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Research Article

Review on The Importance of Geographic Information System (Gis) In Epidemiology: In Prevention and Control of Animal Disease

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Abstract

A literature-based review was made to assess the applications of GIS in veterinary epidemiology and its relevance in the prevention and control of animal diseases. GIS is "a powerful set of tools for collecting, retrieving, transforming, and displaying spatial data from the real world". Overall, a GIS is a platform consisting of hardware, software, data, and people and encompasses a fundamental and universally applicable set of value-added tools for capturing, transforming, managing, analyzing, and presenting information that is geographically referenced. These data can be combined with population data and previous disease records for the prediction of diseases. Applications of GIS are very wide in all human activities. It is used for marketing studies, telecommunications, and the location of restaurants, museums, and hospitals; in tracking truck traffic; in establishing maps of animal population density by species or maps of changes in vegetation; in locating forests, rivers, and mountains and in determining soil compositions**.** The application of GIS to the veterinary field has been developed over the last decade. Specialized software is becoming more affordable and user friendly. GIS can be applied in veterinary epidemiology for investigation of complex disease problems, GIS is used for early warning systems, for recording and reporting disease information and for planning animal disease prevention and control program. One of the most useful functions of GIS in epidemiology is its utility in basic mapping. It is believed that GIS will play an important role in the control and eradication of epidemic Transboundary Animal Diseases (TADs). Thus training of veterinary staff on GIS, its tools, and applications are highly recommended.

Introduction

Geographic Information System (GIS) is a computerized information system that allows for the capture, storage, manipulation, analysis; display, and reporting of geographically referenced data. It makes it possible to integrate different kinds of geographic information, such as digital maps, aerial photographs, satellite images, and global positioning system data (GPS), along with associated tabular database (e.g., „attributes' or characteristics about geographic features). Essentially, the technique is a combination of computerized mapping technology and Database Management Systems (DBMS), in which spatial data sets from diverse sources are managed and analyzed [1].

GIS technology was primarily used for defense purposes or in the military in earlier periods, and then later it expanded wings into other fields. Cartographers and meteorologists were the first to use GIS tools for civic purposes. The potential of using GIS applications in veterinary Medicine is very huge. Nevertheless, the GIS user community in veterinary Medicine is rather small compared to other sectors. There is a need for recognized opportunities to share applications and innovations of GIS specifically focused on veterinary medicine. Its application in this field is rapidly advancing and there is a need for each veterinarian to understand the basics of GIS [2].

Epidemiologists have traditionally used maps while analyzing the relationship between location, surrounding environment, and the disease. GIS is now used for a multitude of purposes, including surveillance and monitoring of vector-borne and water-borne diseases, environmental health,

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modeling exposure of animal disease, quantifying hazards in a neighborhood, and the analysis of disease policy and planning [3]. Effective implementation of GIS allows the realization of this potential while offering efficient ways to perform the functioning, storage, and sharing of data between the organizational units, and their integration with other technologies. The geographical distribution of any disease could be mapped utilizing GIS. It supports public health programs from small to large scales, varying from the management of the departmental functions that run the day-to-day operations of a health organization to epidemiological mapping performed by the public health officials [2]. Therefore the objectives of this review paper were to review the importance of GIS in veterinary epidemiology: its application in the prevention and control of animal diseases.

Definition of GIS

GIS is "a powerful set of tools for collecting, retrieving, transforming, and displaying spatial data from the real world". Overall, a GIS is a platform consisting of hardware, software, data, and people and encompasses a fundamental and universally applicable set of value-added tools for capturing, transforming, managing, analyzing, and presenting information that is geographically referenced [3].

History of GIS

GIS has greatly advanced from its initial use in the 1960s by cartographers (map makers) who wanted to adopt computer techniques in map-making to the versatile tool kit it is today. In earlier days, computerized GIS were only available to companies and universities that had expensive computer equipment. Now, anyone with a personal computer or laptop can use GIS software. GIS is more than just software, it refers to all aspects of managing and using digital geographical data. One of the first major uses for GIS was in 1964 when the Canadian Geographical Information System (CGIS) was launched to assess the productivity of Canadian farmland [4].

At the beginning of the 1970s, Dr. Barnett Cline realized the potential of GIS for epidemiology and public health for the first time. In Africa, GIS has been employed in livestock research since 1987 at the International Livestock Research Institute (ILRI) in Nairobi to develop and improve the ability to understand and anticipate animal health problems faced by African farmers [2].

Concept of GIS in epidemiology

There is a novel history is behind the concept of GIS applied in epidemiology. In 1854, the community in Broad Street, Soho district of London, UK had the most terrible outbreak of cholera that led to the death of more than six hundred people [6].

During that period the prevailing "miasma theory" stated that diseases such as cholera or the Black Death were caused by pollution or a noxious form of "bad air". John Snow, the father of modern epidemiology reasoned that if cholera was spread by bad air, then the cases should be uniformly distributed along the streets. By talking to residents, he identified the location of cholera victims and plotted each case on a spot map [7].

This map revealed that cases of cholera were distributed in a tight cluster around a public water pump located on Broad Street (Figure 1). Snow went to the pump, took a water sample and observed under a microscope. He wondered that the water contained bacteria that he had not seen before. He also made solid use of statistics to illustrate the connection between the quality of the source of water and cholera cases. Snow then went back to the pump and removed the pump handle. The Broad Street cholera outbreak stopped almost literally overnight. Thus it became a legendary example of how maps can be used in the understanding of, and the fight against epidemiological diseases [7].

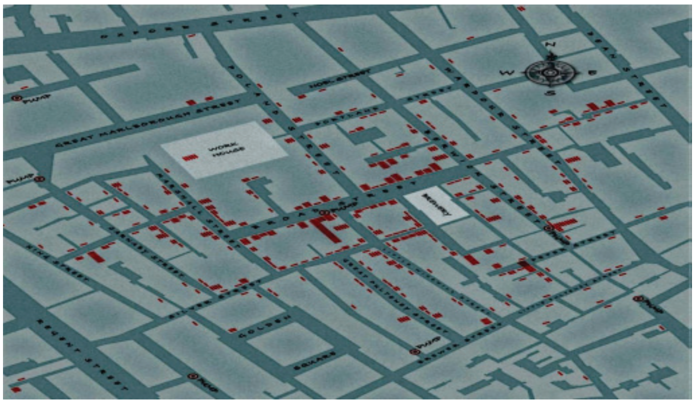

Figure 1: Johon snow"s map of solo, mapping the cholera epidemic of 1854. (source: retrieved from www.merrittcartographic.co.uk/)

Importance of GIS on veterinary epidemiology

Veterinary epidemiology is a holistic approach aimed at coordinating the use of different scientific disciplines and techniques during an investigation of disease and their causation, impaired productivity or welfare of the animal population. In this context, it is highly important to measure the spatial and temporal dimensions of disease occurrence. GIS technology shows the power and the potential of spatial analysis for addressing important health issues at the international, national, and local levels [8].

GIS in animal disease mapping

One of the most useful functions of GIS in epidemiology continues to be its utility in basic mapping. Usually, data collected either routinely or for some purpose are presented in tabular forms, which can be exploited for analytical usage. However, the reading and interpretation of such data is often a laborious and time-consuming task and does not permit easy decision-making. On the other hand, representation of these data in the form of a map facilitates interpretation, synthesis, and recognition of frequency and clusters of phenomena [9].

GIS for epidemiological investigation of complex diseases problems

Geo-spatial tools were used for the collection of data, and outbreak mappings were recorded. The GIS was used in the geospatial analysis and for monitoring the spread of disease outbreaks, herd proximity and outbreak locations and

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topography, distribution of disease serotypes and closeness to features. Recent outbreaks of disease in humans and animals have motivated public health agencies and researchers to develop early disease outbreak detection systems utilizing non-diagnostic information [10]. Advantages of the space-time permutation scan statistic method are that it requires only case data, is easy to use, makes minimal assumptions about the geographic location, time, or size of the outbreak or stranding event, while automatically adjusting for any natural purely spatial and purely temporal variation, and it allows adjustment for space by time interaction [11].

GIS in relation to disease trends

GIS can correlate disease trends with, for example, climatic variation and other information such as entomological data that could be used for predictions. A good example is the prediction of Rift Valley Fever (RVF) in the horn of Africa using satellite images. RVF has been recognized in African countries, for its association with high rainfall and consequential increase in the population of vector mosquitoes. Forecasting can be used to predict climatic conditions that are frequently associated with an increased risk of outbreaks, and help to improve vector-borne disease control Figure 2 [12].

The above map shows as clearly that Eastern Africa was at risk of RVF in January 2007. The dark zones represent regions that have more than normal vegetation coverage during the same period and are zones at risk for vector proliferation and the occurrence of RVF outbreaks in animals and humans [12].

GIS for early warning systems

Early Warning Systems (EWS) is the provision of timely and effective response through the recognized institutions that allows individuals exposed to hazards to take actions, to avoid or reduce risk and prepare for an effective response. EWS is based on the concept of dealing with a disease epidemic in its early stages. From a public health perspective, early warning of outbreaks with a known zoonotic potential of the disease will enable control measures that can reduce human morbidity and mortality rates. The main uses of the early warning system include education as an aid to understanding the crucial elements involved in early detection and response to environmental threats [13].

The availability of climatic, geological, photographic digital data and the accessibility of GIS software also have permitted the implementation of several epidemiological studies in relation to ecological factors and disease prediction, and in providing indispensable evidence that is used before elaboration of control plans Figure 3 [14].

GIS use for disease outbreak

In case of an outbreak of infectious disease, GIS can provide an excellent tool for identifying the location of the case farm and all farms at risk within a specified area of the outbreak. Buffer zones can be drawn around those farms and with a link to tables of addresses of the farms at risk. The farms can be informed within a short time after a notified outbreak. The

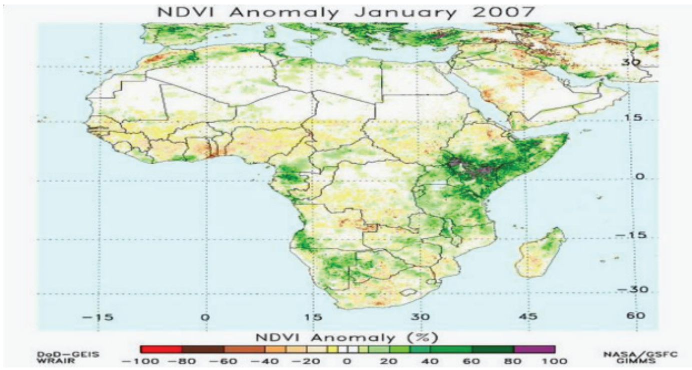

Figure 2: Risk map for Rift Valley fever for the month of January 2007 [12].

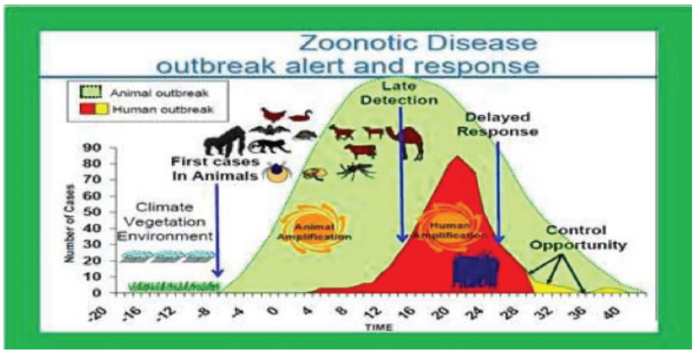

Figure 3: GLEWS approach for prediction of zoonotic diseases (source: Formenty, 2009).

buffer zone can also be generated around other risk areas or point sources, such as roads where infected cattle have been driven or around other risk areas or point sources [15]

GIS for planning disease control strategies

The neighborhood analysis function can be used to identify all adjacent farms to an infected farm. GIS can perform overlay analysis to find high or low-risk areas for diseases which depend on geographical features or conditions related to the geography.

GIS for modeling disease spread

To model the disease spread simulation model using program packages as @Risk (Palisade Corporation, New- field, NY, USA) can be integrated within a GIS. The simulation 16 models can incorporate farm information such as herd size, production type as well as spatial factors like distance from the source of the outbreak, population density, and climate conditions, vegetation, and landscape, all of which have been defined as risk factors for the spread of the modeled disease [14].

Yilmaa and Maloneb (1998) in their study "a geographic information system forecast model for Strategic control of fasciolosis in Ethiopia", they create a model for predicting risk incidences for F. *gigantica* in different agro-climatic regions of Ethiopia by using GIS. The GIS forecast model was constructed based on monthly climate and agroecological zone databases from the FAO Figure 4.

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Use of GIS in the surveillance of animal diseases

To prepare a control strategy, the exact disease status is obligatory to be known. Currently, various monitoring and surveillance networking programs are active. Some of these are the Global Early Warning System (GLEWS) for surveillance of animal diseases such as avian influenza, BSE and FMD [17].

Global Network for Avian Influenza Surveillance (GNAIS), global animal disease information system (EMPRES-i), ArcIMSTM-based web mapping system for swine diseases surveillance, EpiScanGIS geographic surveillance system for meningococcal disease, all India coordinated research project on FMD (AICRP-FMD), Michigan-system to report integrated disease events (MI-STRIDE) for reaching right decisions related to public, animal and environmental health are common GIS programs used in surveillance and control of animal diseases [18].

One good example of the use of GIS in the surveillance of animal diseases is, GIS applied to the international surveillance and control of transboundary animal diseases, a focus on highly pathogenic avian influenza. Occurrences and distribution of HPAI observed from 19 January to 19 July 2006 are represented by the use of maps Figure 5 [19-28].

Conclusion and recommendation

GIS is spreading its wings in veterinary epidemiology, especially on prevention and control of animal diseases to map animal disease information, to study complex animal disease problems and to plan control methods. GIS also provides significant added value on routine data that is usually considered of low value for either epidemiological or management purposes in veterinary sciences. GIS considerably increases the efficacy of communication. The spatial analysis of GIS can be a useful tool in epidemiology, able to add considerable value and insight into animal health problems and their relationship with the physical environment. In the future, GIS will play an important role in veterinary epidemiology to deal with and solve problems of epidemic Transboundary Animal Diseases (TADs) and politically sensitive diseases for which there is a need for theprompt and accurate reporting system.

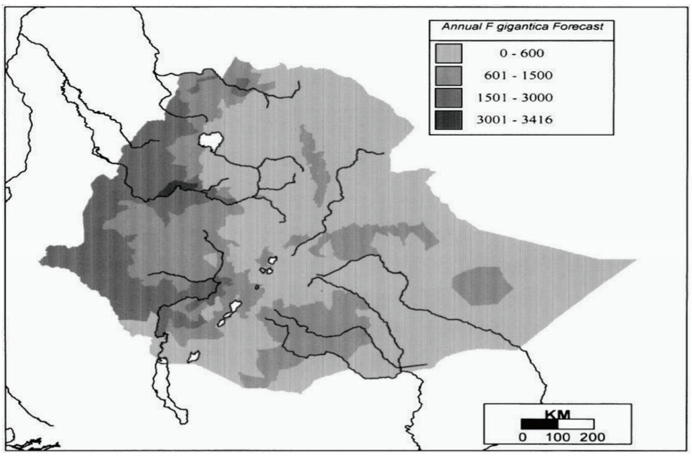

Figure 4: Map of Ethiopia showing annual forecast model of risk indices for F. *gigantica* [16].

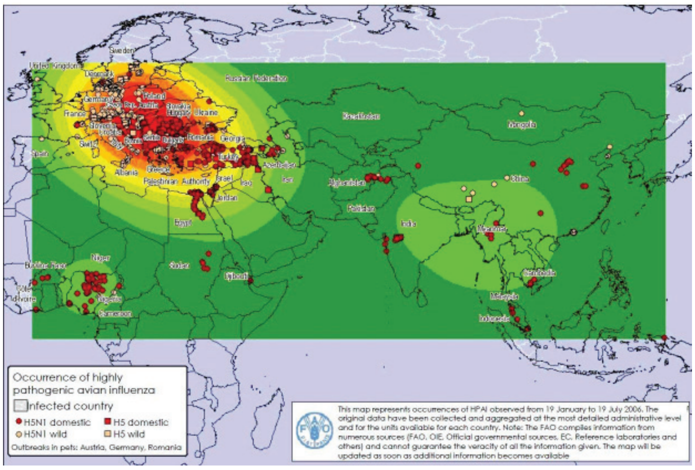

Figure 5: Intensity of highly pathogenic avian influenza occurrence, January-July 2006 [19].

Based on the above conclusion, the following recommendations are forwarded:

- ✓ Veterinary clinicians, field workers, researchers, and university instructors should be a train of using GIS and its application at their respective activities.
- ✓ There should be a further study on GIS technologies, importance, and application in the prevention and control of livestock diseases.

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