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Assessment of a Vulnerable Rural Community to Typhoid Fever using Geospatial-Temporal Analysis: Case Study of Ejule, Kogi State of Nigeria

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Abstract
The rural community of Ejule in Kogi state has suffered for decades to access quality water. Therefore, the high prevalence cases of typhoid fever are largely due to unavailability of safe and clean water in the study area. This study adopts spatial-temporal techniques and Statistical Package for Social Science (SPSS) to analyze the data collected and investigates the spatial variation of typhoid fever in the study area. The results showed that the total reported cases of typhoid fever for a lag period of three years are 12,733, of which the year 2011 recorded 3986 (31.30%), 2012 record 4233 (33.24%) and 2013 also record 4514 (35.45%). This implies that a total of 77.17% of the entire population of the study area were affected in the preceding year of 2011, 2012 and 2013. The results also identify that the high cases of typhoid fever recorded in the dry/cool season is as a result of supply of untreated contaminated stream/river water and the decrease in rainfall amounts, while lower transmission is recorded in the wet/rainy season when partial clean rain water were highly available. The study further indicates that a total of 97,060,000 litres of contaminated river water was supplied to 13,481 people, which are 81.70% of the entire population in the study area. The results of the classification of Land-use (LU) and Land-cover (LC) from satellite imagery confirmed that the study area is without water body. However, the availability of contaminated and polluted river/stream water positively correlates to typhoid fever of which the determination coefficient are 81.03% with high level of confidence and strong strength in their relationship. In the final analysis the spatial spread of contaminated water increase the vulnerability of typhoid fever and health risk to the community, particularly people in the area. It is evident that the only source of water to the community is from river Umomi and Ochadamu, these water points are highly susceptible to contamination, thus the high concentration of water borne diseases (typhoid fever) in the area. The study recommends improved environmental sanitation and enhanced water management strategies.
Keywords: assessment, vulnerable, ejule rural community, typhoid fever, geospatial, temporal, contamination

1.0 Introduction

Adequate safe and quality water (Obiri-Danso, et al. 2009) is one of the major prerequisites for a healthy life, but in a situation where this water is contaminated or polluted, of course water-borne diseases particularly typhoid fever (Adekunle, et al. 2004) could be threatening so it becomes a major significant economic constraint. The access to safe drinking water in Ejule community is still a distant dream and nowhere near meeting the proposed 2015 millennium development goals (MDG). The study area is where a large population of the dwellers cannot access safe drinking water right from their homes which have led to the growing rate of water borne diseases like typhoid fever (Edwards, 1993). In Ejule today most of the streams and rivers that supply them with water are far away, filled with all manner of dirt, rubbish, scrabs and waste (Olajuyigbe, 2010). In the same river we see people defecating and bathing from the same source where they drink from. Secondly, typhoid fever is an acute illness associated with fever caused by the Salmonella typhi bacteria. It can also be caused by Salmonella paratyphi (Okeke,2007) a related bacterium that usually causes a less severe illness. The bacteria are deposited in water or food by a human carrier and are then spread to other people in the area. They are acquired due to lack of good potable water, poor hygiene and lack of sanitation or increasing insect populations that breed in water and then spread diseases. The World Health Organization (2012) says that every year more than 3.4 million people die as a result of water-related diseases, making it the leading cause of diseases and death around the world. The world health body stresses that water- borne diseases account for an estimated 4.1 per cent of the total global burden of disease, and cause about 1.8 million human deaths annually. The United Nations (2003) has set a goal of cutting in half by 2015 the number of people without access to safe drinking water and basic sanitation, yet, I don't see Nigeria, Ejule in particular meeting that set goal when we don't even have access to pipe borne water.

1.1 Background of the Study Area

Ejule rural community is situated in Ofu Local Government Area of Kogi state, Nigeria. The study area has an estimated population of 16,500 people consisting of 8,322 males and 8,178 females (NPC, 2006). It is located in the middle belt region of the country and covers a land mass area of 12sq.km. The study area lies on latitudes 6^{0} 57’ 00” N and longitude 6^{0} 49’ 60” E of the equator (Figure 1). Ejule rural community is bordered to the north by Okale, to the south east by Ofakaga, to the south by Alloma and to the west by Alla. Hence, Ejule community is considered as secondary urbanized but suffers a serious setback in the area of water, health and infrastructure. The study area lies within the humid semi-hot savannah zone. The climate is dominated by two major air masses; the warm and the dry tropical continental wind from the Sahara Desert and the hot, humid tropical maritime wind from the Atlantic zone (the south West Monsoon wind). The wet/rainy season starts from middle of April to October while the dry/cool season runs from November to March. The study area has mean annual rainfall of about 1100mm while the mean temperature ranges between 28 ^{0}C to 34 ^{0}C. Relative humidity is about 74% to 80% for dry and wet seasons respectively. The vegetation of the area falls under tropical Guinean belt.

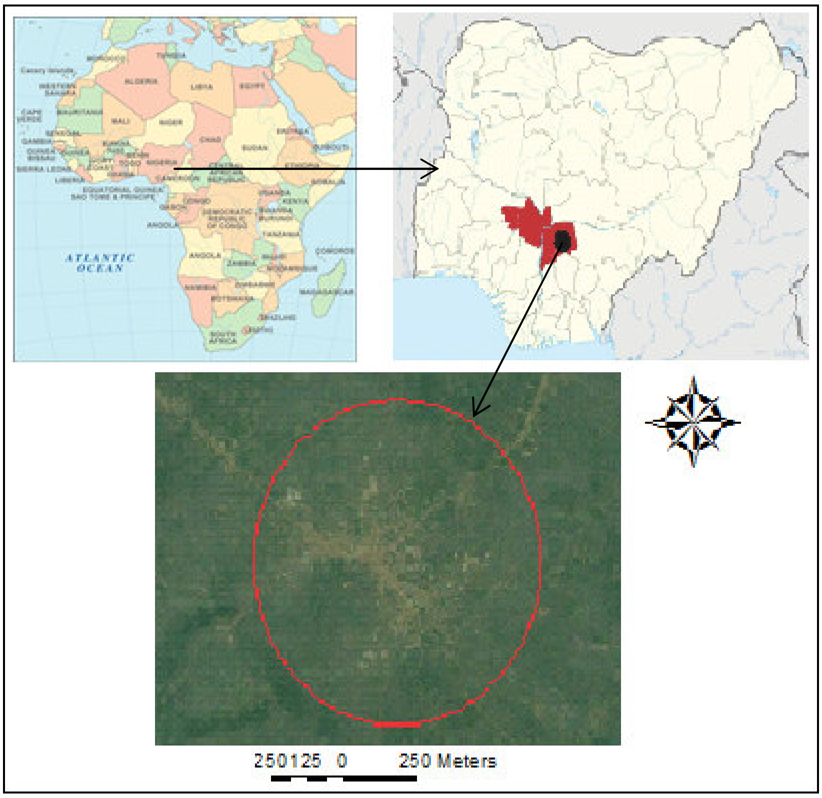

Figure 1. The Study Area

1.2 Statement of Research Problem

Attempting to assess how contaminated river water supplied to the rural community can be vulnerable to occurrences of typhoid fever in the study area could produce appreciable results depending on the classification models used. In sufficient geographical knowledge and lack of data of the study areas is capable of misleading data users. As a result of this, it is necessary to integrate geospatial techniques in aiding surveillance which is one of the major thrust strengthening the health care system.

1.3 The Aim and Objectives

The aim of the study is to assess the vulnerability of contaminated river water supplied and typhoid fever prevalence among the study population in the rural community of Ejule, Kogi state, Nigeria.

Objectives:

a. To identify the presence of typhoid fever in the study area
b. To map the spatial and temporal distribution of typhoid fever
c. To map the availability of water bodies using remote sensing tools
d. To examine the relationship that exist between contaminated river water which is the only source of water to Ejule community and typhoid fever distribution level

e. To test the level of accuracy

2.0 Related Typhoid studies

In the word of Cunha (2004), typhoid fever has received various names, such as gastric fever, enteric fever, abdominal typhus, infantile remittant fever, slow fever, nervous fever and pythogenic fever. Cunha explains that, despite similarity of their names, typhoid fever is distinct diseases and is caused by different species of bacteria. In 2000, typhoid fever caused an estimated 21.7 million illnesses and 217,000 deaths (Crump & Mintz (2010). According to Lozano, et al. (2012), explained that waterborne illnesses (typhoid fever) are caused by various bacteria, parasites, viruses and protozoa which grow as a result of inadequately treated drinking water of which in 2010 caused about 190,000 deaths up from 137,000 in 1990, south-central and Southeastern Asia experience the greatest burden of illness (Crump, et al. 2004). Studies have shown that the outbreaks of typhoid fever are frequently reported from sub-Saharan Africa and Southeastern Asia (Muyembe-Tamfum, et al. (2009). Oguntoke (2009) is of the opinion that water-borne diseases can spread when people drink contaminated water or eat food that has been prepared with contaminated water. Speaking on the subject, Ifabiyi (2011) said evidences have shown that waterborne diseases that had been eradicated in many parts of the world are still persisting in Nigeria. This is further established by the UNDP 2006 Human Development Index as reported by (Nzedkah, 2006) that ranked Nigeria 159th among 177 countries assessed for availability of safe water. The same report also indicted the country as strongly among the 30 nations with the poorest quality of standard of life. Although the common waterborne diseases of the 19th century are now almost unknown in developed countries, it is vital that vigilance is maintained at a high level because these diseases are still common in many parts of the world. According to the WHO World Health Report (2007), over 1 billion people do not have an adequate and safe water supply of which 800 million are in rural areas. There are still an estimated 12.5 million cases of ***Salmonella typhi*** per year (Heymann, 2008; Levine et al. 1982; Gonzalez et al. 2010) and waterborne disease is endemic in many developing countries (Hunter, 1997).

2.1 Water studies

Water contamination is the term used to describe hazardous materials of any kind that are polluting a source of water (Hogan, 2010). *World Health Organization* (2003) enumerates basic polluter, that include both biological and chemical substances, and the water source may be ponds, lakes, seas, oceans, or reservoirs used for drinking and bathing by humans (Fawell *& Standfield,* 2001). The most common types of water contamination are chemical (Avery*,1999)* runoff from homes and businesses and sometimes human or animal waste materials. A report by West (2006) states that water is typically referred to as polluted or contaminated when it is impaired by anthropogenic contaminants and does not support human use, such as drinking and bathing (Richard, 2007). Water pollution is a major global problem which requires revision of water resource policy at all levels. According to Pink, (2006), contaminated water accounts for the leading cause of deaths and spread of diseases, West (2006) estimated that about 580 people in India die of water pollution related illness every day. The run-off or leaching of nutrients into slow flowing or still surface waters can result in excessive growth of cyanobacteria or blue-green algae (WHO, 2003).

3.0 Materials and Methods

The data collected for the study includes, 2007 Landsat-7 ETM+ image of the study area, the water data from Federal Ministry of Water resources and QIB-MDGs consultant of 2008-2013, the traditional history of the study area from Apeideyaima descendent and health data received from the hospitals and clinics of the study area. Other attribute data were acquired from Ofu Local Government Area that includes health, water and diseases data.

3.2 Questionneire Administration

The questionnaire is divided into three broad sections, which are typhoid fever characteristics, water variation characteristics and environmental characteristics. The questions on typhoid fever characteristics were aimed at identifying the types and conditions of typhoid diseases in each ward. The second section of the questionnaire sought information on the variation in water factor; it features questions like variations in river, stream, temperature, precipitation, topography, landuse type, demography and water systems. The third section of the questionnaire deals with the physical elements, aimed at probing the level with the use of remote sensing tools.

3.3 Image Classification Procedure

Bands 4, 5 or 7 from ETM+ are used in combination with 1, 2 or 3 to identify classes of vegetation conditions and presence of water bodies in the radiometric band. Having created the signature file, each pixel in the study area now have a land use and land cover value in each of the eight (8) bands of the 2007 Landsat-7 ETM+ Imagery, hence the data is ready for supervised classification. Two (2) image classification algorithms namely; Maximum Likelihood (MLC) and Minimum Distance (MDC) along with Principal component analysis (PCA) were carried out on the 2007 Landsat-7 ETM+ imagery of the rural community of Ejule, Kogi state, Nigeria using the Image Classification/Hard Classifier module of Arcmap-10.

4.0 Results

4.1 Spatial Distribution of Typhoid fever

Figure 2 shows the occurrences and distributions of typhoid fever in each ward of the rural community of Ejule of which the total reported cases of 12,733 from 2011-2013, therefore, estimated cases of typhoid for the period of three years are as follow; Alome Aboko 8.7%, Iyalobo 9.4%, Oko-Ayigele 9.9%, Obeya 10.3%, Ona-Agojeju 10.6%, Egwubi 11.3%, Odoeto 12.6%, Ofe-Agugu-Ibete 13.3% and Ate-Ajiyolo 13.6%, indicating the distribution intensity of each ward graduating in colour according to typhoid distribution cases. The Figure 2 also indicate that the most affected wards are Ate-Ajiyolo and Ofe-Agugu-Ibete with occurrences ranging between 13.3% and 13.6%, similarly, other wards recorded value ranging from 8.7% and 12.6%. The results buttress those of Baddam, et al. (2012) that notes the outbreaks of typhoid fever are frequently reported from sub-Saharan Africa and countries in Southeastern Asia.

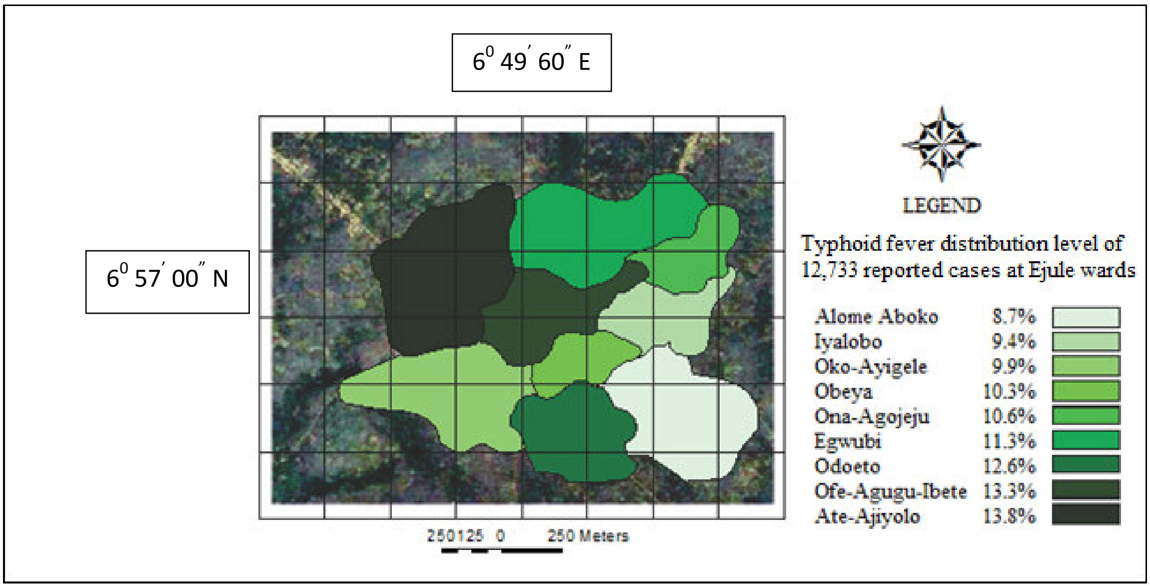

Figure 2. Typhoid fever occurrence and distribution at the Ejule wards level, 2011-2013

4.2 Temporal Distribution of Typhoid fever

Figure 3 shows that typhoid fever was reported from January to December of 2011, 2012 and 2013 respectively. The figure 3 also indicates that the month of January and February during the 2011periods, January and December during the 2012 periods and, January during 2013 periods having the highest occurrences. Likewise the lowest typhoid fever occurrence was reported in the month of September during 2011 periods, August during 2012 and 2013 periods (WHO, 2007).

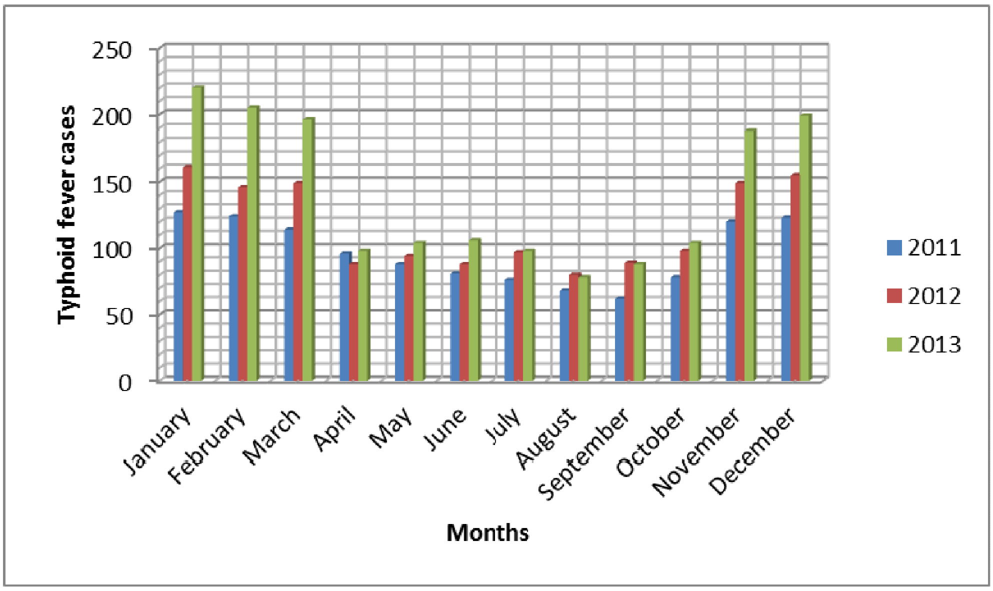

Figure 3. Mean average monthly Typhoid fever distribution cases, Ejule rural community level, 2011-2013

4.3 Analysis of contaminated water supplied to the community

The Table 1 shows the total mean of population that benefitted from the supply of water used for all purposes in the community. Assuming in 2011, the total quantities of water supplied to the community is 32,240,000 litres, of which 7200 litres is given to individual in a year (600 litres in a month), meaning 4,478 individual benefitted of the contaminated water. Likewise, in 2012 and 2013, total quantities of water supplied was 32,400,000 litres and 32,420,000 litres respectively, meaning 4,500 and 4503 individual respectively benefitted from the same water. The cumumlative mean of those suspected to be affected based on water supplied is 13,481 individual (2011, 2012 & 2013), that's 81.70% of the total population.

Table 1. Cumulative quantities of contaminated water and the medium of transportation, 2011-2013.

Name of Trucks transporting contaminated water to the communities	Quantities of contaminated river and stream water (litre)		
	Water supplied in 2011 (measured in litres)	Water supplied in 2012 (measured in litres)	Water supplied in 2013 (measured in litres)
Truck A	2494000	2490000	3122000
Truck B	2454000	2458000	2720000
Truck C	2594000	2480000	2840000
Truck D	2510000	2484000	2560000
Truck E	2430000	2400000	3000000
Truck F	2464000	2480000	2720000
Truck G	2374000	2436000	3072000
Truck H	2458000	2602000	3040000
Truck I	2514000	2510000	3170000
Truck J	2518000	2504000	3124000
Truck K	2450000	2500000	2920000
Truck L	2536000	2542000	2840000
Truck M	2534000	2514000	2480000
Total	**32,240,000**	**32,400,000**	**32,420,000**

4.4 Image classification

Figure 4 shows the spatial distribution of land-use (LU) and land-cover (LC) using maximum likelihood classification (MLC). The LU/LC is relatively free from serious confusion and shows that there is absence of water body within or close to the community. Therefore, it is more tolerable when compared with other classes in the same band (blue, green and red). The Figure 4 further indicate that a substantial part of the community is highly occupied with different categories of vegetation (71.02%), other forms of LULC are built-up areas (16.12%), farmland (7.45%), clear land (3.67%), bare soil (1.74%) and water body (0%).

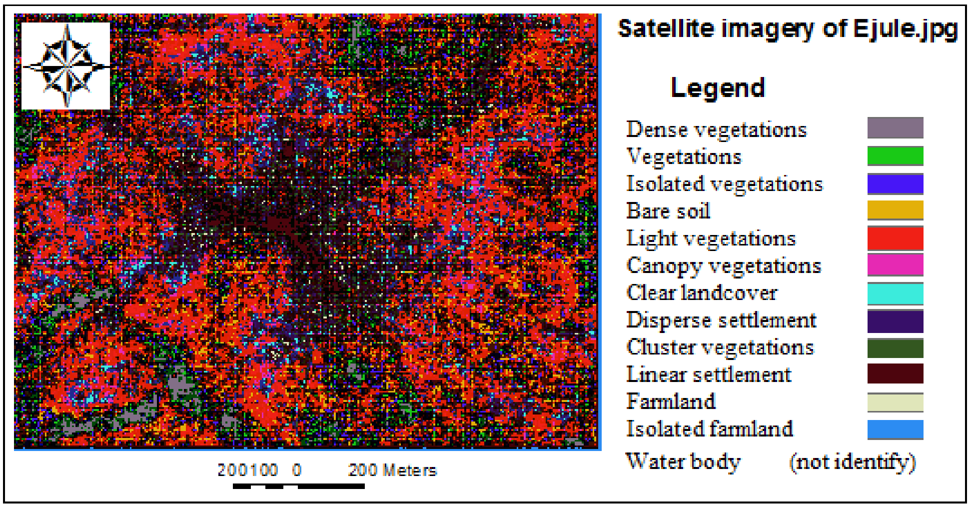

Figure 4. Land-use and Land-cover classified imagery of Ejule community in 2007, using MLC

Figure 5 shows that minimium distance classification (MDC) is used to identify the spatial distribution of land-use (LU) and land-cover (LC). The Figure 5 attempts to explain that LULC is free from serious confusion and shows evidence of non-existence of water body around the perimeter of the community. The study (Figure 5) further indicate that a high land mass of the study area is dominated with various classes of vegetation (69.88%), other forms of LULC are built-up areas (14.12%), farmland (4.05%), clear land (7.07%), bare soil (4.88%) and water body (0%).

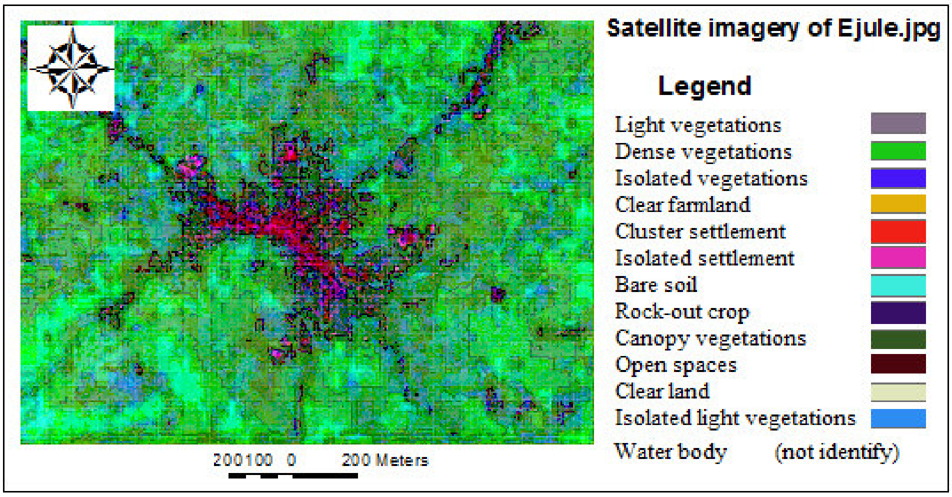

Figure 5. Land-use and Land-cover classified imagery of Ejule community in 2007, using MDC

Figure 6 relatively shows the distribution of land-use (LU) and land-cover (LC) using Principal component analysis (PCA). The classified LU/LC is also free from serious confusion and shows maximium absence of water body in the study area (Ejule rural community). The Figure 6 further expatiate on the mean percentage of LULC distribution of which vegetation occupied larger part of the study area as 53.91%, other types of LULC are built-up areas (11.72%), clear farmland (33.34%), bare soil (1.04%) and water body (0%).

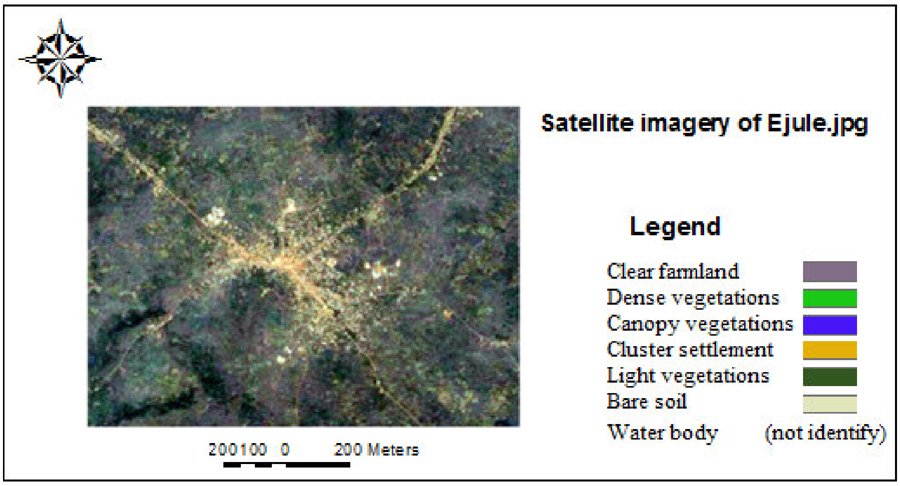

Figure 6. Land-use and Land-cover classified imagery of Ejule community in 2007, using PCA

4.5 Spatial correlation

Figure 7. Shows that a positive relationship actually exists between contaminated or polluted water and typhoid fever of which the coefficients of determination R^2 are 0.8103 (81.03%). The Figure 7 indicate the test of goodness of fit on the regression line conducted shows a high strength in the relationship and that test of level of significance of parameters estimate level shows that both values exceed the critical values. Therefore, the study concludes that both values are statistically significant.

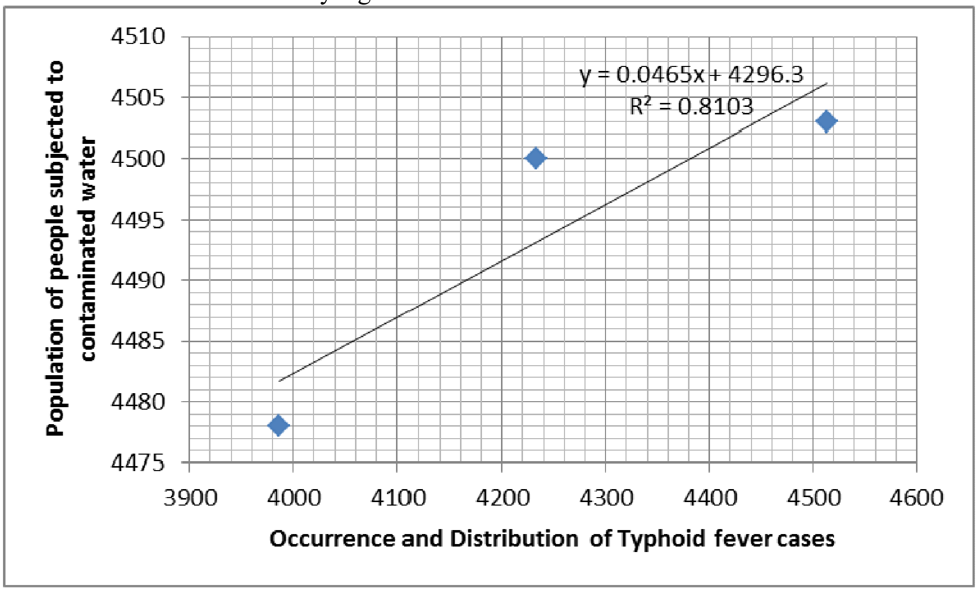

Figure 7. The contaminated water with respect to Typhoid fever, 2011-2013.

Figure 8. Shows that relationship exist in typhoid fever and the corresponding years of 2011, 2012 and 2013 respectively. The Figure 8 also shows that the coefficients of determination R^2 is 0.9987 (99.87%), these results further indicate that the year 2011, 2012 and 2013 correlate with typhoid fever cases with a steady yearly increase of 2.81% in 2011/2012 and 9.6% in 2012/2013. However, the test of level of significance of parameters estimate shows that both values exceed the critical values and statistically significant.

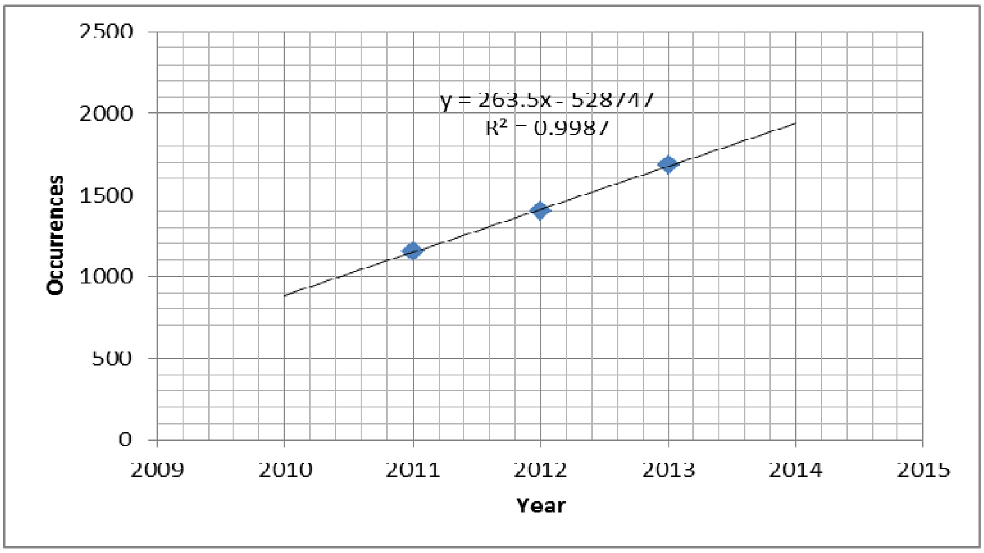

Figure 8. Typhoid fever cases with respect to 2011, 2012 and 2013

4.6 Discussion and Analysis of Results

There is evidence from the study conducted that the study area is highly vulnerable to typhoid fever disease principally due to contamination of the only source of water to the community (river Umomi and Ochadamu). The study area has two seasons, a warm, wet season from April to October, and a cool, dry season from November to March. During the cool, dry season, the supply of contaminated river water is more active and the number of typhoid cases is high. This number decreases considerably during the warm, wet season as a result of rainfall water. These result shows that the month of April, May, June, July, August, September and October during 2011, 2012 and 2013 periods respectively as having lowest typhoid cases, and the highest occurrence was reported during the month of January, February and March in the first quarter, November and December in the second quarter periods. Furthermore, an estimated buffer-zone of 10 km was created with the possibilities of locating water bodies using 2007 LandSat-7 ETM+ within the study area, of course it proves negative. The only water body identified is of 19.34km and 24.20km from the community i.e. River Umomi and Ochadamu respectively. The result of correlation analysis conducted explains that contaminated river/stream water has relationship with water-borne diseases, particularly typhoid fever as 81.03% of coefficients of determination and has an appreciable level of confidence on their relationship. In the final analysis, the reported cumulative typhoid fever cases in 2011-2013 are 12,733 and the population of the people that uses the contaminated water is 13,481. Overall 77.17% of the entire human populations suffered from typhoid fever in 2011-2013, while 81.7% of the population used the contaminated river water (Table 2). Further classification of the level accuracy shows a total of 97,060, 000 litres of contaminated river water was supplied to the community in 2011-2013 periods making it yearly mean average of 32,353,333 litres.

Table 2**.** The Summary of the classifications accuracy

Year	Reported Typhoid fever cases	Quantities of contaminated water supplied (litres)	Total population of people that uses the contaminated water
2011	3986	32,240,000	4478
2012	4233	32,400,000	4500
2013	4514	32,420,000	4503
Total	12,733	97,060,000	13,481

5.0 Conclusion

The study agree that although contaminated water causes all these diseases, improved sanitation and individuals maintaining proper personal hygiene are the best ways to control the widespread of any disease caused by contaminated water. The people of the study area should learn to keep the environment of the river and stream clean. They must monitor the source of this river to stop people throwing things, dumping refuse indiscriminately and clogging the river beds. The community should strive for prevention of water-borne diseases (typhoid fever) by making sure that the water meant for consumption is adequately sanitised and treated to keep it free from germs. Water should be boiled and stored in clean drums and cans. Drink water that has been thoroughly filtered or purified and do not add clean water to unwashed containers as there's a great risk of water contamination. Government and relevant agencies should strive to provide other source of quality water for the community through the production of earth-dam.

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