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Application of Geographical Information System (GIS) and Mobile Application in Livestock Disease Management in Developing Countries

Damaris Mbaluka[1], George Okeyo[2]

School of Computing and Information Technology, Jomo Kenyatta University of Agriculture and Technology,
Po box 62000-00200 Nairobi, Kenya

Abstract: ***Geographical information system (GIS) is a system for capturing, storing, integrating, analyzing and displaying data which is spatially referenced to the earth. The evolution of mobile GIS is upgrading the science and technology to a new horizon. Disease outbreak in livestock especially nomadic pastoralism is major problem which can be solved using this technology. This is due to movement adapted by farmers to meet the demands of seasonally available water and pasture. The main objective was to develop a model that will be used in the veterinary department to report, monitor, and control of livestock diseases. Data was collected using questionnaires in Kajiado County. Veterinarians agreed that tracing farmers in the field while grazing to give health services is difficult currently. A mobile Android-based application to report disease outbreaks by farmers was developed and integrated with GIS which is a web based mapping application to display the details sent by the farmer and location of the farmer using GPS. The evaluation of the model shows Geographical location is important when mapping disease prone areas to control livestock diseases. The study recommends developing of a GIS Cloud Mobile Data Collection system to collect of livestock diseases data in real time mode.***

Keywords: geographical information system, global positioning system, Livestock, Mobile devices, Kajiado County

1. Introduction

Nomadic pastoralism is a major and efficient low-cost method of animal husbandry in arid and semi-arid (ASAL) areas of Africa. It remains one of the indigenous strategies best adapted to climate disturbances due to frequent drought in dry land areas [1]. In arid and semi-arid areas, movements become important adaptive measures used to meet the demands of seasonally available water and pasture. Disease causing agents called pathogens benefit greatly from dynamic states created by animal movements because infected and susceptible animals come into contact as they share common resources e.g. watering points, salt licks or grazing field [2].

In Kenya, 70% of all household are engaged in crop or livestock farming; about 80 % of them depend on livestock in their livelihood in rural area. It estimated that over 60 % of livestock in Kenya is kept by pastoralist in arid and semi-arid lands [3].The lifestyle of the majority of the population depends on livestock and livestock products for subsistence. Many animals in these ASAL areas die in the field out of disease outbreaks. This is because farmers are not able to access veterinary services due to long distance movement looking for pasture and water. Development of the livestock sub-sector is relatively neglected by policy. Public funds allocated to livestock development are low (less than 10% of the annual national development expenditure) [4] thus, most farmers have limited access to better farm technologies, requisite skills and market services. Further, weak linkages between research-extension service providers and farmers are considered to contribute to low and/or inappropriate use of inputs by farmers. As a result, agricultural productivity and growth are relatively low; yet the agricultural sector is expected to play an important role as the engine of national economic development [5]. The popularity in GIS applications leads to development in various GIS tools. The software helps manage geographical information in many ways such as collecting associated data for landmarks in traveling and directions [6]. Disease surveillance in livestock is essential to know the quick status of animal diseases in a region for taking appropriate action. GIS is a good tool to identify the disease that is prevailing in an environment and emphasizes on the proper understanding of the geographical distribution of disease which is essential for the establishment of disease free zones, and management of veterinary resources [7].

It is necessary to build animal disease information system in order to dynamically monitor and predict diseases distribution, and propagation. Powerful functions of data management analysis and display with the GIS can be applied oriented to animal disease information. This disease information platform can be applied to dynamically monitor and predict disease, as well as to support the disease prevention decision making, in order to decrease the loss. GIS is an important tool to locate the farm or place of outbreak and identification of areas at risk if an infectious disease occurs [8]. The spatial as well as the temporal dimension of disease occurrence is important to measure. GIS technology show the power and potential of spatial analysis capabilities for addressing important health issues at the international, national, and local levels. Although the last decade has seen an increase in the application of the GIS in the field of veterinary epidemiology at local and country level, very little has been done on veterinary application to co-ordinate the notification and management of pandemic diseases. Today there are many Geographical Information Systems developed that only target known farms. There is a need for the specialized user-friendly GIS software to become more affordable and readily available for the application of this technology in resource-limited developing countries [9]. Access to global positioning systems (GPS) and mobile computing technology provides opportunities for

integrated data to be transformed into information for action such as georeferenced modeling and risk mapping [10]. This forms ubiquitous GIS which is based on mobile computing technology environment which offers mobile and distributed geographic information services. It integrates geographic information system (GIS), global positioning system and wireless communication [11].

This paper explores the use of geographical information system and a mobile application to locate the farmer in the field and analyze the areas that are prone to disease outbreak. The farmer is provided with a mobile application to send symptoms to veterinary office, where the information is processed. It indicates the location of the farmer and a veterinarian is availed with the right medication. This information is stored in database to be used to analyze areas where diseases are prevalent. This analysis can be used as early warning for disease occurrence in a certain area.

The rest of the paper is organized as follows; section 2 presents literature survey. Section 3 describes the method used. In section 4 the paper presents the result and evaluation of the study and section 5 presents conclusion and 6 future work for the research.

2. Literature Survey

Indeed so much literature exists of work that has applied livestock disease management using GIS. A detailed review was done with different emphasis, on the models developed to control, monitor, record and analyze livestock diseases. The first model reviewed in this study is GeoCREV, which was developed by Unit of veterinary Epidemiology in Italy. It is a geographical information system for accessing and analyzing veterinary data integrated with geographical information, [12].The objectives of GeoCREV are to facilitate and coordinate the exchange of spatial assets among stakeholders of the regional veterinary services. The available information on animal resources is extracted from the following operational source systems: regional livestock holding database, the laboratory information management system (LIMS), animal diseases notification system (ADNS), national cartographic data warehouse at the Italian Ministry for the Environment. Once the requirements for access and the availability of the database content had been specified, the integration and transformation layer (I&T) was developed. A GIS data mart management module, which processes and integrates I&T data into the geo-relational database by means of specific spatial table-views. In GeoCREV data is collected from various sources in the region and integrated with spatial data. This data is collected manual and only used by the veterinarians in the region which can slow data analysis and transmission.

The second model reviewed is ArcIMS^{TM} which is a web based mapping application that enables veterinarians to explore high resolution maps of swine disease surveillance in the state of Minnesota Italy using GIS technology [13]. The system is coupled with a database to enable veterinarians to edit farm attribute data and disease status throughout the internet. It also allows in cooperation of new diseases. A customized database to enable remote web-based data entry by veterinarians using internet is available. This model is only used by the veterinarians to survey swine diseases only and farmers have no access to the system or information in the model which can help in the surveillance.

The third model is EMPRES-i [14], which is a web-based application that has been designed to support veterinary services by facilitating the organization and access to regional and global disease information. It provides a platform to share information among animal health officers in FAO headquarters and in the field as institutions involved in disease-outbreak management and emergency response. The aim of EMPRES-i is to record, analyze, and monitor data on major trans boundary animal diseases. It has been linked to a global information system (GIS) application to provide visual representation of the disease distribution patterns and to explore the relationships among location, environment, and disease.

The fourth model is National Animal Disease Referral Expert System (NADRES) launched for GIS mapping of certain diseases, including FMD, bluetongue, and anthrax in India [15]. NADRES visualizes countrywide digital input of disease data from the field in the near future. It is developed as web based dynamic and interactive livestock disease relational database supported by Geographic Information System (GIS) which serves as an Epidemiology software. It addresses the needs of data collection, transmission, retrieval, analysis of critical reporting of disease events as and when they occur and useful for field veterinarians, administrators, technocrats, research personnel, farmers, veterinary colleges and students. It has no defined way of reporting disease outbreaks by farmers.

The fifth model is Artificial Neural network (ANN) developed to predict the abundance of *C. imicola* and *C. bolitinos in* the Western Cape of South Africa [16]. In doing so they were able to predict the abundance of species at sites where no actual counts were made. The dataset used in the model includes; climate data, distribution of Culicoides imicola and Culicoides bolitinos, Clay areas and water bodies, normalized difference vegetation index and land surface temperatures, altitude and Reported outbreaks of African horse sickness. The data sets described above are combined into a GIS model and after incorporating the data into the GIS, the data were extracted for use in the ANN model using all the Culicoides capture sites as extraction points. To start the ANN training process, the training and verification sets of data were imported into the ANN software, which uses a feed-forward network with back propagation as a training algorithm. This prediction can also be used for subsequent years provided that anomalies in monthly temperatures or rainfall are minor. By extrapolation, this model can be used to anticipate potential outbreaks of diseases like bluetongue, epizootic haemorrhagic disease and equine encephalosis, which emphasizes the importance of this predictive model internationally. By using this model as an early warning system to predict the abundance of these vectors action can be taken to protect animals at risk and thereby lessen the impact of the disease The model is not trained to make predictions in certain areas because there are no actual counts that can be used to train the ANN and combined use

of a GIS and ANN to predict species distribution lacks of a direct interface between the models hence a high level of software knowledge and computer training is required.

The proposed model is an integration of GIS and mobile application for reporting, recording, monitoring and controlling livestock diseases in ASAL areas. The model is aimed at improving disease control for livestock for farmers who are not necessarily stationed on known farms, but move from one place to another in to meet the demand of seasonally available water and pasture. The model takes the advantage of evolution of mobile devices which is a cellular phone which executes computer programs, and connects to the internet and/or mobile/computer devices. Mobile devices have become the preferred mechanism for many people to interact. The model integrates GIS technology with mobile devices to facilitate communication which is called mobile GIS where there is an Extension of a GIS from the office into the field. To report disease outbreak farmers use a mobile application to send details and with the use of GPS the veterinarian is able to trace the location of the farmer and respond promptly.

3. Method/Approach

Research design

This study was conducted through experimental research design and descriptive survey design. During development the model was tested to experiment and ensure that the model is working in the manner in which it was intended. A descriptive survey was also used which provides numeric description of some part of population. This design was used by distributing questionnaires to veterinarians to the information they have about current methods used in disease control, the use of GIS in livestock disease control. Veterinarians from different sub counties participated by filling questionnaires and gave their feeling on what was happening currently in the county to control livestock diseases. This was done in the light of investigating the use of GIS in livestock disease management in the sector. The effectiveness and performance of the developed model, was evaluated by administering questionnaires to the veterinarians. The questionnaires were analyzed using a statistical package.

Methodology

Rapid application development (RAD) was used as the methodology to design the model. This method uses minimal planning in favour of rapid prototyping. In RAD model the components or functions are developed in parallel as if they were mini projects. The method helps in integration from very beginning to solve a lot of integration issues. The web application of the model was developed independently, and then the mobile application developed, then integrated. The presence of the prototype being examined by the user prevents many misunderstandings and miscommunications that occur when each side believe the other understands what they said. Since users know the problem domain better than anyone on the development team does, increased interaction can result in a final product that has greater tangible and intangible quality. The final product is more likely to satisfy the user's desire for look, feel and performance.

The proposed GIS model

Model Architecture

A mobile GIS model was developed to allow farmers report disease outbreak using a mobile application. The mobile application is used to report an issue from the grazing field. The veterinarian is able to locate the farmers using GPS with ease and respond fast. The mobile application is used by farmer to send some information whenever they notice a disease. The information is directed to the database and it is displayed on the veterinarians' desktop and location of the farmer on a web application. Output will be displayed on a map in the veterinarians' desktop for decision making and further direction as shown in figure 1 below. Disease information is stored in a database in the desktop for further analysis and disease mapping. The GIS model is an integration of two components, which are; a mobile application and a web application.

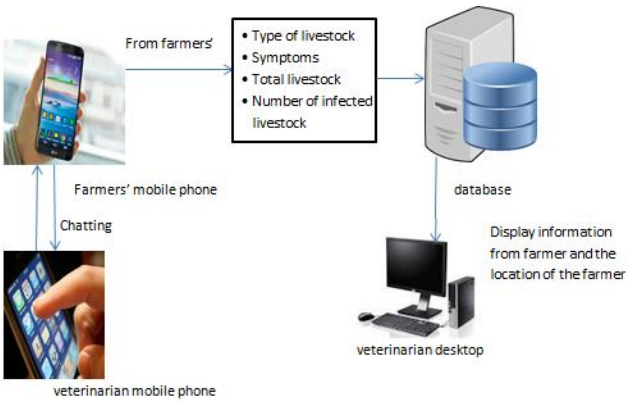

Figure 1: Architectural design of the model

The mobile application

A mobile application is used by the farmers to report disease incidences. The mobile application allows the farmer to send; the type of livestock infected (e.g. cow, goat or sheep), the observable symptoms which are already populated in the database, the number of the infected livestock and the total livestock that the farmer has. This is done by filling a form as shown in figure 2 below. This information gives the veterinarian some background information to prepare before visiting the farmer. The mobile application has a chat option for the farmer and the veterinarians to communicate more for any further clarification as shown in figure 3 below.

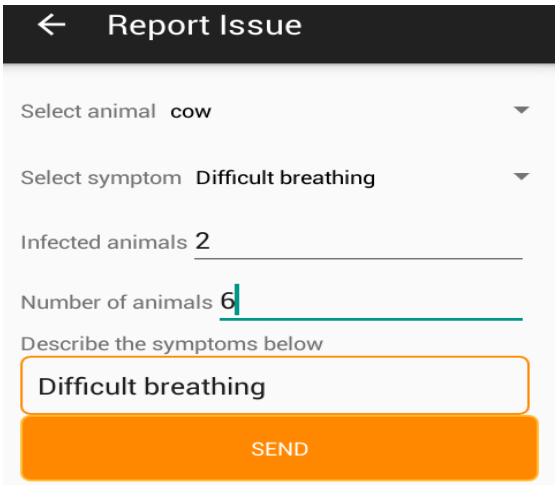

Figure 2: Disease reporting form

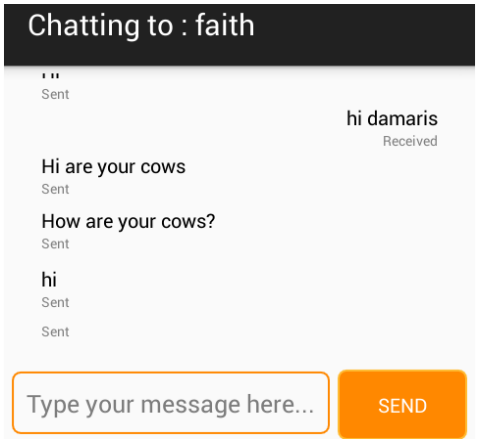

Figure 3: Chatting screen

The web application

A web based mapping application is used by the veterinarians. The web application in a map displays the exact position of the farmer using GPS, this is after a farmer reports an issue as shown in figure 4 below. The map also shows the information that the farmer sends i.e. type of livestock infected, the observable symptoms, the total number of livestock and the number of the infected livestock, date and time sent in a popup screen as shown in figure 5 below. This would help the veterinarian to figure out the kind of first aid requirements to be carried in the field and also know the exact position of the farmer. A veterinarian can query posts from farmers done in a given period of time for analysis the kind of diseases reported in a certain period of time in a given area. This will assist in mapping areas prone to disease outbreak hence improve disease control and early warning as shown in figure 6 below.

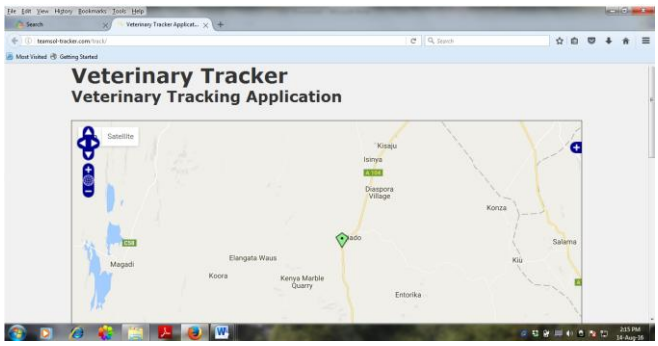

Figure 4: Web application showing the location of farmer

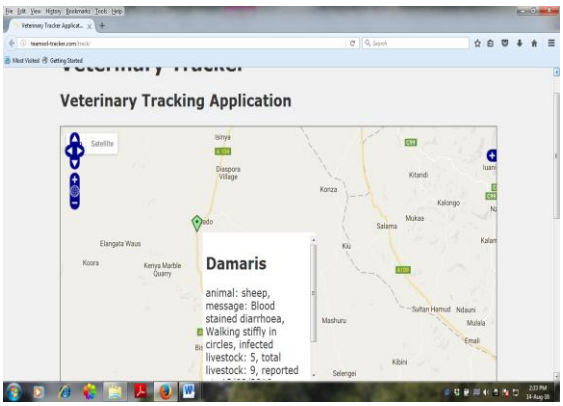

Figure 5: Web Application showing the information sent by the farmer

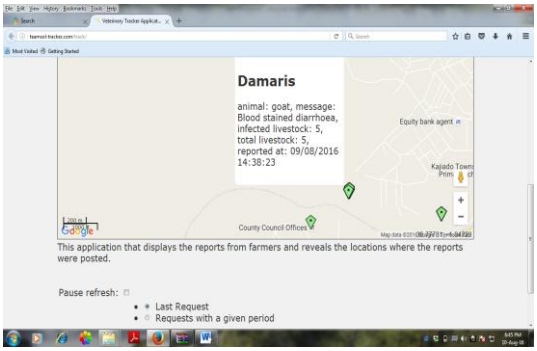

Figure 6: Web Application showing output of a query

4. Results and Discussion

Initial investigation results

Data was collected using questionnaires in Kajiado County, with 36 veterinarians purposively sampled to providing information on what is currently in the ground. The initial investigations in this study shows 47% of the veterinarian think that the method used to report livestock disease outbreak is not efficient, 27% of the veterinarians feel that some farmers are far from the vet offices which makes it very difficult to control diseases, 22% of the veterinarians feel that phone call from the farmers have helped in livestock disease control and 4 % think some farmers use traditional herbs instead of reporting which hinder proper disease control. Further in study 52.8% veterinarians felt that the method in place is poor for disease control and it requires improvement, 30.6% felt that the method in place is average for disease control and 16.7% veterinarians feel the method is excellent for disease control.

Web application evaluation

To evaluate the performance and effectiveness of the model, a demonstration of the model was done to the veterinarian and questionnaires were administered to 22 veterinarians who participated. The evaluation was done on the web application, the mobile application and the integrated model. In this study the results show that 36% of the participants feel that the model will enable faster reporting and disease control, 36% of the participant feel that the model helps in disease preparedness, the study shows 14% of the participants feel that the model is effective in monitoring of diseases, 9% of the participants feel that the model enables proper recording of disease outbreak thus timely response and 5% feel that mapping helps in disease control as shown in figure 7 below.

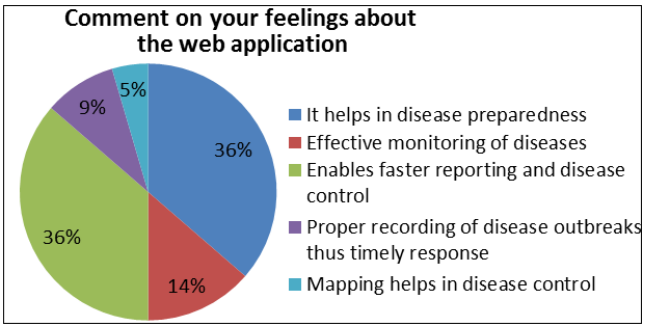

Figure 7: Comments on feelings about the web application

Mobile application evaluation

During evaluation of the mobile application, 45.5% felt that the mobile application is very effective in disease reporting and control, 40.9% felt that farmers can be easily reached in the field, 9.1% felt that the affected location are easily reached and 4.5% felt that the mobile application is easy to use as shown in figure 8 below.

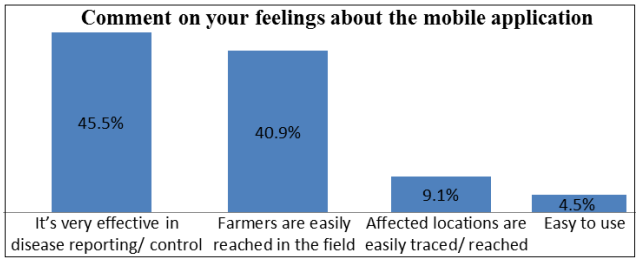

Figure 8: comments on feelings about the mobile application

Evaluation of the GIS integrated model

The integrated model was evaluated and the results are shown on table 1 below. On disease analysis 82% of the veterinarians strongly agreed that the GIS model can help analyze disease incidences very fast. Further on record keeping, 82% agreed that the model can enhance proper recording keeping while 68% felt that the model allows fast record retrieval. In terms of disease report reporting, 77% agreed that the GIS model allows for fast reporting of diseases hence quick response. On monitoring, all the farmers agreed that the model allows for proper monitoring of livestock disease outbreak with 45.5% strongly agreeing and 54.5% agreeing. On early warning, all the veterinarians feel it can be used with 31.8% strongly agree that the model can be used for early warning hence proper preparedness and 68.2% agreed.

Table 1: Veterinarians feeling about the GIS model

Statement	SA(5)		A(4)		NS(3)		D(2)		Sd(1)		Weighted Mean
	f	%	f	%	f	%	f	%	F	%	
The GIS model can help analyze disease incidences very fast	18	81.8	4	18.2	0	0	0	0	0	0	4.82
The model enhances proper record keeping	4	18.2	18	81.8	0	0	0	0	0	0	4.18
The model allows fast record retrieval	7	31.8	15	68.2	0	0	0	0	0	0	4.34
The GIS model allows for fast reporting of disease hence quick response	17	77.3	5	22.7	0	0	0	0	0	0	4.77
The model allows for proper monitoring of livestock disease outbreaks	10	45.5	12	54.5	0	0	0	0	0	0	4.46
The model can be used for early warning hence proper preparedness	7	31.8	15	68.2	0	0	0	0	0	0	4.34
Fast and informed decisions can be made when using the model	9	40.9	13	59.1	0	0	0	0	0	0	*4.44*

Discussion

The study shows Geographical location is important when mapping disease prone areas and mapping areas prone to disease outbreak encourages disease control and early warning. It is evident that disease reporting method is poor since many farmers make call, others walk to the offices while others do not report hence poor disease management. Veterinarians agreed that tracing farmers in the field while grazing to give health services at the moment is difficult hence a mobile application can be used to help fast reporting of diseases and trace farmers in the field while grazing. A GIS model taking advantage of GPS and mobile technology was, developed to meet veterinary sector demands for a method of reporting, mapping, recording diseases and improve disease control and management in nomadic pastoralism. The model can also be used to gather more information from farmers through chatting which can be useful to make informed decisions further the model helps trace the exact location of the farmer in the grazing field which is usually a challenge due to movement. It is evident that animal movement promotes fast disease spread and quick response is of importance to reduce the rate of deaths due to disease outbreak. The evaluation results show that many veterinarians felt that the web application can help to monitor disease occurrences, help in early preparedness hence proper disease control. The veterinarian felt that the mobile application was effective to report disease outbreak and help to reach farmers easily using GPS. It is evident that most of the veterinarians felt that the GIS model can help analyze disease incidences very fast, enhance proper record keeping, and allow for fast reporting of disease hence quick response.

5. Conclusion

This study investigated application of geographical information system (GIS) and mobile platform in livestock disease management. It aimed to develop a GIS model integrated by a mobile application to facilitate disease reporting, recording, monitoring and control. This was in relation to problem of controlling livestock diseases in arid and semi-arid areas. In ASAL areas movement is an important adaptive measure use by pastoralist to ensure that livestock survive. Disease causing agent area spread very fast due to animal movement. The study established that GIS integrated with a mobile application is a very effective tool to control livestock diseases in arid and semi-arid areas though it has not been majorly exploited in Kenya. In view of these findings, the study concluded that geographical information system integrated with a mobile platform is very effective and efficient in livestock disease management in ASAL areas where livestock movement is inevitable. The evolution of mobile GIS is upgrading the science and technology to a new horizon. Hardware and software for mobile devices is advancing at a very high rate hence giving a chance for developer to explore new dimension of their application. The mobile devices a rich in their communication capabilities with the increase in bandwidth of present wireless networks, and it is a handy tool to geospatially transfer knowledge online as it connects the owner of the knowledge to the requester.

6. Future Work

The study recommends developing of a GIS Cloud Mobile Data Collection system for web and mobile devices which would allow collection of livestock diseases data in real time mode.

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