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THE APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEMS TO VETERINARY MEDICINE: AN OVERVIEW

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Abstract

Geographical Information Systems, (GIS), are powerful computerized systems with inputting, storage, mapping, analysis and display of spatial data capabilities (spatial data are associated with a location on the earth's surface). Geographical Information Systems have tremendously enhanced Ecological Epizootiology, the study of diseases in relation to their ecosystems. It has found increasing application for surveillance and monitoring studies, identification and location of environmental risk factors as well as disease prediction, disease policy planning, prevention and control. This article is an overview of the application of GIS to veterinary and medical research, education, decision support and information systems in different parts of the world, including Nigeria.

Introduction

Geographical Information Systems (GIS) are powerful computerized systems for collecting, inputting, storing, managing, mapping, analyzing and displaying spatial data i.e. data associated with a location on the earth's surface (Burrough 1986). They enable display in a graphic form, large quantities of information within a geographic context (Antenucci *et al*, 1991, Thrusfield, 1997). Geographic Information Systems owes its origin to the implementation of the Canadian GIS developed in 1960. With the rapid reduction in cost of hardware and the development of versatile software, rapid progress in GIS was made in the 1980s.
Disease can be mapped and analyzed using GIS (Maguire, 1991). The emergence of GIS marked a development in ecological/landscape/geographical epizoo-tiology or medical ecology (which has been a traditional branch of epidemiology/ epizootiology). Ecological epizoootiology, the study of diseases in relation to the ecosystems, was expounded (Andy 1958, 1960, 1962) and developed in Russia (Pavlosky, 1964. Galazo 1975) Ecological epizootiology is founded on the

premise that locating the natural home (nidus/nest) of a disease in an environment will enable prediction of its occurrence, and the devising of appropriate prevention and control mechanisms. Epizootiologists and their human medicine counterparts (the Epidemiologists) have traditionally used maps when analyzing associations between location, environment and disease. Geographic information systems are particularly well suited for studying the associations because of its spatial analysis and display capabilities.

Maps (cartography), as used in epizootiology are important for the following reasons:

- They display the geographical (spatial) distribution of disease and related factors.
- They enable one to see at a glance where diseases are present.
- They are valuable for investigating the mode and direction of transmission of infectious diseases.
- They suggest possible causes of diseases of unknown aetiology. (For example the association of jaw tumors of sheep with areas where bracken fern was common, led to the hypotheses that bracken fern causes tumor. This was later supported by experimental investigation – (McGea and Head 1978, 1981), and
- They facilitate the quantitative display of the number of cases, populations at risk and prevalence/incidence of diseases.

Application of GIS to the cartography of veterinary diseases has taken a new and rapid dimension in the present age of advanced information technology. Thrusfield, (1997) observed that in addition to traditional mapping, GIS can be applied to the following:

Neighborhood analysis which allows an investigator to list all features that meet specified criteria (e.g. identification of livestock units adjacent to an infected area). Buffer generation around or along certain features e.g. definition of all properties at risk of infection within a given distance of an infected farm, or along a road that has been used by infected animals.

Overlay analysis in which two or more data sets are superimposed on top of another and areas of intersection (overlay) of features identified (e.g. overlaying land, farm, vegetation and watering point locations to identify areas where animals are to be mustered for tuberculin testing).

Network analysis permitting optimal routing along networks of linear features.

Three-dimensional surface modeling- GIS provides user ability to store, integrate, query, display and analyze data from molecular levels to that of satellite resolution. Field observations on environmental conditions including vegetation, water and topography, can be combined in GIS to facilitate characterization of the landscape in terms of vector and pathogen prevalence. The associations between disease risk variables (e.g. vector, pathogen and reservoir host abundance and dis-tribution) as well as environmental variables can be quantified using the spatial analysis capabilities of GIS.

Landscape pattern analysis combined with statistical analysis allows us to define landscape predictor of disease risk. This can be applied in large regions where field data are unavailable, thus making GIS a powerful tool for disease surveillance, for predicting potential disease outbreak and targeting interventions programmes (CDC 1994, 1998).

This paper is thus an overview of the application of GIS to the practice of veterinary medicine, research and education.

Existing application of GIS in Epizootiology and Epidemiology

In the related Human Medicine field of epidemiology, GIS has been used for:

Surveillance and monitoring of vector-borne diseases *(Onchocercosis* in Guatemala, Malaria in Israel and *Trypanosomosis* in Africa*)*. Spatial and ecological data are combined with epizootiological data to enable analysis of variables that play important role in disease transmission. In the Malaria studies in Israel, data on locations of the breeding sites of anopheles mosquitoes, imported malaria cases and population centers were integrated to provide means for administrative collaborations, health policy planning, decision making and ongoing surveillance efforts. Available information concerning human and tsetse populations were synthesized and developed into a spatial GIS model to estimate the future effects of human populations on tsetse population. It was concluded that by 2040 AD many of the 23 species of tsetse will begin to disappear and infested land area and human contact will also decline.

Surveillance and Monitoring of waterborne diseases e.g. UNICEF Guinea-worm Eradication Projects. GIS enabled the researchers to locate high prevalence areas and population at risk, identifying areas in need of resources and making decisions on resource allocation. Pumps were then placed in villages most affected to ensure access to safe water. This led to marked reduction in prevalence of guinea worms in villages where pumps were introduced.

Identification and location of environmental risk factors associated with lyme disease in Baltimore county, Maryland. Ecological factors such as water shed, soil type, land use, geology and forest distribution were collected at residences of lyme disease patients and combined with data collected at randomly selected set of addresses. A risk model was generated combining both GIS and logistic regression analysis to areas where lyme disease was most likely to occur. (Athenucci *et.al* 1991; Reid *et. al,* 2000)

In Nigeria, GIS principles have been used to study risk factors associated with malaria in Ibadan, Nigeria (Idowu, 2000). The author associated the risk of malaria to the presence of disposing factors such as swamps, refuse dumps and population density, and then showed this associations in GIS maps that classified the study area into potential and low risk areas to malaria.

In the field of epizootiology, (Veterinary Epidemiology) GIS has been used to study *the ecology and control of tuberculosis in New Zealand.* Areas with endemic infections of tuberculosis in possum populations for the years 1981, 1986 and 1990 respectively were shown in a map constructed using a GIS.

The epidemiology of cattle diseases caused by *Theilera parva*. (Lasserd *et al.*, 1990). Data on selected variables, which influence the epidemiology of the disease, were assembled and entered into a computerized GIS. Variables studied included the distribution of the major host (cattle and buffalo), the tick vectors (*Rhipicephalus appendiculatus* and related species), and the reported presence of east coast fever, corridor disease and January disease. In addition, the distribution of climate suitability of *R. appendiculatus* was assessed using the model CLIMEX on a climatic database developed for Africa. Distribution maps were produced for each variable i.e. cattle, buffaloes, ticks, eco-climatic index for tick survival and development, as well as the distribution of mean monthly normalized vegetation index. These buffered maps were then overlaid and points of overlap indicated areas of greatest risk for incidence of *Theliorosis*. GIS was thus used to portray at a glance the epizootiological parameters relevant to Theliorosis, and to analyze the complex relationship between them on a geographical basis.

The development of a GIS database of the poultry industry of the Delmarva Peninsula in the United States (Colby *et al.* 2000). This was for the purpose of disease surveillance, outbreak control and emergency management. Knowing the exact location of farms and the nearest road and water works will enhance control efforts by allowing rapid identification of infected farms and others that are at risk due to proximity to infected farms or along transport routes. A GIS database containing farm locations, poultry industry resources, roads, waterways and geographical/ architectural features can be used to identify vaccination zones, flock depopulation regions and transport routes that minimize the risk of disease transmission. These are important factors in protecting export market during disease outbreak. Such database will also enhance planning and budgeting efforts, provide important data to secure financial support for needed improvement in infrastructure. In event of natural disaster and other emergencies, a database of this type will assist in both planning and relief efforts. Information could then be collected from farm owners, government offices in charge of planning, highway administration and environment; from maps and from veterinary records. This can also be applied to other animals health and production industry at national and regional levels.

In Argentina, Maretto and Urcelay (2000) used GIS to *identify* and differentiate in a single map, all the three hundred and sixty-five (365) farms in a district of Argentina according to *the risk of* introducing Foot and Mouth Disease- It also permitted the appreciation of risk clusters according to geographical distributions to simultaneously prepare strategies, and assign human and economic resources to disease surveillance and control measures. This can also be applied for risk assessment of other diseases at national or regional levels. Ehlers and Mollex (2000) used GIS technology to spatially separate and analyze densely and sparsely populated livestock areas in

Northwest Lower Saxony in Germany, as part of the strategies for fighting animal diseases such as classical swine fever (CSF). Their work was part of the European Community (EC) project titled *"Development of Prevention and Control strategies to address animal health and related problems in densely populated livestock areas of community"* (FAIR CT 97-3566).

The area under study was differenttiated into sparsely populated livestock areas (SPLA) with 0-50 pigs/km² midsize populated livestock area (MPHA) 250-300 pigs/km and densely populated livestock area (DPLA) >300 pigs/km² A density of more than 200pigs/km² was used as threshold for declaring as epizootiological risk area. Circles with appropriate radius depending on risk factors were drawn around location of outbreaks. For control measures, restrictions ranging from killing animals in inner circle to prohibiting trade in outer circles were to be imposed. By using a veterinary GIS shell, the numbers of animals within a given circle around every individual farm could be checked. An ArcView GIS 3.1[R] was used to model maps showing *the predicted probability of Arbovirus vector activity in Australia on weekly basis*. The country was thus divided into two - a zone of potential viral activity and the remainder of the country considered free of virus activity. Such a map was envisaged to enhance Australia's capability to meet trading partner health certification requirement and ensure a negligible risk of international spread of selected Arbovirus (Cameron, 2000). Cameron, (2000a) also reported a system designed to assist with the implementation of a predictive tempora-spatial distribution model to forecast the risk of blue tongue virus activity in Australia. An ArcView 3.1[R] was used to combine various data sources (including data from the Australian National Arbo-virus Monitoring Programme), mete-orological observations, livestock distri-butions, vegetation cover and topography. The collection of epizootiological data by remote sensing. Hugh-Jones, (1989) and Rogers, (199) have applied GIS to remotely sense data to detect ticks, mosquitoes and trematodes, as well as tsetse fly respectively.

At the University of Ibadan, Nigeria, two ongoing projects seek to apply GIS to identify risk factors for Trypanosomosis in its ecological area, and to identify veterinary risk factors at Apete village, in its neigh-bourhood. These are to help the University's Veterinary Teaching Hospital provide relevant veterinary services to the neighbourhood. In one of the studies (Oguamanan, Babalobi and Fabiyi, 2001), three factors conducive to the prevalence of *Glossina palpalis* - forest reserve area, rivers and animal host locations - were identified, buffered and overlaid to highlight the potential and medium risk areas to trypanomosis at Apete Village, Ibadan. Such application can also be done at regional and national levels to help veterinary practi-tioners, animal health, production and policy planners to identify problem areas and devise appropriate control strategies.

GIS principles are to be used to highlight the incidence and distribution of tuberculosis in Ibadan (Cadmus, personal communication) to typograph the epizootiology of the recent African Swine Fever outbreak in Oyo State, Nigeria (Olugasa, personal communication) and to type the dynamics of transhumance pastoralism in Nigeria (Babalobi, personal communication).

Thrusfield (1997) has listed some other GIS application to veterinary and related fields in other countries of the world to include Aujeszky's disease (US); bovine tuberculosis (Ireland, New Zealand, UK); *dracunculiasis* (West Africa); foot-and-mouth disease control (Brazil, New Zealand Gastric cancer (UK); Habitat of the snail *Fossaria builmoides* (intermediate host of *Fasciola hepatica)'*, US, Handing epidemiological data (US); Mosquito population dynamics (US); Site selection for fish farming (Ghana); Theileriosis (Africa); Tick habitats (St Lucia); *Amblyomma variegatum* (Guadeloupe); Lyme disease tick distribution (US); *Rhipicephalus appendiculatus* Czechos-lovakia, Africa.

GIS Software

Various GIS software programmes/ products exist to perform the spatial operations task in GIS. (A GIS software is the computer program that is used to perform spatial operations i.e. the different tasks performed in GIS. There are six basic properties of a GIS software; Automated mapping function, Database management function, Typology building, Spatial and attribute data linkage, Spatial analysis model and Output module

Vine *et al.* (1997) have listed some questions to consider when selecting a GIS software product. These include.

- How easy is it to learn and read?
- Does it have good documentation and technical support?
- Is the company stable and has long range plans for future development?
- Will the features meet the demand of the current (and future) research needs?
- How about future projects?

There are many types of GIS software in the market, they include AreViewGIS®, ArTnfoGIS® and EDRASImagine. Others include ATLAS *GIS®, ALEXANDER®, ARCARD®, AutoCAD®, EAS/PACE®, ERDASImaginé® GIS PLUS® GRASS®* and Map Info®

Areview GIS is one of the most widely used GIS software worldwide. It is preferred because of its UGI (user graphical interface) that is a simple, very user-friendly. It is portable and interface efficiently with other platforms and packages. The programme is modular in structure which encourage efficiency in the operation mode of the package. It possesses extensions and functions form, improved functionality and adaptation for the unique requirement of different project Arcinfo is also a product of ESRI (Environmental Systems Research Institute) based in Redlands and it is the most popular GIS in the world. Its popularity is based on the architecture; it is portable and can be installed even on a very low capacity computer e.g. 286 motherboard. It also has some data cleaning capabilities which enable more efficient data capture and spatial analyst Mostly used by a professional, as it requires knowledge of geographic concept

Arcview and Arcinfo are very robust, user friendly and have excellent spatial analyses modules that enable various forms of applications in environmental context. Both are vector-based packages but have some extensions to work in the raster environment. They can be used to produce precise locations of nondescript features such as street, fan. boundaries, telephone poles etc.

EDRASImagine: this is essentially a raster based package but with further extensions to do bevond raster GIS. It is also a robust software and is quite popular in the raster-based analysis. It combines spatial analysis in the raster environment with image processing.

Selection of the software should be based on the needs of the researcher and the software capabilities. Consultation with GIS specialist is always recommended before final selection is made.

Conclusion

GIS has opened new vistas for epizootiological studies of disease phenomenon in population and in the context of their environment, both in human and veterinary medicine. It also has applied research value for prediction, prevention and control of diseases and other problems of populations and their environment. They are also integral part of the veterinary decision support system and information system. Veterinarians in Nigerian should thus make conscious efforts to inculcate and apply GIS to Veterinary Medicine Practice: Research and Education in Nigeria.

The greatest limitation to the use of GIS anywhere is the development of GIS database (or map layers) which can account for up to seventy percent (70%) of time and resources necessary to conduct research (Biggs and Elliot. 1995). There is thus the need for collaborative efforts with geographers and statisticians to develop such GIS database relevant to veterinary medicine in Nigeria. Also the accuracy and relevance of GIS to epizootiological research depends on the quality, accuracy, appropriateness and relevance of epizootio-logical data fed into the systems. As noted by Vine *et al.* (1997) GIS technology may enhance epidemiological research by making some steps quicker, easier and cheaper to accomplish, it does not replace traditional fieldwork based epizootiological methods and approaches to outbreak investigations and studies in the natural history of epizootics.

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