International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
www.allsubjectjournal.com
Volume 3; Issue 6; June 2016; Page No. 286-291

Monitoring of malaria prevalence using GIS technology (A case study of Kitwe district clinics, Zambia)

Zita Lifelo, Nchimunya Chaamwe, Maybin Lengwe

Computer Science Department, Copperbelt University, P.O. Box 21692, Kitwe, Zambia

Abstract

This study aims to determine how GIS technology can be used to obtain accurate and timely information about malaria in Kitwe district of Zambia. To better understand community needs and burden of malaria illness managed by health workers, a geospatial analysis at the sub-district level was performed on malaria patient health registries. The study was conducted to identify high incidences of malaria illness, in 32 clinics within the district. All cases of both confirmed and clinical malaria over a time-period of twelve months, for each clinic were geocoded for geospatial analyses. Of the 32 clinics, 22 clinics were geocoded and mapped. Results were used to create thematic maps illustrating disease distribution and incidence for malaria in the clinics.

Keywords: GIS, ICTs, Malaria, e-Health, GPS

1. Introduction

The health sector in Zambia has for a long time been struggling with data collection. Data is usually collected using paper based methods which is later entered using a tool known as health management information system and is referred to as district health information software at district level. Due to this there are statistical inconsistencies and inaccuracies in regard to data collection. Additionally, delays in reporting malaria patterns and failure to accurately visualize its prevalence according to locations using maps suggest under-utilization of GIS technology. GIS technology has increasingly been utilized in public health research, planning, monitoring, and surveillance within many developing countries and low-resource settings. This has resulted in opportunities for better understanding of spatial variation of diseases and the correlations with environmental factors. Providing accurate malaria risk maps can effectively guide the allocation of malaria resources and interventions in the country.

Advances in information and communication technologies (ICT) have provided opportunities for improving community health services delivery both in Zambia and across developing regions. The introduction of ICT devices such as computers and mobile phones, and training of health workers to use such technologies, has strengthened the health worker's capacity. It has also opened up opportunities for improving the quality of health service delivery at a community level. The use of mobile devices has been most beneficial for health workers working within communities located far from the district health office. ICTs are an example of how technology can be used to improve service delivery in rural and remote parts of Zambia.

Information collected by each clinic is aggregated and reported on a monthly basis to district health centers. In this reporting scheme, health information is aggregated via a bottom up hierarchy converging at the national level to provide evidence-based support for new health policies and eventual policy dissemination of national health strategic plans back down to the districts. The challenge with this hierarchal reporting system is that information often travels slowly between various levels of government, and is often non-responsive to the individual community level needs. Additionally, community level information provided by clinics is attenuated as a result of aggregation of sub-district level data to district and provincial centers (Freifeld *et al*. 2010) [1]. Furthermore, the current reporting system is labored and time intensive during outbreak investigations (Kamanga *et al*. 2010) [2]. It is often difficult to evaluate the overall clinics' contribution towards disease identification, treatment of illnesses, and in reducing disease burdens.

1.1 Malaria Disease Burden in Zambia

Zambia is a malaria endemic country. Malaria is fever related illness that is both preventable and treatable, and wherever environmental controls fail, the need for rapid response and effective treatment is imperative. Malaria annually affects more than 4 million Zambians and accounts for 30% of outpatient visits. It is the primary cause of nearly 8,000 deaths annually (UNICEF Zambia 2014) [3]. The most vulnerable populations susceptible to malaria are those located in remote or rural areas, pregnant women, persons who are immuno-compromised, and children under the age of 5. These groups are at an increased risk of death attributable to malaria, with 20% of deaths occurring among pregnant women and 35–50% percent of deaths occurring in children under 5 (UNICEF Zambia 2014) [3]. Zambia's National Malaria Strategic Health Plan for 2011–2015 cites the scale up of malaria interventions, including prevention and treatment services, as a main focus area.

The introduction of rapid diagnostic test (RDT) in Zambia in the last 6 years has led to more efficient and accurate confirmation of malaria cases. This has culminated into timely and more cost effective malaria case management, especially among those living within remote areas (Chanda *et al*. 2011) [4]. Yet despite the availability of RDTs, low rates of routine usage and adherence to diagnostic guidelines for malaria confirmation have been documented (Chipwaza *et al*. 2014; Kamanga *et al*. 2010) [2, 5]. These findings may be a result of inadequate training of workers or stock outs of RDTs within an area as a result of lapses in the health system infrastructure.

Stock outs of health commodities in Africa are a common occurrence and in areas where RDT stock outs frequently occur, the health worker's capacity is reduced to reliance on symptomatic diagnosis for malaria using the onset of fever to determine probable malaria cases (Mayando *et al*. 2014) [6]. Symptomatic diagnosis for malaria has often led to inaccurate diagnosis and over-treatment for malaria. Furthermore, this has resulted in unnecessary costs and side effects associated with the use of anti-malaria drugs and possible exaggeration of local malaria disease burden (Derua *et al*. 2011) [7]. Equally, non-febrile malaria cases may be under-diagnosed often leading to progression into more severe non-malaria cases, which would then lead to delayed treatment and death. It has been documented that non-malarial febrile illnesses result in higher childhood mortality across malaria-endemic countries than malaria (Black *et al*. 2010) [8]. The increased likelihood of population level drug resistance over time, which is associated with over prescription of anti-malarial drug treatments, is also a consideration. These scenarios are more likely to occur, within remote malaria endemic areas where malaria control interventions are poor, RDT use is inadequate or consistently unavailable, and the existence of overlapping febrile illness outcomes is common.

It is for these reasons that routine disease surveillance and programmatic evaluation should be performed at the community level for all malaria illnesses and management. The use of GIS to conduct a geospatial assessment of the disease burdens in malaria endemic areas at the community level could help stakeholders to better understand the local variations in overall disease burdens. Evaluation of malaria registry data for community health management has the potential to provide greater insight into local spatial variations in disease burdens and illness case management at a local level. This would allow for further exploration into disease/illness incidence for evidence-base support for future policies encouraging targeted distribution of healthcare commodities and resources.

This paper describes the application of GIS to assess malaria illness distribution and illness case burdens at the sub-district level for each clinic in Kitwe, Zambia. This geospatial analysis of malaria registries explored community level illness distribution. The analyses served to illustrate the benefits of sub-district area level data analyses in order to provide a better understanding of the extent to which illness cases exists in each clinic throughout the district.

2. Materials and methods

2.1 Data Sets

Demographic data and malaria incident data was collected from Central Statistics Office, Ndola and individual clinics respectively. The data collected for malaria cases from the clinics registries was for the year 2015 (January-December). To spatially examine the malaria registries with GIS, there was need to geocode health center facility's location. Three methods were used to determine the locations of the health centers by name. The first involved the use of Google maps and Google Earth software to enter the clinic names directly into the search bar to determine the geo-coordinates for each clinic. This was unsuccessful as only two clinics out of the 32 included in this study were geocoded. The second method required collaboration with other government organizations like CSO and Ministry of Health Kitwe district office. This was also unsuccessful as the organization had no record of the coordinates points for clinics in Kitwe. The third option required using a mobile GPS coordinate application called map coordinates with google maps and going to individual clinics to get the locations. In total of the 32 Government clinics, 22 clinics were identified with corresponding geo-coordinates and malaria registry health data. Table 1 below shows the details of the clinics indicating whether they were geocoded or not.

Table 1: Clinics geocoded

Health Facility Names from District Health Office	Malaria registry Data obtained / Locations geocoded: Health Facility Included (Yes/No)
Buchi Main	Yes
Bulangililo	Yes
Chavuma	Yes
Chilobwe	No
Chimwemwe	Yes
Community College	No
Kwacha	Yes
Kamitondo	Yes
Ipusikilo	Yes
Cosetco	Yes
Garneton	Yes
Itimpi	No
Mindolo 1	Yes
Kitwe College	Yes
Kitwe District Police	No
Wusakile GRZ	Yes
Luangwa	Yes
Miseshi	No
Mulenga	No
Mwaiseni	No
Kakolo	Yes
Riverside	No
ZNS	Yes
Zamtan	Yes
Kamfinsa	Yes
Mwekera	Yes
Ndeke	Yes
Ndeke Village	No
Kawama	Yes
CBU	Yes
Mawlaik	Yes
Twatasha	No

After the coordinate locations were identified and entered into the Excel spreadsheet for the health facilities, verification on the accuracy of these coordinates was performed using the administrative area shapefiles obtained for Kitwe district from CSO, in a GIS. The health facilities were input into ArcGIS 10.2 as 'X, Y' coordinate points and were then projected onto the district area shapefiles. The points were validated through visual inspection and all were accurately placed within the Kitwe district area boundary. For every clinic coordinate location identified, each location represented multiple patient cases within that particular area.

2.2 CSO Administrative Area Shapefiles

A request was made to CSO to have an administrative area shapefile for the district of Kitwe. The next steps required that the points be assigned to lower level administrative areas. The data collected from the registries for each health facility was collected at the second lowest administrative unit, which is the ward administrative area. Therefore, three hierarchal administrative area boundaries for Kitwe were obtained from CSO; the district, constituency and ward boundaries. These were then uploaded into ArcGIS.

2.3 CSO Population Datasets

Population data was also added to the dataset for each ward administrative area. This data included 2010 population estimates for each ward area. This population and administrative area was best for analyses regarding the clinic health outcomes. Each health facility operated in a catchment area that was at the ward level and would provide insights into the total number of cases per the total population in the area. The population tables for the district and wards were used to identify the population distributions for each ward area.

2.4 District Health Facility Dataset

In addition to the overall population distributions for the sub-district areas, the actual clinic catchment populations were also included in the dataset. A request was made to the District Health Office for clinic catchment area populations. This information was then added to the dataset for each clinic location, prior to the upload into ArcGIS.

2.5 Variables

The complete spatial dataset included coordinate locations for clinics, administrative area information, and malaria health outcomes. All the variables were incorporated into the dataset in excel. The total number of clinical, confirmed malaria cases and RDT were tabulated for each clinic. This information was later added to a secondary dataset in excel spreadsheet for each location. The dataset was later imported into ArcGIS 10 and spatially joined to the existing shapefile. Prior to adding any data in ArcGIS, the data frame was set to a projected coordinate of Arc 1950 UTM Zone 36s in preparation for analysis and mapping.

3. Results

3.1 Population density distributions

To determine the population densities for the Ward areas, the area of the various geographic boundaries was calculated first. The geographic areas were determined by creating a new field for each Ward level geography areas in ArcMap. In ArcMap the new field, ‘Area’, was added to the attribute tables and areas were calculated in square kilometers for each location and administrative level using the ‘Calculate Geometry’ function.

After areas were determined, the population densities were calculated into an additional field for population density in the attribute tables using the ‘Field Calculator’ function to divide the total populations by the total square kilometer areas. The result was used to map the population densities for the respective Ward area levels. Chloropleth maps showing the population densities using quintiles were created to evaluate the population distributions and case count distributions.

The population density of the Ward area level was mapped to visualize the population distribution throughout the district. Figure 1 below shows Kitwe district population density for ward areas. Darker areas of blue indicate higher population densities for the Ward areas. The distribution Health Center locations can also be observed. The Ward area level maps provide insights at the sub-district level for clinics.

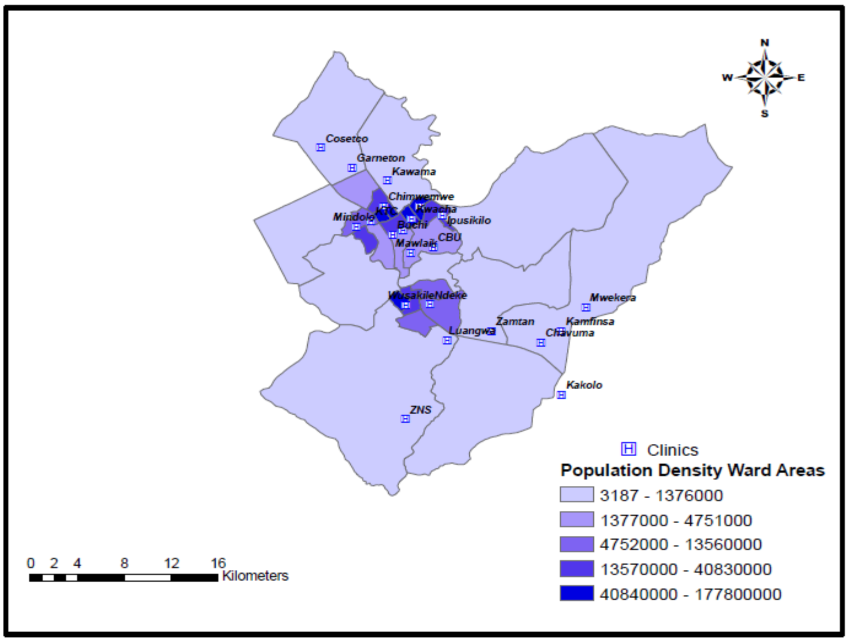

Fig 1: Kitwe district population density for ward areas administrative areas with Clinic locations

3.2 Illness Case Count Distributions

Total number of cases for confirmed, clinical and RDT usage for each clinic were mapped. Maps of proportional case counts for each clinic operating at Ward level were produced for exploratory data analysis and descriptive epidemiology of the general distribution of illnesses. The counts were shown using proportional symbols to illustrate the volume of cases for each clinic in comparison to other clinics. These proportional symbol maps helped to visually evaluate different illness distributions for each clinic. Larger circles indicate more cases or counts and smaller ones proportionately fewer counts. For some maps, multiple variables were overlaid to identify areas were symptoms occurred together or to evaluate number cases versus interventions. Three proportional symbol variables were overlaid together on the same map as shown in figures 2 and 3 below; confirmed malaria, clinical malaria, and RDT usage to identify areas where clinical counts were high and confirmed malaria cases were low, and where clinical cases were high and RDT counts use was low to see possible areas of concern for effective case management. Clinics were identified where RDT use was proportionately less than in areas with high clinical and confirmed malaria counts, indicating a need for more RDT implementation in these clinics.

The proportions of cases in the clinics indicated areas where possible clusters of illness may exist and were potential areas for further interventions. Additionally, there were areas where malaria cases were higher in proportion to RDT usage, and these areas are of equal concern because they may be potential areas for targeted RDT resource allocation.

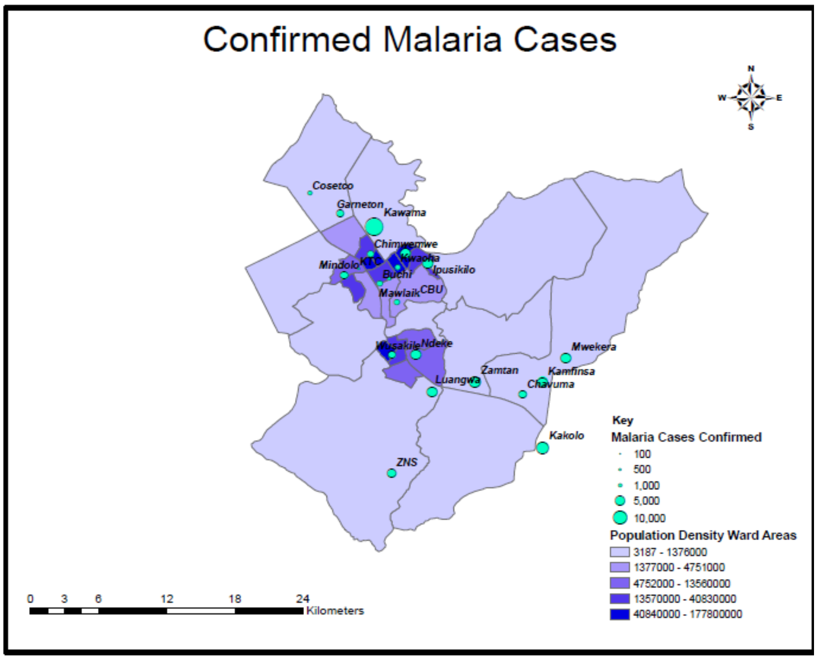

Fig 2: Confirmed malaria cases

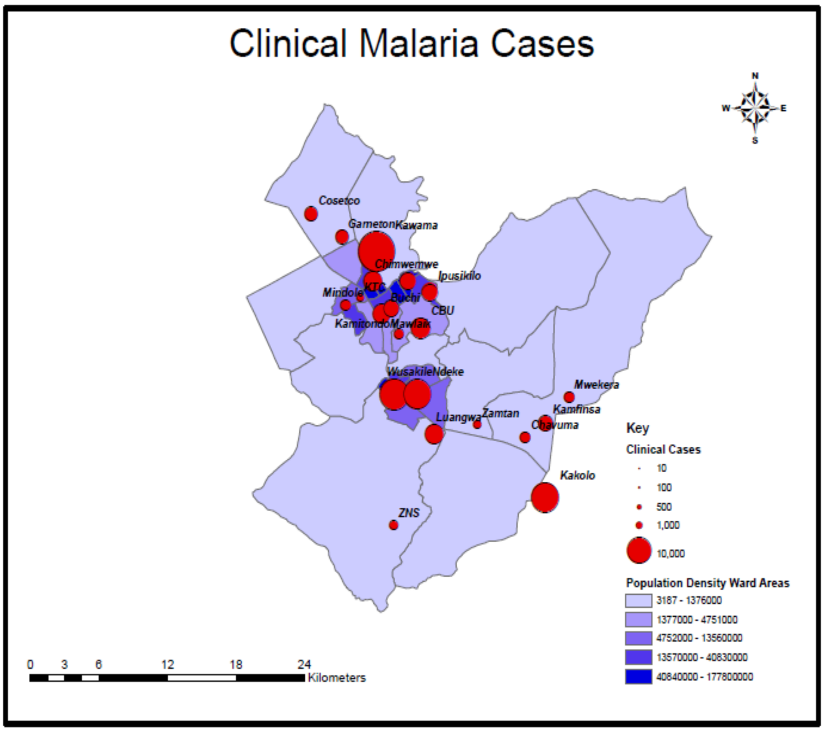

Fig 3: Clinical malaria cases

Once the total numbers of case counts were determined for each location, the incidence rates were calculated in Excel using the formula *cases/population catchment * 10^2* annually. The incidence rate for each clinic was calculated and recorded into the dataset. Chloropleth maps showing the incidence rates per 1000 persons were produced. The incidence maps created an opportunity for understanding of the spatial distribution of diseases. It was also visualized that the highest incidence rates occurred in remote and less densely populated areas as shown in figure 4 and 5 below.

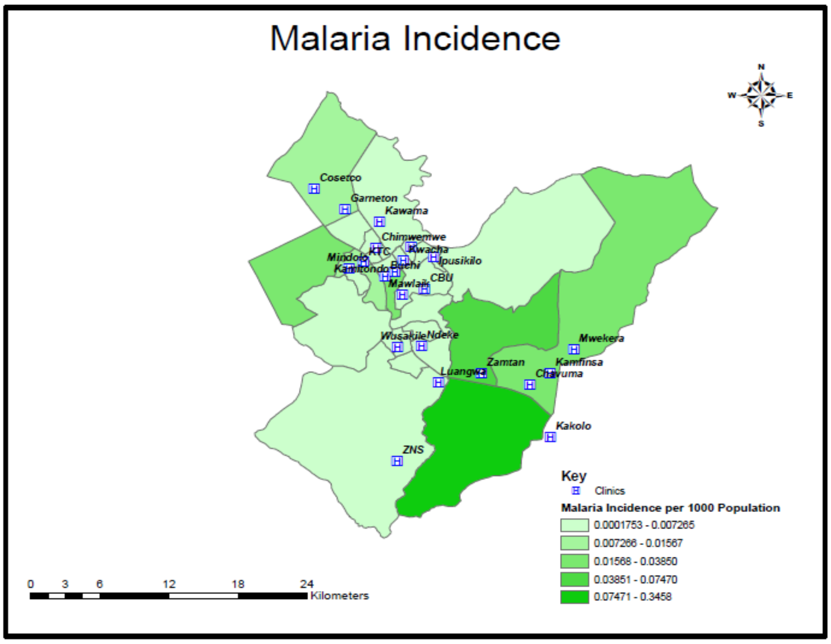

Fig 4: Malaria incidence for Kitwe district

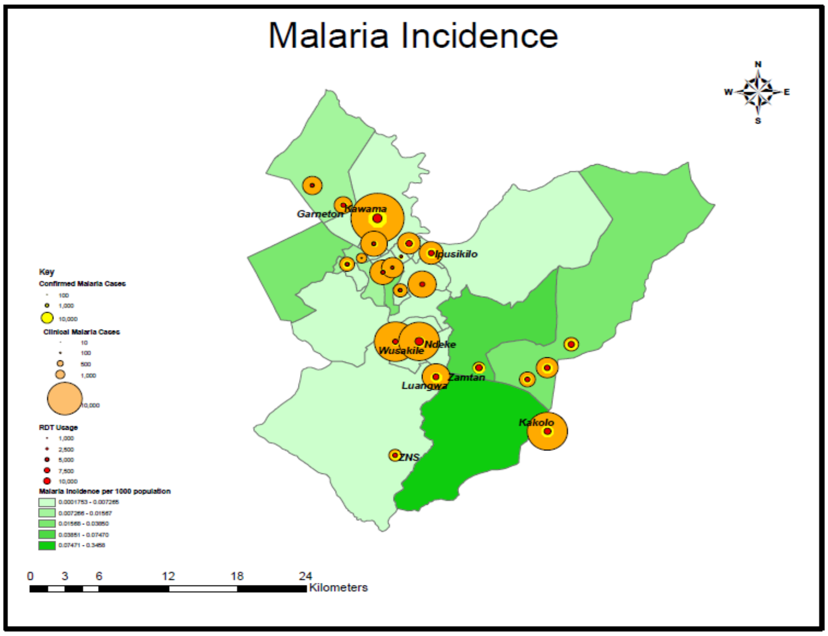

Fig 5: Malaria incidence showing confirmed, clinical and RDT usage in selected clinics

4. Discussion

Based on the findings of this study, it can be established that existing malaria data registries can be used to create sub-district level geo-datasets and that the registries are an underused data source capable of providing beneficial health information at the sub-district and community levels. The geodataset created was a complete digitization of paper-based clinic health registries managed at the sub-district clinic. It served as a model for the type of output that could be created if mHealth or eHealth devices were enabled with GPS capabilities for routine clinic activities.

The geodataset had census data added and population densities, case counts, and incidence rates were calculated. A visual exploration of the data was then performed. Through this visual exploration, the geographic distribution of malaria incidence cases was observed. This visual evaluation process was informative and provided insight on the community health burdens tackled by each clinic. Looking at the preliminary maps it was clear that most health facilities were located in densely populated areas. It could be inferred that health workers in these areas may have a larger volume of incident cases and may potentially experience frequent shortages in supplies and resources. It was noted that there were clinics with high clinical malaria counts but RDT usage was low, indicating potential areas of concern for misdiagnosis and mismanagement of malaria illness cases.

Current data management processes attenuate the underlying epidemiology of malaria illnesses occurring within a district in Zambia. Data collected by each clinic is aggregated, to the district health centers, once at the district health centers the data is sent to the provincial health centers who then report data for the district to the Ministry of Health located at the central level. This process is time consuming and potentially masks any hot spots or cluster areas occurring in a sub-district area.

For other low-resource settings similar, this project illustrates not only the importance of geospatial thinking in disease surveillance and disease management, but also that barriers associated with GIS technology costs can be mitigated. The methods used for the retrospective analysis of the patient registries can be applied to any registry or database that had a geographic place or name that can be identified on a map. Additionally, it provides an opportunity for more remote settings to be mapped and databases generated. The geocoding process may take time, but the benefits outweigh the cost in time or in not doing so at all.

Secondly, the use of an open-sourced software also illustrates way in which GIS cost barriers can be overcome. There have been a number of open-sourced GIS programs that are available for data analysis and mapping. One that is most frequently used is QGIS, which is completely free and is capable of performing the same data analysis of commonly used proprietary software.

Lastly, the main take-away from this research is that geospatial thinking and implementation can be achieved without the need of expensive technology or software. In many developing regions, paper-based methods are still the primary form for data management. Even with these practices and norms, geospatial methods can be applied as long as a geography component exists in the data.

5. Conclusion

In conclusion, the findings of this study support the concept of applying GIS to patient registries. The model dataset yielded beneficial health information and provided geospatial insight into the distribution of disease/illness at each clinic in the district. It also provided support for both mHealth and eHealth initiatives to incorporate routine activities into applications for use with a GIS. By coupling initiatives with GIS, it provides opportunities to explore disease incidence over space and time, further encompassing the epidemiological tenets of person, place, and time. Thus resulting in more efficient and accurate epidemiological assessments within the district.

The use of GIS on health registries creates an opportunity for more informed decision-making, through evidence-based support for community interventions and policy development. Analysis of sub-district level disease/illness distributions would have immediate impact on health policies at the community level. Using GIS to identify cluster areas would provide evidence for more targeted interventions and strategic roll out of implemented programs. Additionally, stakeholders and community developers could make better-informed decisions on where new clinics would be most beneficial using incidence and population density maps. Routine surveillance and maps of sub-district areas would also inform stakeholders and policy makers on programmatic impact and efficacy. In clinics where malaria cases where high, policy makers could make informed decisions on where limited RDT resources should be allocated.

Finally, geospatial applications are becoming a crucial part of information systems as they provide detailed information regarding the attribute data of spatial objects in real world. Due to the rapid technological developments in web based geographical information systems, the uses of web based geospatial application varies from Geotagging to Geolocation capabilities. Therefore, effective utilization of web based information system can only be realized by representing the world in its original view, where attribute data of spatial objects are integrated with spatial object and available for the user on the web, using integrated Google API. It was for this reason that an online map application was proposed to tackle the problems facing the health centers in the district.

6. References

1. Freifeld CC, Chunara R, Mekaru SR, Chan EH, Kass-Hout T, Ayala Iacucci A *et al*. Participatory epidemiology: use of mobile phones for community-based health reporting. *PLoS medicine* 2010; 7(12):e1000376.
2. Kamanga, A., P. Moono, G. Stresman, S. Mharakurwa, and C. Shiff. 2010. Rural health centres, communities and malaria case detection in Zambia using mobile telephones: a means to detect potential reservoirs of infection in unstable transmission conditions. Malaria Journal. 9, 96.
3. United Nations Children’s Fund. 2014. Malaria. *UNICEF Zambia Fact Sheets*. http://www.unicef.org/zambia/5109_8454.
4. Chanda P, Hamainza B, Moonga HB, Chalwe V, Pagnoni F. Community case management of malaria using ACT and RDT in two districts in Zambia: achieving high adherence to test results using community health workers. Malaria Journal. 2011; 10:158.
5. Chipwaza B, Mugasa JP, Mayumana I, Amuri M, Makungu C, Gwakisa PS. Community knowledge and attitudes and health workers’ practices regarding non-malaria febrile illnesses in eastern Tanzania. PLoS Neglected Tropical Diseases 2014; 8(5):e2896.
6. Manyando C, Njunju EM, Chileshe J, Siziya S, Shiff C. Rapid diagnostic tests for malaria and health workers’ adherence to test results at health facilities in Zambia. Malaria Journal. 2014; 13:166.
7. Derua YA, D.R. Ishengoma, Rwegoshora RT, Tenu F, Massaga JJ, Mboera LE *et al*. Users’ and health service providers' perception on quality of laboratory malaria diagnosis in Tanzania. Malaria Journal. 2011; 10:78.
8. Black RE, Cousens S, Johnson HL, Lawn JE, Rudan I, Bassani DG *et al*. Global, regional, and national causes of child mortality in a systematic analysis. *Lancet* 2008-2010; 375(9730):1969-87.