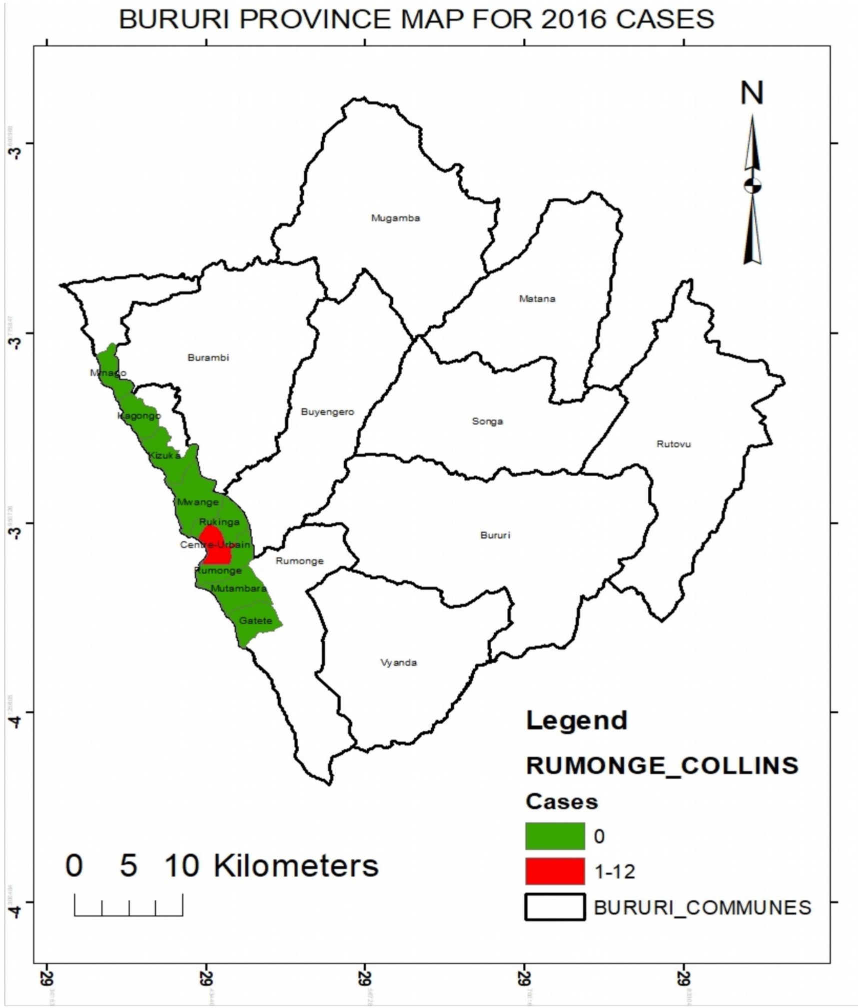
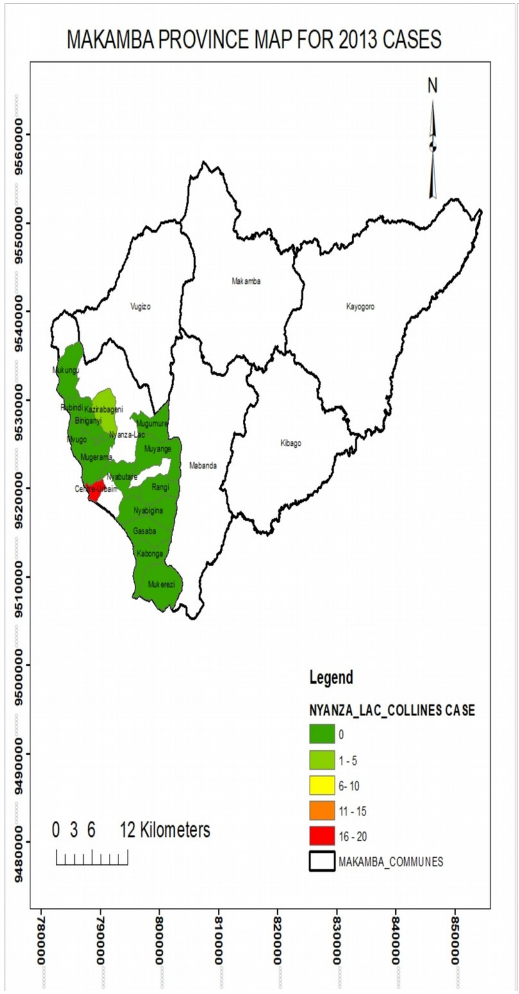
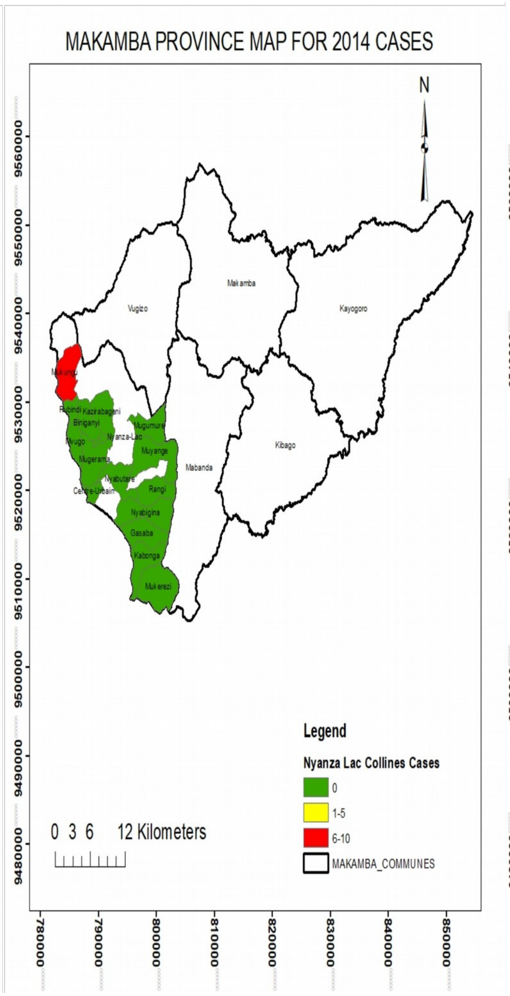


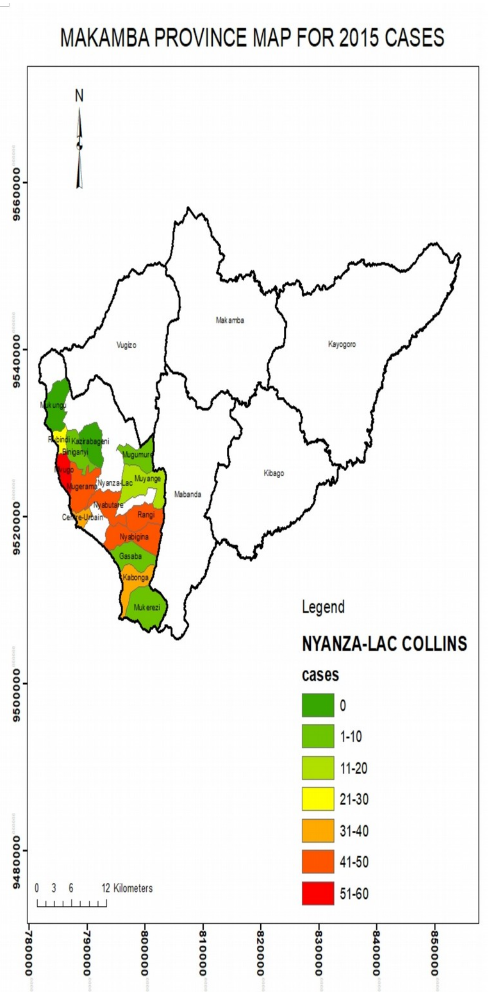
Figure 33: Bururi Province 2016 cases

3.7.6 Makamba Province

Makamba Province in Nyanza-Lac commune, no cholera cases in 2012 and 2016. The Urban center was the mostly affected area in 2013 and 2017 (Figure 34 and Figure 37). In 2014, Mukungu ward was the mostly affected area (Figure 35) while Mvugo ward in 2015 (Figure 36).


MAKAMBA PROVINCE MAP FOR 2013 CASES
N
Vugizo
Makamba
Kayogoro
Kibago
Mabanda
Legend
NYANZA_LAC_COLLINES CASE
0
1 - 5
6- 10
11 - 15
16 - 20
MAKAMBA_COMMUNES
0 3 6 12 Kilometers


MAKAMBA PROVINCE MAP FOR 2014 CASES
N
Vugizo
Makamba
Kayogoro
Kibago
Mabanda
Legend
Nyanza Lac Collines Cases
0
1-5
6-10
MAKAMBA_COMMUNES
0 3 6 12 Kilometers


MAKAMBA PROVINCE MAP FOR 2015 CASES
N
Vugizo
Makamba
Kayogoro
Kibago
Mabanda
Legend
NYANZA-LAC COLLINS
cases
0
1-10
11-20
21-30
31-40
41-50
51-60
0 3 6 12 Kilometers

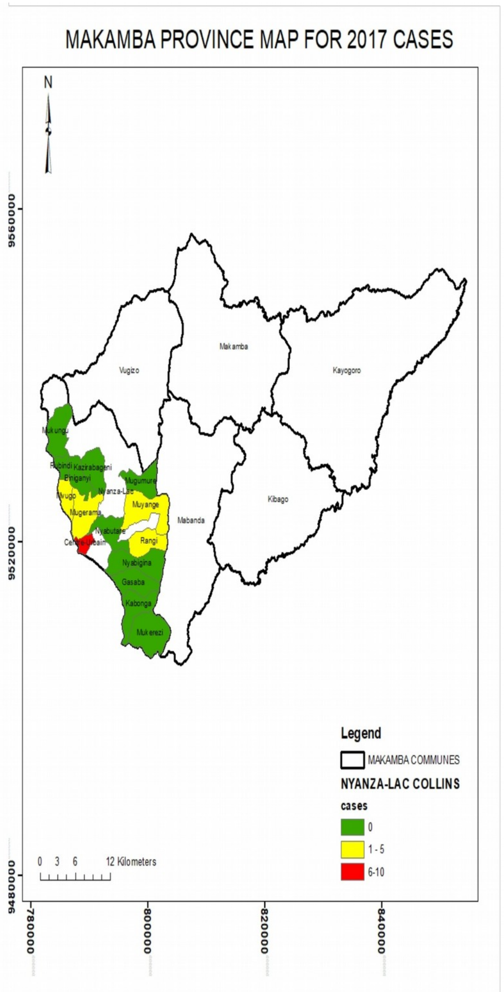

MAKAMBA PROVINCE MAP FOR 2017 CASES
N
Vugizo
Makamba
Kayogoro
Kibago
Mabanda
Legend
MAKAMBA COMMUNES
NYANZA-LAC COLLINS
cases
0
1 - 5
6-10
0 3 6 12 Kilometers

Figure 34: Makamba Province 2013 cases

Figure 35: Makamba Province 2014 cases

Figure 36: Makamba Province 2015 cases

Figure 37: Makamba Province 2017 cases

CHAPTER FOUR

4.0 DISCUSSION

This was a retrospective study aimed to determine spatial-temporal distribution of cholera outbreaks and to identify its risk factors in Imbo Region of western Burundi. Areas (wards) with high annual cholera cases were: Munyika, Mparambo, Shari, Gahwazi, Buringa, Gihosha, Buterere, Kinama, Kamenge, Kinindo, Rukaramu, Kinyinya, Nyamaboko, Gatumba, Kizuka, Urban center (Rumone and Nyanza-Lac), Rumonge, Mukungu and Mvugo. Citegetse *et al.* (2013) and Otto (2015) found that peripheral municipalities in Bujumbura Mairie province such as Gihosha, Kamenge, Buterere, Kinama, Kanyosha, Musaga and Cibitoke were the mostly affected areas by cholera outbreaks.

In peripheral urban areas, potable water becomes a serious problem during the dry season where public standpipes are no longer functional, which leads to the population seeking water from unsafe sources. In addition, Imbo Region has a high human concentration with a population density of 300/km^2 with some new unserved neighbourhoods without potable water (Citegetse *et al.* 2013). Ousmane (2008) in Mali found that the cholera outbreak was associated with poor hygiene and lack of potable water. Touré (2013) in Mali also reported that a cholera outbreak that occurred in the Mopti Urban community was likely to be linked with the unhealthy conditions associated with the overcrowding and poor individual hygiene. Similarly, in Burkina Faso, Kyelem *et al*. (2005) found that the affected area was located in the western peripheral part of the town which was characterized by unhealthiest, promiscuity, lack of latrine and no access to potable water. Cholera is known as a disease of poor sanitation and hygiene especially in overcrowded areas (Ali *et al.*, 2015).

This study found that most of outbreaks occurred during dry seasons. However, in Rumonge, Bubanza and Cibitoke most of the outbreaks have occurred during the rainy seasons. During previous studies by Otto (2015) and Citegetse *et al*. (2013) most of the cholera cases in Bujumbura Mairie were detected in April, July and August. April is the precocious beginning of dry season in Burundi, where lack of potable water is common. Additionally, there is a decrease of water level of Lake Tanganyika in dry season due to global warming phenomenon, which lead to lack of potable water (Citegetse *et al.*, 2013).

Cholera epidemics are most often observed in the warm season when temperature is high or during drought and heavy rainfall (Moradi *et al*, 2011; Fouda *et al.*, 2012). A study in the neighbouring Upemba and Tanganyika in the Democratic Republic of Congo reported repetitive seasonal patterns of cholera outbreaks between October and April (Muyembe *et al.*, 2013).

In multivariate logistic regression, females were at higher risk of getting cholera infection than males. These results are consistent with the findings in Mali (Traore, 2008). Most of women are engaged in domestic activities by taking care of the sick family members, cleaning latrines, fetching and handling untreated water and preparing contaminated raw food, which expose them to cholera infection (Nterventions *et a*l. 2017; Rancourt, 2013). Hence, occupation was maintained in the final model because it was a confounder for sex. Use of tap water was protective compared to use of surface water, which means individuals using surface water were at higher risks of contracting cholera than individual using tap water. Similar results have been reported in Uganda, Peru, Mexico and Ecuador (Malavade *et al.*, 2011; Davis *et a*l., 2018; Swerdlow *et al.*,1992).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

In Imbo Region, most of outbreaks have occurred in dry seasons when potable water is in shortage supply and the population is using surface water for their domestic and drinking needs. Improving population access to the potable and safe water distribution system will likely reduce the transmission and spread of cholera infection by enabling enhanced hygiene and limiting the contamination of water sources. Most of women are engaged in domestic activities, and they were exposed to cholera infection. Improving sanitation, hygiene and food safety practices; proper waste management and health education will also help to prevent the occurrence of the disease.

5.1 Limitations of the Study

The study was limited by the fact that laboratory results and cholera prevalence records for the successive years of cholera outbreaks were hardly available. This study did not include laboratory study of the 2019 and 2020 cholera outbreaks as well. This made it difficult to estimate whether there was significant difference in disease prevalence among different successive years so as to ascertain whether the difference in the change of prevalence is related to the change in intervention measures strength or it is the pathogen itself that had mutated to more or less virulent form. Therefore, laboratory molecular analysis of the cholera strains causing the outbreaks need to be further investigated.

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