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Application of geographical information system for lymphatic filariasis and malaria control in Nigeria

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Abstract
Geographical Information System (GIS) is defined as an information system used to capture, store, edit, retrieve, analyze and visualize geographically referenced data. The use of GIS is one technology that is very useful in the prevention and control of Vector Borne Diseases (VBDs) such as lymphatic filariasis (LF) and malaria which cause high morbidity and mortality in Nigeria.This paper focuses on how the use of Geographical Information System (GIS) can be harnessed for surveillance, prevention and control of LF and malaria in Nigeria. GIS can be used as an operational tool to assist with resource allocation, as a monitoring and evaluation tool and as a tool to investigate various research projects on spatial aspects of LF and malaria epidemiology. This paper provides information on the benefits and potential of using GIS as a tool for the national malaria and LF control programmes with particular reference to Nigeria.

Keywords: *GIS, Nigeria, Malaria, Lymphatic filariasis, Mosquitoes, Mapping*

Résumé
Le Système d'information Géographique (SIG) est défini comme un système utilisé pour capturer, pourvoir, éditer, retriever, analyser et visualiser les données géographiquement rapportées. L'usage du SIG est une technologie est très utile dans la prévention et control des Maladies à Voie de Vecteur (MVV) telles que la filariose lymphatique (FL) et le paludisme qui causent grande morbidité et mortalité au Nigéria. Cet article met au point à comment l'emploie du Système d'information Géographique (SIG) peut être harnachée pour la surveillance, prévention et control du FL et paludisme au Nigéria. Le SIG peut être utilisé comme un outil opérationnel pour assister avec l'allocation de ressource, comme un outil de surveillance et d'évaluation et comme un outil pour investiguer divers projets de recherche sur les aspects spatial de l'épidémiologie du FL et paludisme. Cet article procure information sur les bénéfices et potentiel d'utilisation du SIG comme un instrument pour les programmes de control national du paludisme et FL avec un renvoi particulier au Nigéria.

Mots clés : SIG, Nigéria, Paludisme, Filariose lymphatique, Moustiques, Tracement d'une carte.

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Introduction
Vector-borne diseases (VBDs) are diseases that have been targeted for control because of the high morbidity and mortality associated with these diseases. In Nigeria, VBDs include among others, lymphatic filariasis (LF) and malaria, which are both transmitted by *Anopheles* mosquitoes. Lymphatic filariasis is a neglected tropical disease (NTD) caused by parasitic worms and transmitted to humans by *Anopheles, Culex, Aedes* and *Mansoni* mosquitoes [1]. It is caused mainly by *Wuchereria bancrofti,* which accounts for 90% of the cases while most of the remainder of the cases is caused by *Brugia malayi* [1,2]. Nigeria has the greatest number of cases of LF in Africa as about 106 million people in Nigeria are at risk of the disease [3,4]. Malaria is a parasitic disease caused by the protozoan parasite of the genus *Plasmodium* [5]. Nigeria accounts for about a quarter of the estimated global death due to malaria in Africa [5] and about 97% of the Nigerian population is at risk of malaria and there are an estimated 100 million malaria cases annually [6]. The vectors of LF and malaria in Nigeria are the anopheline mosquitoes of the *Anopheles gambiae* and *An. funestus* species complexes [7–9]. The high morbidity and mortality associated with these diseases has led to the intensification of efforts to develop new techniques for their control.

There have been technological advances over the last decades with relevance to VBDs. These include the development of molecular techniques for vector species and parasite detection and identiûcation and the development of robust software as well as hardware used in data collection, management, and analysis of spatial data. Spatial technology has advanced the understanding between the disease prevalence and vector distribution. It has opened great windows of opportunities in the interpretation of epidemiological data as it relates to to environmental factors by defining the geographical limits of diseases and identifying the risks of infection [10].

Spatial technology is an information system used to collect, analyse, display and distribute data based on geography, space and time [11]. It includes Geographic Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS) technologies. Geographical Information System is defined as an information system used to capture, store, edit, retrieve, analyze and visualize geographically referenced data [11]. Remote sensed data are collected through satellites, aerial photo and videography. The Global Positioning System is a satellite-based navigation system which consists of 24 satellites and allows points on or near the earth to be measured. GIS integrates datasets from GPS and RS. Remote sensing helps in providing environmental information from satellites by proxy and enhances GIS applications. With the improvement in spatial technology, the capacity to predict, prevent, and control VBDs has greatly been enhanced [12].

The use of GIS is one technology that has been deployed for the analysis of disease patterns over time and space since disease distributions vary in space and in time. Hence the knowledge of spatial distribution and pattern of diseases is important when aiming for control. Monitoring, distribution and control of VBDs can be made more effective and efficient by the use of climatic parameters in different geographical areas and time periods. GIS can be used in resource allocation by predicting hotspots, foci and potential epidemics in order to adapt and implement the most appropriate control method [13]. Distribution maps showing mosquito vector data and epidemiological data can be used to depict the geographical range of mosquito vectors, assess coverage of vector control activities and identify broad areas where exposure to vector-borne pathogens is likely to occur [14,15].

The use of spatial format to display disease information has various advantages. For example a map can be used to decipher the course of a disease, show the distribution of a disease in different places, over time, or in relation to other factors such as climatic/environmental factors, human movement, etc. This can be very helpful in planning, improving and development of control methods [16]. Maps and spatial information technologies help in effective communication of findings and are very useful resources in decision making. This is because displaying information in a spatial format has a huge visual impact in the presentation of complex data not easily presented in tabular or other understandable format. They can deliver a message without pages of text and therefore present a strategic view of the situation and can thus be useful disseminating information to the general public and decision makers. Maps and spatial information technologies can be used to show linkages between two or more variables, indicate areas of concern, show the extent of a problem, and can be used to compare information obtained in different time periods.

Because LF and malaria are transmitted by the same *Anopheles* mosquitoes in Nigeria, modelling their distribution and abundance can be used to assess potential risks for both diseases. In Nigeria, GIS is used mainly in the analysis of retrospective data rather than in real time to predict disease outbreaks, and plan control strategies. Its use has been limited to single isolated studies conducted by individuals or various Non Governmental Organizations (NGOs) and Non-Governmental Development Organizations (NGDOs), thus, GIS has not had desirable effect on policy and decision making. In the National Strategic Health Development Plan Framework (2009-2015) [17], GIS was listed as one of the priority areas to "Improve geographical equity and access to health services." In the Neglected Tropical Disease (NTD) master plan for Nigeria for 2013 to 2017, GIS was mentioned once under one of the strategic objectives as a tool for capacity building at national and zonal levels on NTD data [4]. There was no mention of the role of spatial information in the strategic plan of the National Malaria Control Programme [18].

Future directions for incorporating GIS into LF and malaria control in Nigeria

GIS as a tool for resource allocation

The use of GIS in the mapping of health facilities in Nigeria is one fundamental application of GIS that will be extremely useful. Mapping of the health facilities can be used in deciding where new health services should be sited. When these maps are combined with population density, they could help pinpoint where there are gaps in health care facilities and/or laboratory facilities, the proportion of the population using each health care centre as well as the distance to be travelled to the nearest health facility (especially in the rural areas).

GIS as a tool for identifying geographical limits and distribution of LF and malaria vectors

GIS can be used to identify geographical limits and distribution of *Anopheles* mosquito vectors as this is important for strategic planning of the LF and malaria programmes. For example, GIS was very useful in describing the spatial distribution of vectors of LF and malaria across Nigeria over a 100 years' period [9]. The geographical limits of insecticide resistance patterns in the vectors can also be determined.

GIS as a Spatial Risk Modelling tool

The control programmes can use Spatial Risk Models to make extrapolations based on associations between vector or disease prevalence data and environmental or socioeconomic predictor variables. This will help in continuous monitoring and will be useful even in areas where surveillance has not been done. In combination with population data, proportion of a human population that is potentially at risk for exposure to vectors and vector-borne pathogens can be assessed [12]. This can help to predict future changes in the disease prevalence, vector distribution and the spatial risk of exposure to vectors and vector borne pathogens as it relates to climatic patterns (such as land use, soil type, temperature-related factors, or rainfall) or socioeconomic variables (e.g. presence of pipe borne water, housing characteristics, and income). For example, a predictive model can be developed based on data collected on mosquito density as well as disease prevalence in different locations. This approach will help to identify environmental or socioeconomic predictors for risk of exposure to vectors or vector-borne pathogens. This information can be presented in an easily understandable map to decision makers, researchers and the community at large in the form of point locations for disease cases, aggregation of disease case counts or disease incidence according to location [12].

GIS-based statistical models that exploit spatial autocorrelation of vector abundance or environmental associations of the vectors can be created to predict spatial distribution and abundance patterns of mosquito vectors. The knowledge of where exposure to vectors is likely to occur will be useful for personal protection against mosquitoes and in awareness creation in the Nigerian populace to specific areas where the risk of infection is high.

GIS as a mapping tool

There is tremendous potential for using mapping and modelling approaches in both disease and research arena that can enhance operational vector and disease control [11]. Geographical information system can be successfully implemented into the malaria notification system to monitor and map vector control data by geographical area as was done in South Africa [19]. Also, GIS has made it possible to combine two or more maps with different information in building spatial analysis. A combination of global distribution of malaria combined with human population distribution has been used to estimate the global population at risk of *P. falciparum* [11]. Mapping can be used to identify patterns through simple overlays and to determine correlations when spatial models are developed to predict changes in health based on environmental changes in relation to spatial coverage of implemented interventions. For example, using Micro-stratification Overlap Mapping (MOM) in Nigeria, the distribution and potential impact of multiple disease interventions that geographically coincide in LF endemic areas has been highlighted and their impact determined [20]. Specifically, the LF prevalence distributions; prevalence of loiasis (eyeworm disease); ongoing onchocerciasis (river blindness) community-directed treatment with ivermectin (CDTi); and long-lasting insecticidal mosquito net (LLIN) distributions were incorporated into overlay maps using geographical information system (GIS) software [20]. This study provides an important overview for the LF Programme and will assist the programme to maximize existing interventions and ensure cost effective use of its resources.

GIS as a monitoring and evaluation tool

GIS mapping can help the LF and malaria control programmes in monitoring and evaluation of control interventions such as for spatial targeting of drug administration, or education awareness campaigns; selection of sentinel sites to monitor vector abundance; and identifying areas to target for control [14]. For example, GIS can be used to map the distribution of Long Lasting Insecticidal Nets (LLINs) and to provide information on areas where more nets are needed. This information can be made easily accessible so that the disease prevalence can be correlated with the LLIN distribution as well as the vector distribution for better disease control. It can be used to monitor indoor residual spraying (IRS) coverage, insecticide use and application rates used. It can also be helpful in mapping prophylaxis with antimalarials for pregnant women and in mapping areas that have received mass drug administration (MDA). GIS mapping can be used to identify population coverage of these interventions by their locations and relate them to disease morbidity and mortality so that disparities can easily be corrected [11]. Generally, GIS can assist in interpreting results of intervention studies by taking account of the variability of confounding factors.

Challenges in using GIS technology in LF and malaria control in Nigeria

Nigeria is a vast country and the use of GIS in VBDs control and surveillance in Nigeria will be faced with a lot of challenges [12,14,21,22]. These include the following:

1. Lack of the relevant epidemiological, entomological, parasitological and geographical data which needs to be acquired through collaboration with each state/LGA, research institutions, etc.
2. The cost of field sampling so as to generate data.
3. The financial demands of purchasing and maintaining specialized GIS software.
4. Lack of qualified staff and the cost of training staff on the GIS software and the use of statistical tools.

Requirements for using GIS technology in LF and malaria control in Nigeria

Setting of goals and priorities

It will be imperative for the LF and malaria control programmes to determine the type of information required by the target audience so as to determine optimal map and text formats that will be informative to the user [23]. This is because a map showing case counts and disease incidence can mean different things to different groups of people. For example, the programmes may be interested in determining where high numbers of the disease cases occur so as to implement their control efforts and reduce the burden of LF and malaria. On the other hand, a member of the public seeking information for personal protection to these diseases may be more interested in spatial risk estimates based on disease incidence [12]. For a researcher, the map may tell where there are gaps in the study of the disease while the policy maker may want to know the extent of the problem (e.g. disease distribution) or impacts of intervention implemented so far.

Generation of data and setting up of an effective surveillance systems

It is important for the control programmes to generate information on *Wuchereria* and *Plasmodium* infection rates in both mosquitoes and humans over a period of years in combination with mosquito abundance, population density, etc. so as to produce reliable maps for malaria and LF, respectively. The best scenario will be to produce spatial risk models based on epidemiological and mosquito vector data as both complement each other [14]. To achieve this, it may be more useful to adopt a nationwide systematic sampling approach that will yield accurate data. Therefore, the LF and malaria control programmes must have effective surveillance systems which will provide prompt and accurate data for mapping and for the appropriate action to be taken [19]. Sentinel sites will need to be established and maintained and active epidemiological surveillance must be in place at these sites. In an audit of risk maps used by National Malaria Control Programmes in Africa, some African countries displayed maps produced from data from routine or national surveys, however, the map presented on Nigeria was based only on the public domain based models of transmission developed by the MARA/ARMA project [24]. This shows that there is a gap that needs to be filled.

Development of risk maps

To better inform the LF and malaria control programmes and the Nigerian community regarding spatial risk patterns for exposure to these diseases, there is a need for risk maps to be developed at different levels in the country (nationwide, state, LGA and village levels). There is the need to present spatial maps and risk models at the lowest level in countries like Nigeria where LGAs/ villages may cover a vast area of land. Presenting spatial maps and risk models at high level such as state level will help to display the right information which may not be obvious when incidence/ prevalence data is displayed at the level of states and local government areas [19].

Collaboration with other programmes and countries

For the use of mapping and GIS technologies in operational vector and disease control to be successful in Nigeria, control programmes will need to collaborate with control programmes within and outside the country and share their experiences with GIS through publications and other media. With this other vector and disease control programmes in other disease endemic countries will gain from their failures and successes [12].

Capacity building

For the control programmes to succeed with the use of GIS, they must have dedicated and well trained staff, including a GIS data manager as well as support staff which will help in data entry and data quality management. The database managers have to be empowered in the entering and manipulation of data in different software packages and statistical software. This is more important considering that for a country as vast as Nigeria, the management and analysis of data can be a complex undertaking involving large amounts and different types of data. The process of data entry is made easier with the wide option of mobile data capturing technology now available such as a laptop, a personal digital assistant (PDA), or a smart phone. The locations where vector data were collected or where human disease cases occurred can be determined using a GPS or handheld personal data assistants so as to facilitate rapid transfer of data to an electronic database and then GIS can be used to analyse and visualize the data [15].

Although some of the GIS technologies are expensive, some can be easily adapted for use in resource-constrained disease-endemic countries like Nigeria. Majority of Nigerians own cell phones and this can serve as a rapid and inexpensive way to transfer information and this has great potential for implementation in rural areas where internet access may be poor or lacking. The availability of many free user friendly open source software that can be downloaded easily, as well as environmental GIS and RS data as well as demographic and socio economic data provides the opportunity for control programmes to visualize spatial and space-time patterns of entomological and parasitological data, and to generate risk models and is something the control programmes can build on.

Conclusions

The deployment of a GIS tool for LF and malaria control in Nigeria can have a wide range of applications. Many benefits can be derived from setting up a health GIS infrastructure in Nigeria. Using GIS as a tool will 1) Improve health services provision and healthcare access to deprived communities especially in the rural areas. 2) Ensure cost effectiveness as it will help the programme to locate target populations in shorter periods of time and will help public health agencies to allocate limited prevention, surveillance, and control resources to best use and allow for efficient allocation of resources. 3) It can improve our understanding of how environmental factors affect insect vectors and transmission of vector borne diseases. 4) Drivers (such as level of education, age, income) of LF and malaria can be identified using GIS and relationships between variables can be evaluated visually and linked geographically before using rigorous statistical testing methods. This information can be used to identify gaps in areas where community-based mobilization and awareness campaigns can be targeted. 5) GIS can be used as a research tool by the academia to give further insights into LF and malaria epidemiology in Nigeria. 6) Research findings can be presented in an easily understandable visual format. There is great potential to use GIS technology to improve LF and malaria surveillance, prevention and control in Nigeria.

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