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Use of Interactive 3-Module Integrated Livestock Health Service Mobile Application-Livestock Diseases Adaptive Capacity and Capability Building

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Abstract:- Integrated veterinary service mobile applications provides a faster, nearly real-time, and accurate reporting of livestock diseases. Active participatory epidemiological data collection using an online platform forms a prerequisite for early detection and response which prevents the spread of the disease outside the foci of the outbreak. Compared to the traditional pen and paper method, the use of mobile applications was faster and reliable and connected farmers to animal healthcare service providers more reliably. In the backend, the disease data was aggregated by animal species and to farmer biodata and geolocation. Animal health care provider module allowed a quick response focusing on spatial location. Detailed list of signs and symptoms as described by the farmer allowed a putative disease diagnosis and follow-up at all administrative levels. Researchers, we are able to collect current epidemiological data of the most prevalent diseases of cattle, sheep, and goats. Most of the diseases reported through the app were classified as notifiable diseases in Kenya which impose international livestock trade restrictions. Initially, heavy losses are occasioned in livestock due to lack of reliable reporting to facilitate faster response. The tool was also able to map and assess the disease burden and potential zoonotic disease risk. Although reporting through the e-platform resulted in much more timely and reliable reporting and feedback, limited connectivity and lack of smartphones in some regions delayed the process. However, in the long run, with the widespread use of smartphones, the approach will greatly improve animal disease reporting and surveillance, enhance data integrity, and enhance disease response strategies. Field data collection, transmission, and analysis allowed dissemination of validated feedback prompting an immediate response, and served as an early warning response.

I. INTRODUCTION

In the past, disease incidence reporting relied on pen and paper for reporting and data collection. Technological advancements have allowed not only digitization of data collection but also real-time data transfer. Digitizing this process has hastened the response by enabling mobilization of all involved stakeholders with a touch of a button and in a real-time manner. Digital processing and storage of disease data form a disease reporting database from which geo-health analytics and dynamics of various diseases can be made possible. In the same light, the technological surveillance tools developed will enhance almost real-time reporting of disease incidence in Arid and Semi-Arid Lands (ASAL), upgrading the rigorous and time-consuming method. Chethan Kumar et al., 2021) Pilot studies have shown that this model can be very sustainable as a three-face business model connecting the main actors in the community benefiting across professional, social, and economic spectra.

Kenya in the past years has had an increase in livestock population going by the statistics over the years since 2009, and the recent in 2019, that is, 2.3 million animals by Kenya National Bureau of Statistics (*Livestock Population - Kenya National Bureau of Statistics*, 2019.). Prediction of trends in the future can be based on the valid available data in that an increase is expected as well as determining the expectancy of produce increase of animal food sources (Merianos, 2007). Arid and semi-Arid regions account for over 60% in the past years. A background check on its marginalization then the various challenges that the ASAL's areas experience in terms of livestock keeping varies from the technological aspect of veterinary services provision, elaboration of reporting, and collection of data. Therefore, Information Communication Technology (ICT) is a big player in the new age information system in the light of one health approach, enhancing detection, almost real-time reporting and response, then there is a need to have a surveillance tool that that incorporates technology in service delivery (Karimuribo et al., 2017).This research details a technology surveillance tool used by farmers to record data and the developers in processing it. The technology was aimed at having a variety of information; disease incidence, treatment practices, antibiotics, vaccines, and animal health services reliability in conjunction with affordability. However, not only can the technology be used in assessment of the above, but also other animals, human disease surveillance, and even other agricultural purposes. The application examined data collection, analysis, presentation, and reporting findings on disease surveillance. The core objective of the research was to establish a disease surveillance database and collect data represented on a recurrent geographical map which is important in the provision of data regularly on animal health status and give variation in seasonality.

Many disease reporting e-platforms have been developed (*Animal Disease Information System (ADIS)*, 2020)(Hernández-Jover et al., 2021). A similar approach was made for epidemiological risk surveillance (Lesmanawati et al., 2020), ranks diseases risks by relevance to country and epidemiological risk as per periodical epidemics. This was devolved further in our approach to report and capture data from the village level. The surveillance technology app was objectively used in the prediction of future health risks, using information on animal disease dynamics with climate change and human factors. This is to enhance change and adaptive behavior in nomadic pastoral communities. In addition, assessment of emerging and reemerging diseases that have the potential to be epidemic and have socio- economic impact on farmers in terms of mortality and morbidity (Wu et al., 2016). For example, during an outbreak of animal disease, intervention can be done by restricting animal movement to slow down and stop the transmission of diseases to other regions.

This tool will be of importance to various stakeholders' locally, regionally, and globally. It seeks to benefit the government by ensuring that resource mobilization for sustainable health management is appropriately distributed, for instance; in case of an outbreak of a disease in a certain area, then vaccines or drugs can be distributed to them to solve the situation instead of mis appropriately distributed equally even to areas that are not endemic. The researchers also become beneficiaries through understanding on the disease trends in predicting the future and know on which research topics to pick on, also farmers get to benefit from health care through direct linkage to the Animal Health Assistant and Veterinary Officers in treatment and managing diseases The disease surveillance database was developed using new open-source technology that are easily retrievable (Guernier et al., 2016; McGreevy et al., 2017) Building on such previous studies, we used new language technologies to improve real-time data information generation and retrieval. Real-time information generation is an uphill endeavor from previous technologies. This involves a geolocated skeleton mapping of data surfacing. Two methods were applied; quantitative study of epidemiological alerts, followed by an in-depth qualitative data collection by interviews using the methods described by to determine the completeness of data.

II. MATERIAL AND METHODS

➢ *Study Area*

The study was conducted in Kajiado County of Kenya located within the Rift Valley region of Kenya spanning an area of 21,292 sq kilometers. It borders Nairobi, Kiambu, Machakos Taita Taveta and Norok counties bordering Tanzania to its South. It has an estimated population of 117,840. Agro-pastoralism and nomadic pastoralism are the main livestock production systems practiced and participants were selected based on these criteria. The study was a collaborative project between Veterinary science Research Institute (VSRI)- Muguga of Kenya Agricultural & Livestock Research Organization (KALRO), University of Nairobi (UON), Directorate of Veterinary Services (DVS) Kajiado and Ministry of Interior and Coordination through area and local authorities. This research was funded by Kenya Climate Smart Agricultural Program (KCSAP). Selected locations of the study included; Magadi, Matapato South, Rombo, Matapato North, Kenyawapoka, Dalaketuk, Ewasokedong, Kimana and Imaroro locations.

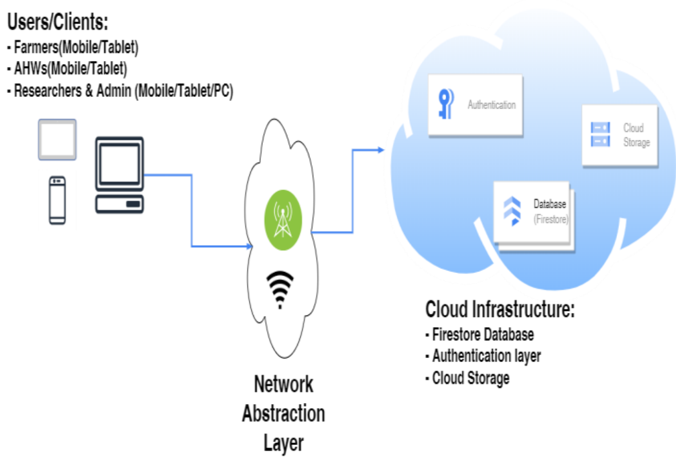
➢ *Study Design*

Descriptive study was based on the analysis of routine data transmitted by Community Disease Reporters (CDRs) from all selected areas. A total of 109 community disease reporters (CDRs) were identified with the help of Kajiado County Directorate of Veterinary service (CDVS) and the local chiefs. The CDRs were trained on the use of technology as a reporting tool for diseases. The phone application was installed in their phones and subsequently trained on data entry. Participants were selected based on the criteria that they had a heterogenous herd composed of cattle, sheep, and goats. The study involved participants from 11 regions, from each region, 10 representatives were picked to represent the village or a location. Questionnaires were also administered to 102 participants in nine focus group discussions at selected sites to assess the completeness of data.

➢ *Mobile Application Architecture & tools*

The architecture of the app was split into three main layers, namely; user layer, network abstraction layer, and cloud infrastructure. User layer includes the user interfaces utilized in data collection and visualization. It also features the basic app functionality such as user location determination, camera protocols, etc. Network abstraction layer is the internet connectivity of the user devices that allows data to be posted to the cloud database as well as uploading of the picture files associated with each post. Cloud infrastructure has three main components. The online database that holds all user data, the authentication layer for security, and cloud storage to store the picture files sent by users.

The architecture can be summarized as follows:



The app was developed utilizing a number of open-source tools and platforms, namely; Android platform, Firebase, and Node package Manger. Android platform was utilized to create the user interface and app functionality for the farmer and AHW modules. This was done using the Android Studio IDE where elements of the user interface were designed using the XML language while the functionality was developed using the Kotlin language. Firebase, which is a Backend-as-a-service (BaaS) app development platform, was utilized to host the app as well as give cloud functionality to the app. Through this, an online database was setup to allow for the gathering of data from the app. It also allows for the setup of security features, i.e., user authentication, as well as cloud storage for photos taken through the app. All this was done using the Firebase Fire-store tool for the online database, Firebase Authentication tool for security features, and Firebase Storage tool for cloud storage. Node Package Manager (NPM) was utilized for the development of the server functions through the use of the TypeScript language.

As part of a capacity and capability building initiative, the app was disseminated through direct installation of the app APK into the phones of selected farmers and animal healthcare providers. The farmers were then taken through the prompts of the system, recording their biodata as well as the reporting of animal cases and underlying syndromes and medical interventions made by them, further allowing the animal health professional to have a wholistic view of the reported case. This was further enhanced by the farmer being required to submit a photo of the sick/dead animals. The same mobile application was provided to selected animal health workers of the region. They were also taken through the reporting process that the farmers went through as well as the case solving process through the application. From the back end hosting the research and admin module, data was organized, processed, and synthesized.

➢ *Data Analysis*

Data was extracted from the backend interface of the surveillance platform, manually organized in Microsoft Excel, and cleaned. It was then classified into key thematic areas of the surveillance platform to allow qualitative analysis. It was then exported to GraphPad Prism version 9.3 and analyzed, then presented using charts, graphs, and spatial representation on climate maps for temperature and rainfall. Collectively, qualitative data were synthesized and identified the capacity and capability of an integrated veterinary service mobile application alongside its constraints. A thematic illustration of the various diseases focusing on space was created to summarize the key findings.

III. RESULTS

Active farmer participation through farmers' group discussion established that shortage of pasture due to prolonged drought and lack of water for their animals was the main challenge in nomadic pastoralism. Diseases were the second most devastating challenge due to lack of animal health products and services such as agrovet supplies, vaccines, and veterinary services. Lack of agricultural extension services ranked third due to the few numbers of extension officers covering a very wide area. Wildlife conflict ranked the least challenge in the ASAL area of Kajiado. Wildlife conflicts may arise within human-livestock-wildlife interfaces when farmers raid parks for pasture and when wildlife raid agropastoral areas. These interactions were observed to increase the risk of disease.

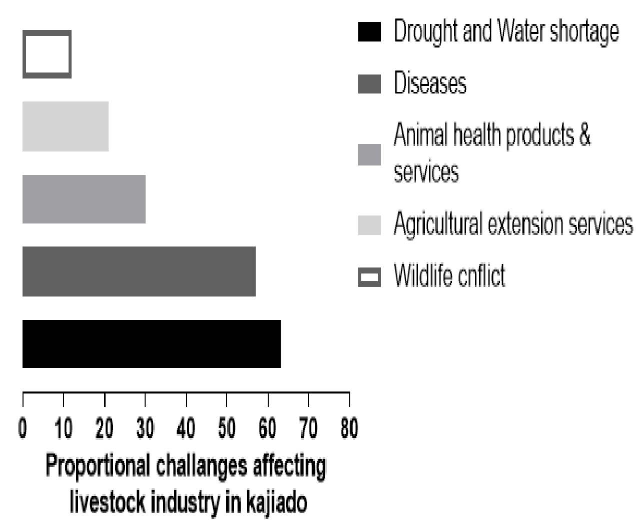


Fig 1: Proportional challenges reported to affect livestock farmers in Kajiado County

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➢ *Animal Disease Reporting*

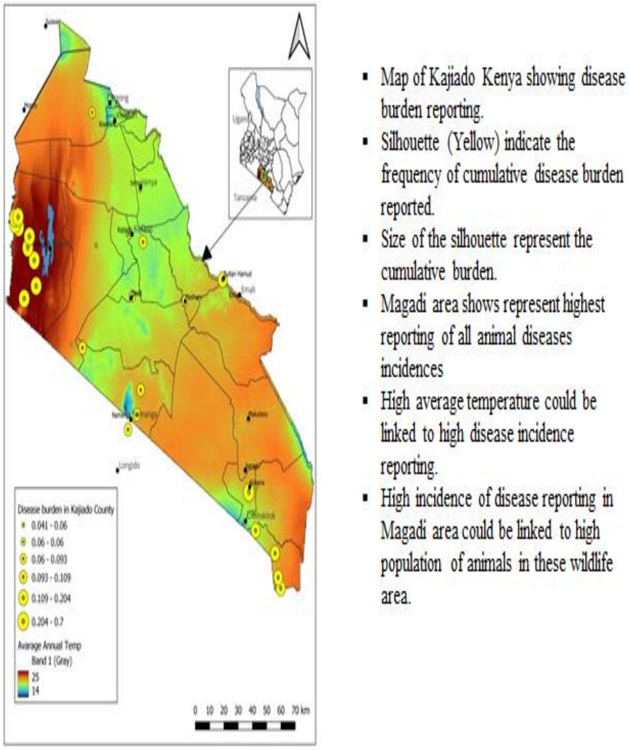

Fig 2: Map of Kajiado, Kenya, showing relative disease burden reported

- *Cattle Diseases*

In cattle, the viral diseases that were frequently reported include lumpy skin, FMD, bluetongue virus, and pox. Bacterial diseases include pink eye and foot rot. Protozoan diseases include trypanosomiasis, ECF, and mange. Helminthiasis includes the bottle jaw. Cattle showed a high prevalence of lumpy skin disease in the region, and per location trypanosomiasis was more prevalent in Magadi. Magadi location had the highest cumulative reporting for all diseases categorized. Cattle are the most important livestock to the Maasai community. Being a small community, set back by new information and technology, Maasai people struggle to treat their cattle or find professional assistance. Pink eye was the least reported of all cattle diseases found in the study area. When ranked by occurrence; lumpy skin disease, trypanosomiasis, and FMD were the diseases of most concern in the Kajiado region. Among the classes of diseases, viral diseases showed the most prevalence at 56%, protozoan diseases 29%, helminthiasis 9%, and bacterial diseases at 6%.

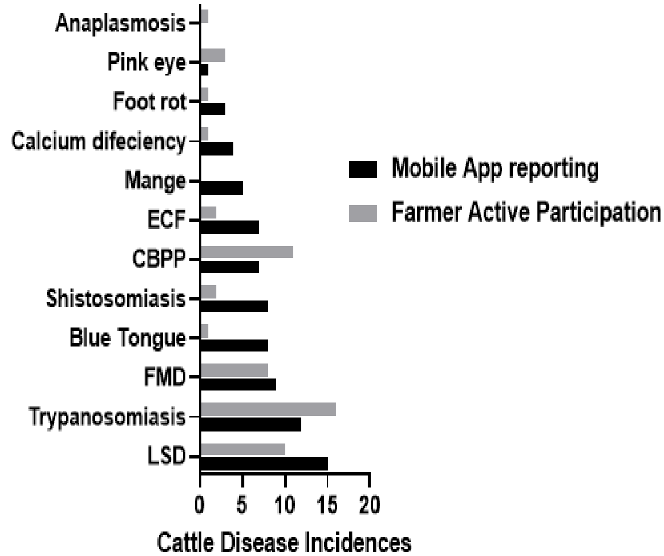

Fig 3: Proportional cattle disease incidence reported over the study period

- *Sheep and Goats' Diseases*

Diseases that were reported in many cases in Kajiado county were; Sheep and Goat pox, PPR, bluetongue virus, anthrax, CCPP, enterotoxaemia, pink eye, heartwater, hemonchosis and mange. Small ruminants are more susceptible to diseases than large ruminants. As such, viral diseases showed the highest prevalence in small ruminants, 43% (per cent), with PPR showing the highest prevalence of all cases reported. Heartwater has been an emerging disease with a relatively high prevalence rate. The farmers described the diseases by their clinical symptoms, for instance, PPR was described by dysentery, nasal discharge, and lesions in the mouth. Heartwater was described by their clinical symptoms of imbalance and confusion. CCPP was described as nasal discharge, respiratory distress, lack of appetite and coughing, and sudden death. Magadi locations had the largest representation of cumulative totals of disease occurrence when ranked per location. Hemonchosis coenurosis was the most prevalent helminthiasis of all diseases reported in small stocks. Hemonchosis was characterized majorly by anaemia, bottle jaw, and diarrhea. Coenurosis was characterized by confusion and loss of balance in the animals. Moreover, spinal cyst was common among the small stock where sheep and goats presented with paralysis.

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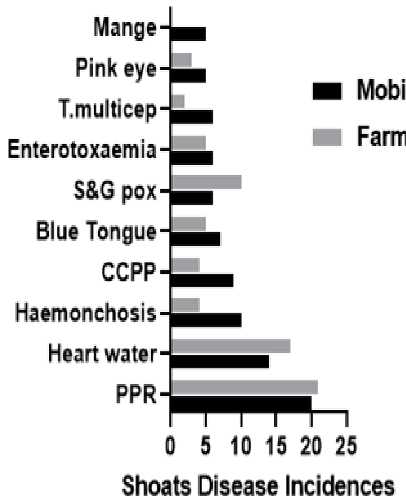

Fig 4: Proportional shots diseases reported in Kajiado county over the study period.

- *Animal Treatment and Care.*

Animal health treatment and care services were low in Kajiado county (19.27%). In fact, this has led the majority of the treatments to come from the farmers themselves (58.85%). Veterinary services are required as locals may injure or misdiagnose the animal during treatment and care. In some areas, the animal health assistants and farmers would both treat the animals.

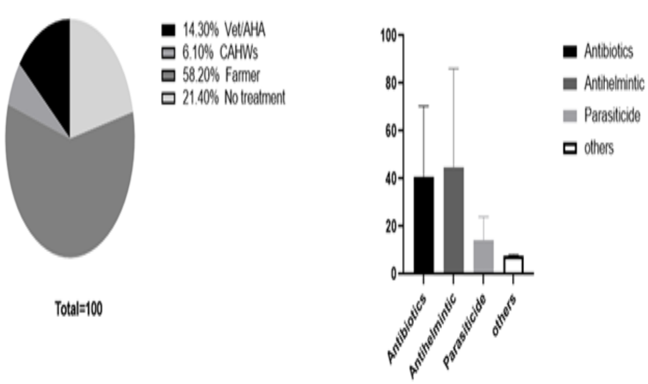

Fig 5: Proportional service delivery and commonly applied drugs for animal treatment

- *Antimicrobials And Anthelmintics Used by Farmers.*

Majority of participants indicated that they treated their animals individually due to the unavailability of veterinarian services, and if present, they were unreliable. Antibiotics that were commonly used in Kajiado county were; penicillin-streptomycin, tylosin, oxytetracycline, Meriquin, and ivermectin. Tetracycline was the most used broad-spectrum antibiotic to treat most diseases, some participants stated that they used tetracycline concentrations from 5 to 30%. Most participants used ivermectin as both an antibiotic and anthelminthic drug. Tetracycline and PenStrep (penicillin and Streptomycin) were the most used to remedy for most diseases, viral and bacterial. Furthermore, participants identified that they used Novidium to treat trypanosomiasis and Buparvaquone to treat ECF. Cases of wrong prescription were also identified during the study whereby the Maasai farmers revealed to use Novidium as an anthelminthic: they dissolved the tablet in water and administered it orally. Participants also mentioned that they applied tradional methods in some cases, for instance, washing with concentrated salt solution and acaricides, to treat LSD in cattle, goats, and sheep pox. Some farmers stated that they managed goat and sheep pox using applied directly to the lesion on the animals. Magadi salt to treat and prevent foot rot was applied as a solution in muddy animal sheds during the rainy season. Levamisole, Ivermectin, and benzimidazole (albendazole) are anthelmintic drugs used for the control of helminths and parasites. Levamisole accounted for the most widely used anthelmintic drug in our area of study. Antimicrobials used include tetracyclines, macrolides, beta-lactam aminoglycosides, diminizines, levocetirizine, quinolones and novidium. Antimicrobials commonly used in Kajiado County were categorized and summarized below.

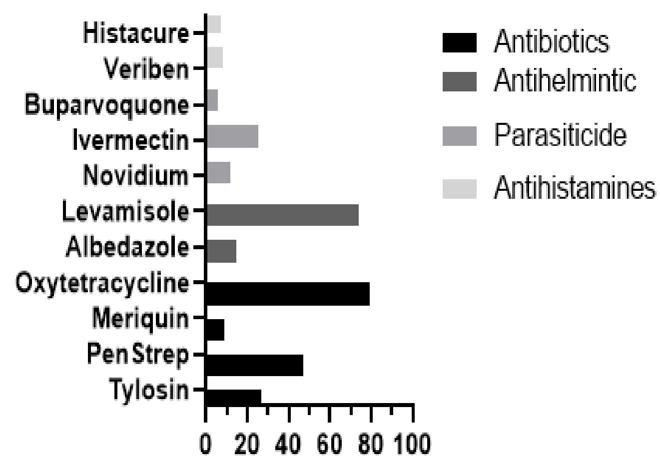

Fig 6: Commonly used drugs and their classification.

- *Animal disease Vaccinations*

Participants felt that government intervention in preventing disease through vaccination was quite poor, without equity in deployment, especially in remote areas of Kajiado. Larger populated agropastoral regions showed higher rates of individual vaccination initiatives. Cattle were vaccinated at a lower rate compared to small ruminants. The median vaccination value was average on an empirical presentation but stable, considering the region regarding socio-economic status of the most impoverished farmers. As shown per the data, small ruminants were given more attention compared to cattle, with some associated factors being the ease of managing the small ruminants, culture of trade, and community-based economics, which indicate the animals to be quite economical.

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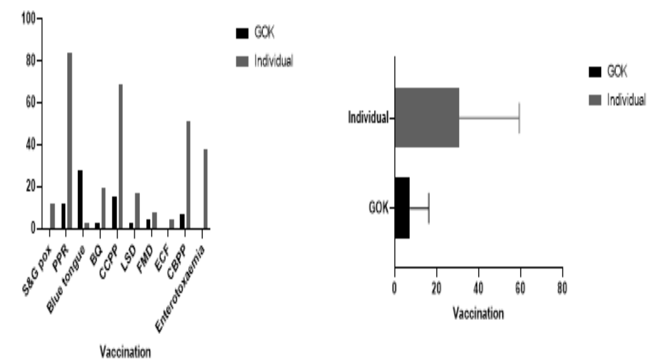

Fig 7: Relative livestock disease vaccination data from individual and government initiatives.

- *Animal Health Services Availability and Reliability.*

Overall, veterinarian services were poor in Kajiado County considering the livestock population and relative animal treatment by farmers and the few animal healthcare providers. Magadi region had the largest population of participants, however, from the collected data, the veterinarian services availability was among the lowest (34.48%) and reliability even lower (3.45%).

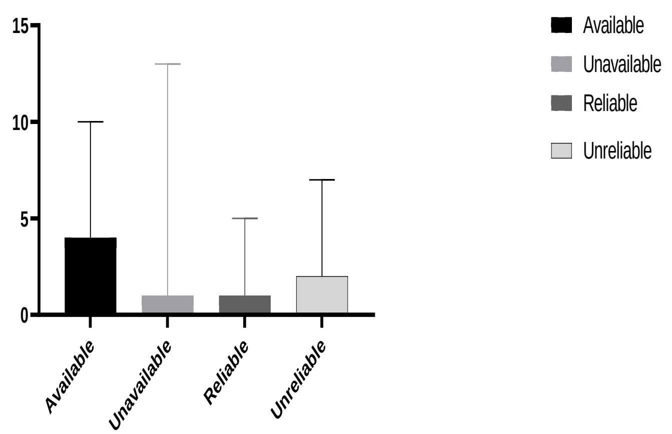

Fig 8: Animal health cares availability and reliability in Kajiado county

IV. DISCUSION

Integrated livestock monitoring mobile application was developed for data collection. The app is an Android based mobile application that allows for monitoring of diseases in livestock at the grassroots level. It leverages the use of mobile technology to allow farmers to report cases of various diseases within their stock, while at the same time getting the necessary medical attention for their affected livestock. Each reported case is geotagged allowing for appropriate mapping of the particular disease in the region allowing for better planning for vaccination drives, a process that was initially carried out with an unreliable traditional pen and paper method. The main objective of the app is to allow for grassroots livestock disease surveillance using a participatory framework. This approach achieves its functionality through its three key inputs: Real time reporting of diseases by farmers at the grassroots level, updating on the risk presenting and the measures to take from the backend interface; intervention of the reported cases through linking farmers to preregistered animal health care providers through the application; gathering insights from the collected data thus allowing for a relatively more accurate disease proliferation mapping. Regulators and key actors in animal health can rank the disease in terms of the cases reported and asses its economic impact. Surveillance data over time provide surfacing data and a skeleton map which help in enhancing capabilities against various diseases. Regular data on the health status of the animals at the grass root equip people with real-time data and information which interface direct action and precautions to take. Predictive mathematical modelling can be utilised to analyse the future health risk. Through the e-platform, farmers adaptive behaviour and spread of disease can be explored to enhance the sensitivity to climate change impacts and adaptive capacity in ASAL areas.

The application consists of three main modules: Farmer's module, a platform through which the farmer is able to report sick/dead animals as well as the associated observable syndromes. This is also accompanied by a photo and geotag of the location of the respective farmer to allow for a better understanding of the situation of the farmer; Animal healthcare provider module: This is a platform through which preregistered animal health care providers can solve cases and further allow the accurate scientific representation of what was initially reported. Research and administrative modules: This are the platform through which all data collected can be manipulated, allowing for the gathering of insights as well as mapping of diseases. It also reserves all rights of operation within the farmer and healthcare provider modules.

The development process followed the agile- Rapid Application Development (RAD) model. It is split into three main modules; Farmer module, Animal healthcare provider module, and the Research and administrative module. The Farmer module entails the development of interfaces that allow farmers to report cases of sick and/or dead animals from the grassroots. It interrogates the farmer on the intervention previously applied. This module further allowed for the provision of access to veterinary services through the Animal healthcare provision module. The Animal healthcare provider module entailed the development of a platform that allowed preregistered animal health professionals to access data on reported cases from the farmers module, from which these professionals would then provide their advice to the affected farmers. This module provides the farmers details including telephone numbers and geolocation for fast response. It also offers a case definition window which the animal healthcare provider updates the case definition and intervention details to the next module. The third phase was the development of the Research and administrative module. It entailed the development of a platform from which all data can be viewed, manipulated, and insights drawn from the same. Researchers would be able to access the data collected through the app, allowing them to draw insights on the same. Simple analytics, such as the proliferation of a particular disease in the region, were also a feature of the module.

An integrated livestock health and reporting app was developed to facilitate faster reporting and allow better coordination of animal health systems. A pilot study involved a small-scale study conducted in Kajiado County to evaluate the feasibility, capability, and capacity of mobile application in early detection of animal disease outbreaks in remote areas by engaging community disease reporters (CDRs). Active surveillance for livestock diseases is the cornerstone of decision making and practice in response and control (Rosenberg, 2015). Improving the existing reporting systems through the use of technology improved disease reporting with near real-time response and control. Use of technology avails itself to advance the development of an integrated reporting system using data and information systems to communicate efficiently and effectively at all levels of disease control. Automation of capture and data analysis make the data readily available electronically with spatiotemporal space(Jaya & Folmer, 2022). Engaging and empowering farmers at grassroot level in disease surveillance in a apastoral area improved quick detection of disease outbreaks and response at ward, subcounty, county and at national level. Integrating human and animal health would further improve the response to animal and human diseases, including the zoonotic for effective one health approach (Yahya, 2021)

Integrated animal health monitoring could contribute significantly in strengthening existing AMR and anthelmintics surveillance as a precautionary measure against the risk of resistance that has a great implication on human health. (Mremi et al., 2022)Available data demonstrated and indicated deficiencies in the quality of the veterinary service in Kajiado County presented by unavailability of veterinary services and lack of reliability. (Thumbi et al., 2019). This challenge contributed significantly to the mortality and morbidity due to the large proportion of sick animals not getting treatment, variations in the drugs used, and inappropriate use of drugs. For example, Novidium, an injectable drug, was mostly administered orally alongside anthelmintic drugs. Most farmers were observed to treat their animals and this contributed to inappropriate use of drugs and irregular dosage for most diseases. Drug dosage, duration and recommended withdrawal period were not followed by many farmers and this affected the outcome of the treatment of sick animals. Inadequacy and inefficiencies in veterinary care in Kajiado County may be improved through streamlined policy and regulation of agrovets, training of community animal health workers at the grassroot level, supportive supervision, and monitoring. Tetracyclines are the most commonly used drug as we and other studies have reported (Bangura et al., 2022). Supervision and monitoring of these classes of drugs with strict observation of antibiotic stewardship as their wide unregulated use poses a great challenge to antimicrobial resistance. Enforcement of policies that regulate drug use is important at the verge of AMR superbugs as we may lack substitutes for resistance emergencies (Florio et al., 2020). Misuse of certain antimicrobials may lead to AMR development and therefore there is a need to regulate, support, and monitor the use of certain important antimicrobials under a routine pastoral setting. Injudicious use of critical antimicrobials presents a relatively high risk of selection for antimicrobial resistance, posing a threat to public health threats, for example, augmenting AMR in human medicine.

Integrated livestock surveillance app reporting contributed significantly to reduction mortality and morbidity by enhancing near real-time surveillance and response. Formers could easily report diseases and get connected to the nearest animal healthcare provider for professional veterinary services. Many households in Kajiado county depend on livestock for livelihood. Empowering these farmers, the majority of whom are smallholder farmers with a reliable reporting and feedback platform not only enhance security for their animals but also improve the quality of life. This study established livestock diseases and lack of veterinary services as the main threat to the economy of the poor marginalized farmers. Livestock diseases can cause a loss translating to billions of dollars each year. An integrated surveillance approach will have a positive impact in mitigating livestock diseases and enhancing farmers adaptive capabilities to these challenges in a grassroot socio-economical and epidemiological context. Backend analysis of epidemiological data will enhance the mobilization and deployment of resources including enhanced vaccination programs focusing on geographical spaces. Farmer led syndromic system of livestock disease surveillance presents an efficient and reliable and near real-time way to report surveillance data. Trained community disease reporters (CDRs) log discernable clinical presentations and upload on to the fronted end-User interface

Pastoralists have found a way to cope with the uncertainties of that way of life and living in the rangelands, this has been seen to decline over the past recent years. They have been greatly influenced by climate change that has caused the death of most of their livestock due to lack of pasture and water. (Bedelian & Ogutu, 2017). Among other factors, overgrazing has also greatly contributed to the problem of lack of pasture, as it causes the top soil to be loose, and when it rains, they are washed away. They have been able to cope because of their extensive knowledge of their areas and diseases that affect their livestock and how to control them. Disease risk increases with the interaction within the human, livestock, and wildlife interface. Diseases have the potential to affect both wildlife and livestock, especially when they share the same environment. (Njenga et al., 2021)Due to the enormous pasture areas being converted to farms, pastoral mobility has decreased overtime, and their propensity for sedentary lifestyles has increased. Once established, it would be challenging for them to relocate in the event of sickness, whereas they would have done so in the past when there were vast rangelands (Ottichilo et al., 2000; Voeten & Prins, 1999). Due to their coexistence, formerly controlled diseases like trypanosomiasis are still a menace with diseases like ECF having devastating on livestock and having a high fatality rate.

The majority of cattle infections in the study area are believed by the pastoralist to be naturally transmitted by African buffaloes, therefore grazing livestock through the wildlife interface puts them at danger, as in the cases of East Coast Fever (ECF) and Foot and mouth disease (FMD) (Omondi et al., 2020). Animal diseases that have a high incidence of occurrence in cattle include: ECF, trypanosomiasis, and FMD in cattle. ECF and trypanosomiasis are vector borne and they are controlled by ectoparasite control and a combination of vaccination and acaricide spraying in the case of ECF. ECF is a disease spread by ticks, it has a significant impact on animal output. In addition to being found on livestock, ticks are also found in wildlife, and their interactions has made tick management less effective (SONENSHINE et al., 2002). Trypanosomiasis is spread by tsetse flies; some wildlife can harbor the disease without showing any clinical signs making them natural reservoirs. There has been reemergence of trypanosomiasis due to poor management practices and decreased veterinarian services in the endemic areas (Okello et al., 2022). FMD being a highly contagious viral disease that affects domestic and wild even-toed ungulates, has been identified to have a high incidence in cattle. Foot and mouth high transmissibility and impact on livestock health and its value chain makes it the most economically important transboundary animal disease. (*Understanding the Socioeconomic Impact of Foot-and-Mouth Disease Control in Kenya | The Cattle Site*, 2020.). It imposes restrictions to local and international trade constraining on the development of country pastoralism, where large herds of cattle mingle was attributed to be a contributing factor in the disease's rapid spread.

Sheep and goats are the most kept livestock by the pastoralist communities in ASLAS areas(*Kenya's Sheep and Goat Meat Market Report 2023 - Prices, Size, Forecast, and Companies*, 2023.). PPR, sheep and goat pox, heartwater, and CCPP are diseases that have been identified to be the major problem to ``the small stock. PPR was reported to be the most common among small stocks and CCPP was more prevalent in goats. Despite the efforts made by vaccination, but because it is less accessible to pastoralists due to poor veterinary services in remote pastoral areas, the disease is more common. Heart water has a higher incidence of occurrence in both sheep and goats. The farmers have identified that the disease spread more during the rainy season, for example, the case of trypanosomiasis, because it spreads more in the rainy season and because tsetse thrive best under this climate. CCPP is also a problem in cold seasons together with pneumonia in shoots.

Other factors that contribute to disease spread is: poor animal health services and the existing ones are no longer in use, like cattle dips which have been abandoned in many areas. In ASALS anima health services have deteriorated, which has made it difficult for famers to access drugs and vaccines for their livestock. Pastoralism provides livelihood to 90 percent of rural families living in dryland and is one of the major economic activities for people living in arid and semi-arid lands of Africa.(Bin Tarif et al., 2012)(Diuk-Wasser et al., 2021) (*Climate Change Destroys the livelihoods of Kenyan Pastoralists | Africa Renewal*, n.d.; Maciej Serda et al., 2013) Growing human population lead to agricultural expansion and increased deforestation resulting to great negative impact on the environment, climate, and wildlife population. Livestock and wildlife coexistence in areas that border wildlife zones increase the risk of disease in areas as wildlife are potential natural reservoirs of livestock disease (Mworia et al., 2008). Grazing livestock in wild life lands expose them to these diseases. When wildlife trespass onto human land, they run the risk of being hurt because people want to stop any losses they might create due to arising human wildlife conflict.(Tyrrell et al., 2017). Although wildlife-protected zones have been established, this cannot be totally relied upon to sustain biodiversity because wildlife is a migratory species and will eventually move into human areas. Additionally, wildlife has seasonal migration, such as in the case of the wildebeest, and must relocate. Due to the collapse of government veterinary services and the decreased availability of medications and vaccines, previously controlled diseases have begun to reemerge in certain regions, indicating a decline in disease control(*Kenya - Food Security Outlook Update: Sat, 2022-12-31 | Famine Early Warning Systems Network*, 2022.). Disease transmission can be mitigated by utilizing vector management techniques, such as bush burning in tsetse fly infected areas, the use of acaricides to prevent diseases transmitted by ticks, and vaccination to stave off future infections. The quarantining of domestic animals and the isolation of wildlife reserves during crucial transmission periods can both prevent the spread of illnesses from wildlife to livestock.

V. CONCLUSION

Integrated livestock monitoring mobile application is a real-time participatory epidemiological data collection using an online platform. Early reporting enabled early response which prevented the spread of the disease within the foci of the outbreak and helped save the marginalized farmers livelihoods. Through the platform, the farmers learnt how to detect diseases, report them in real-time, take the necessary control measures through feedback, and ensure a prompt response to the situation at hand. This greatly improved the efficiency of the field animal healthcare providers for their daily fieldwork, as well as the management of various diseases affecting the communities in the research setting. This technology has enabled accurate and near real-time reporting of disease, which is a key requirement in the detection of disease outbreaks and response measures for their control. Use of mobile application tool enabled the collection of demographic data, geo-locations, and lists of syndromes in addition to putative diagnosis and disease identification. Moreover, compared to the traditional pen and paper methods, the data is immediately available in real time to all mitigation levels via a cloud-based server. Through the E-platform, farmers are able to report livestock diseases and get the required help from the animal health providers offered through a feedback module to farmers. Researchers, we are able to collect current epidemiological data of the most prevalent diseases of cattle, sheep, and goats. Most of the diseases reported through the app were classified as notifiable diseases in Kenya which impose international livestock trade restrictions. Initially, heavy losses are occasioned in livestock due to lack of reliable reporting to facilitate faster response. The tool is also able to map and asses the disease burden and potential zoonotic disease risk. Although reporting through the e-platform resulted in much more timely and reliable reporting and feedback, limited connectivity and lack of smartphones in some regions delayed the process. However, in the long run, with the widespread use of smartphones, the approach will greatly improve animal disease reporting and surveillance, enhance data integrity, and enhance disease response strategies. Field data collection, transmission, and analysis allowed dissemination of validated feedback, that prompted an immediate response, and served as an early warning response. Central data points enabled quick analysis and validation by veterinary epidemiologists and ensured immediate and safe sharing of data among health care providers, decision makers, public health officials, diagnostic labs, and wildlife service departments. Strong surveillance and reporting capacity of the mobile application contributes to enhanced early warning of animal disease occurrence at the grassroot level. This greatly reduced delays in feedback and response to disease outbreaks, saving time, resources, and livelihoods with a touch of a button. Cloud based database system created offers storage of real-time georeferenced animal disease reports which is easily accessible.

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AUTHOR CONTRIBUTIONS

Dr. Rosemary N. Ngotho-Esilaba, Stephene Ongalo and Ngari P. Muriuki conceived the idea, coordinated this work, developed the mobile application and trained participants how to use the app. Ngari P. Muriuki organized the data downloaded from the cloud server, analyzed the data, interpreted results, wrote the manuscript. David N. Njoroge and Stephen Ongalo generated the map. All the authors approved the manuscript.

DISCLAIMER

The findings in this research article are those of the authors and do not necessarily represent the official position of the donor (Kenya Climate Smart Agriculture Project (KCSAP)), the Ministry of Agriculture, Livestock, Fisheries State Department for Crop Development and Agricultural or those of Kenya Agricultural and Livestock Research Organization (KALRO) nor the official position of the Government of Republic of Kenya

Data Availability

All data and material that support the findings of this study are included in this manuscript.

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Conflict of interest

The authors have no competing interest.

Ethical Statement

This work did not require neither sampling nor experimentation on animals or humans. However, informed consent was taken from animal owners during data collection. In addition, the handling of animals was overseen by the appropriately qualified veterinarian under the normal procedures approved by the Animal care and Use committee of Veterinary Science Research Institute (VSRI)-Muguga of Kenya Agricultural and Livestock Research organization (KALRO)

REFERENCES

[1]. *Animal Disease Information System (ADIS)*. (n.d.). Retrieved March 25, 2023, from https://food.ec.europa.eu/animals/animal-diseases/animal-disease-information-system-adis_en

[2]. Bangura, F. I., Leno, A., Hann, K., Timire, C., Nair, D., Bah, M. A., Gborie, S. R., Satyanarayana, S., Edwards, J. K., Davtyan, H., Kamara, S. M., Jalloh, A. T., Sellu-

Sallu, D., Kanu, J. S., Johnson, R., & Nantima, N. (2022). An Update on the Surveillance of Livestock Diseases and Antimicrobial Use in Sierra Leone in 2021—An Operational Research Study. *International Journal of Environmental Research and Public Health*, *19*(9), 1–12. https://doi.org/10.3390/ijerph19095294

[3]. Bedelian, C., & Ogutu, J. O. (2017). Trade-offs for climate-resilient pastoral livelihoods in wildlife conservancies in the Mara ecosystem, Kenya. *Pastoralism*, *7*(1), 1–22. https://doi.org/10.1186/S13570-017-0085-1/FIGURES/8

[4]. Bin Tarif, A., Lasecka, L., Holzer, B., & Baron, M. D. (2012). Ganjam virus/Nairobi sheep disease virus induces a pro-inflammatory response in infected sheep. *Veterinary Research*, *43*, 71. https://doi.org/10.1186/1297-9716-43-71

[5]. Chethan Kumar, H., Hiremath, J., Yogisharadhya, R., Balamurugan, V., Jacob, S., Manjunatha Reddy, G., Suresh, K., Shome, R., Nagalingam, M., Sridevi, R., Patil, S., Prajapati, A., Govindaraj, G., Sengupta, P., Hemadri, D., Krishnamoorthy, P., Misri, J., Kumar, A., Tripathi, B., & Shome, B. (2021). Animal disease surveillance: Its importance & present status in India. *The Indian Journal of Medical Research*, *153*(3), 299. https://doi.org/10.4103/IJMR.IJMR_740_21

[6]. *Climate change destroys the livelihoods of Kenyan pastoralists | Africa Renewal*. (n.d.). Retrieved March 9, 2023, from https://www.un.org/africarenewal/magazine/january-2023/climate-change-destroys-livelihoods-kenyan-pastoralists

[7]. Diuk-Wasser, M. A., Vanacker, M. C., & Fernandez, M. P. (2021). Impact of Land Use Changes and Habitat Fragmentation on the Eco-epidemiology of Tick-Borne Diseases. *Journal of Medical Entomology*, *58*(4), 1546–1564. https://doi.org/10.1093/JME/TJAA209

[8]. Florio, W., Baldeschi, L., Rizzato, C., Tavanti, A., Ghelardi, E., & Lupetti, A. (2020). Detection of Antibiotic-Resistance by MALDI-TOF Mass Spectrometry: An Expanding Area. *Frontiers in Cellular and Infection Microbiology*, *10*(November), 1–7. https://doi.org/10.3389/fcimb.2020.572909

[9]. Guernier, V., Milinovich, G. J., Santos, M. A. B., Haworth, M., Coleman, G., & Soares Magalhaes, R. J. (2016). Use of big data in the surveillance of veterinary diseases: Early detection of tick paralysis in companion animals. *Parasites and Vectors*, *9*(1). https://doi.org/10.1186/S13071-016-1590-6

[10]. Hernández-Jover, M., Phiri, B. J., Stringer, L., & Martínez Avilés, M. (2021). Editorial: Developments in Animal Health Surveillance. *Frontiers in Veterinary Science*, *7*, 1233. https://doi.org/10.3389/FVETS.2020.637364/BIBTEX

[11]. Jaya, I. G. N. M., & Folmer, H. (2022). Spatiotemporal high-resolution prediction and mapping: methodology and application to dengue disease. *Journal of Geographical Systems*, 1–55. https://doi.org/10.1007/s10109-021-00368-0

[12]. Karimuribo, E. D., Mutagahywa, E., Sindato, C., Mboera, L., Mwabukusi, M., Njenga, M. K., Teesdale, S., Olsen, J., & Rweyemamu, M. (2017). A Smartphone App (AfyaData) for Innovative One Health Disease Surveillance from Community to National Levels in Africa: Intervention in Disease Surveillance. *JMIR Public Health Surveill 2017;3(4):E94 Https://Publichealth.Jmir.Org/2017/4/E94*, *3*(4), e7373. https://doi.org/10.2196/PUBLICHEALTH.7373

[13]. *Kenya's Sheep and Goat Meat Market Report 2023 - Prices, Size, Forecast, and Companies*. (n.d.). Retrieved March 9, 2023, from https://www.indexbox.io/store/kenya-sheep-and-goat-meat-market-report-analysis-and-forecast-to-2025/

[14]. *Kenya - Food Security Outlook Update: Sat, 2022-12-31 | Famine Early Warning Systems Network*. (n.d.). Retrieved March 9, 2023, from https://fews.net/east-africa/kenya/food-security-outlook-update/january-2023

[15]. Lesmanawati, D. A. S., Veenstra, P., Moa, A., Adam, D. C., & Macintyre, C. R. (2020). A rapid risk analysis tool to prioritise response to infectious disease outbreaks. *BMJ Global Health*, *5*, 2327. https://doi.org/10.1136/bmjgh-2020-002327

[16]. *Livestock Population - Kenya National Bureau of Statistics*. (n.d.). Retrieved March 25, 2023, from https://www.knbs.or.ke/livestock-population/

[17]. Maciej Serda, Becker, F. G., Cleary, M., Team, R. M., Holtermann, H., The, D., Agenda, N., Science, P., Sk, S. K., Hinnebusch, R., Hinnebusch A, R., Rabinovich, I., Olmert, Y., Uld, D. Q. G. L. Q., Ri, W. K. H. U., Lq, V., Frxqwu, W. K. H., Zklfk, E., Edvhg, L. V, … فاطمی, ح. (2013). Synteza i aktywność biologiczna nowych analogów tiosemikarbazonowych chelatorów żelaza. *Uniwersytet Śląski*, *7*(1), 343–354. https://doi.org/10.2/JQUERY.MIN.JS

[18]. McGreevy, P., Thomson, P., Dhand, N. K., Raubenheimer, D., Masters, S., Mansfield, C. S., Baldwin, T., Magalhaes, R. J. S., Rand, J., Hill, P., Peaston, A., Gilkerson, J., Combs, M., Raidal, S., Irwin, P., Irons, P., Squires, R., Brodbelt, D., & Hammond, J. (2017). VetCompass Australia: A National Big Data Collection System for Veterinary Science. *Animals 2017, Vol. 7, Page 74*, *7*(10), 74. https://doi.org/10.3390/ANI7100074

[19]. Merianos, A. (2007). Surveillance and response to disease emergence. *Current Topics in Microbiology and Immunology*, *315*, 477–509. https://doi.org/10.1007/978-3-540-70962-6_19

[20]. Mremi, I. R., Rumisha, S. F., Sindato, C., Kimera, S. I., & Mboera, L. E. G. (2022). Comparative assessment of the human and animal health surveillance systems in Tanzania: Opportunities for an integrated one health surveillance platform. *Global Public Health*, *0*(0), 1–17. https://doi.org/10.1080/17441692.2022.2110921

[21]. Mworia, J. K., Kinyamario, J. I., & Githaiga, J. M. (2008). Influence of cultivation, settlements and water sources on wildlife distribution and habitat selection in south-east Kajiado, Kenya. *Environmental Conservation*, *35*(2), 117–124. https://doi.org/10.1017/S0376892908004670

[22]. Njenga, M. K., Kemunto, N., Kahariri, S., Holmstrom, L., Oyas, H., Biggers, K., Riddle, A., Gachohi, J., Muturi, M., Mwatondo, A., Gakuya, F., Lekolool, I., Sitawa, R., Apamaku, M., Osoro, E., Widdowson, M. A., & Munyua, P. (2021). High real-time reporting of domestic and wild animal diseases following rollout of mobile phone reporting system in Kenya. *PLoS ONE*, *16*(9 September), 1–13. https://doi.org/10.1371/journal.pone.0244119

[23]. Okello, I., Mafie, E., Eastwood, G., Nzalawahe, J., Mboera, L. E. G., & Onyoyo, S. (2022). Prevalence and Associated Risk Factors of African Animal Trypanosomiasis in Cattle in Lambwe, Kenya. *Journal of Parasitology Research*, *2022*. https://doi.org/10.1155/2022/5984376

[24]. Omondi, G. P., Gakuya, F., Arzt, J., Sangula, A., Hartwig, E., Pauszek, S., Smoliga, G., Brito, B., Perez, A., Obanda, V., & VanderWaal, K. (2020). The role of African buffalo in the epidemiology of foot-and-mouth disease in sympatric cattle and buffalo populations in Kenya. *Transboundary and Emerging Diseases*, *67*(5), 2206–2221. https://doi.org/10.1111/TBED.13573

[25]. Ottichilo, W. K., De Leeuw, J., Skidmore, A. K., Prins, H. H. T., & Said, M. Y. (2000). Population trends of large non-migratory wild herbivores and livestock in the Maasai Mara ecosystem, Kenya, between 1979–1997. *African Journal of Ecology*, *38*(3), 202–216. https://doi.org/10.1046/j.1365-2028.2000.00242.x

[26]. Rosenberg, R. (2015). Detecting the emergence of novel, zoonotic viruses pathogenic to humans. *Cellular and Molecular Life Sciences*, *72*(6), 1115–1125. https://doi.org/10.1007/S00018-014-1785-Y

[27]. SONENSHINE, D. E., LANE, R. S., & NICHOLSON, W. L. (2002). TICKS (Ixodida). *Medical and Veterinary Entomology*, 517–558. https://doi.org/10.1016/B978-012510451-7/50026-8

[28]. Thumbi, S. M., Njenga, M. K., Otiang, E., Otieno, L., Munyua, P., Eichler, S., Widdowson, M. A., McElwain, T. F., & Palmer, G. H. (2019). Mobile phone-based surveillance for animal disease in rural communities: Implications for detection of zoonoses spillover. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *374*(1782). https://doi.org/10.1098/rstb.2019.0020

[29]. Tyrrell, P., Russell, S., & Western, D. (2017). Seasonal movements of wildlife and livestock in a heterogenous pastoral landscape: Implications for coexistence and community based conservation. *Global Ecology and Conservation*, *12*, 59–72. https://doi.org/10.1016/J.GECCO.2017.08.006

[30]. *Understanding the socioeconomic impact of Foot-and-mouth Disease control in Kenya | The Cattle Site*. (n.d.). Retrieved March 9, 2023, from https://www.thecattlesite.com/articles/4396/understanding-the-socioeconomic-impact-of-foot-and-mouth-disease-control-in-kenya

[31]. Voeten, M. M., & Prins, H. H. T. (1999). Resource partitioning between sympatric wild and domestic herbivores in the Tarangire region of Tanzania. *Oecologia*, *20*(2), 287–294. https://doi.org/10.1007/s004420050860

[32]. Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International*, *86*, 14–23. https://doi.org/10.1016/J.ENVINT.2015.09.007

[33]. *Animal Disease Information System (ADIS)*. (n.d.). Retrieved March 25, 2023, from https://food.ec.europa.eu/animals/animal-diseases/animal-disease-information-system-adis_en

[34]. Bangura, F. I., Leno, A., Hann, K., Timire, C., Nair, D., Bah, M. A., Gborie, S. R., Satyanarayana, S., Edwards, J. K., Davtyan, H., Kamara, S. M., Jalloh, A. T., Sellu-Sallu, D., Kanu, J. S., Johnson, R., & Nantima, N. (2022). An Update on the Surveillance of Livestock Diseases and Antimicrobial Use in Sierra Leone in 2021—An Operational Research Study. *International Journal of Environmental Research and Public Health*, *19*(9), 1–12. https://doi.org/10.3390/ijerph19095294

[35]. Bedelian, C., & Ogutu, J. O. (2017). Trade-offs for climate-resilient pastoral livelihoods in wildlife conservancies in the Mara ecosystem, Kenya. *Pastoralism*, *7*(1), 1–22. https://doi.org/10.1186/S13570-017-0085-1/FIGURES/8

[36]. Bin Tarif, A., Lasecka, L., Holzer, B., & Baron, M. D. (2012). Ganjam virus/Nairobi sheep disease virus induces a pro-inflammatory response in infected sheep. *Veterinary Research*, *43*, 71. https://doi.org/10.1186/1297-9716-43-71

[37]. Chethan Kumar, H., Hiremath, J., Yogisharadhya, R., Balamurugan, V., Jacob, S., Manjunatha Reddy, G., Suresh, K., Shome, R., Nagalingam, M., Sridevi, R., Patil, S., Prajapati, A., Govindaraj, G., Sengupta, P., Hemadri, D., Krishnamoorthy, P., Misri, J., Kumar, A., Tripathi, B., & Shome, B. (2021). Animal disease surveillance: Its importance & present status in India. *The Indian Journal of Medical Research*, *153*(3), 299. https://doi.org/10.4103/IJMR.IJMR_740_21

[38]. *Climate change destroys the livelihoods of Kenyan pastoralists | Africa Renewal*. (n.d.). Retrieved March 9, 2023, from https://www.un.org/africarenewal/magazine/january-2023/climate-change-destroys-livelihoods-kenyan-pastoralists

[39]. Diuk-Wasser, M. A., Vanacker, M. C., & Fernandez, M. P. (2021). Impact of Land Use Changes and Habitat Fragmentation on the Eco-epidemiology of Tick-Borne Diseases. *Journal of Medical Entomology*, *58*(4), 1546–1564. https://doi.org/10.1093/JME/TJAA209

[40]. Florio, W., Baldeschi, L., Rizzato, C., Tavanti, A., Ghelardi, E., & Lupetti, A. (2020). Detection of Antibiotic-Resistance by MALDI-TOF Mass Spectrometry: An Expanding Area. *Frontiers in Cellular and Infection Microbiology*, *10*(November), 1–7. https://doi.org/10.3389/fcimb.2020.572909

[41]. Guernier, V., Milinovich, G. J., Santos, M. A. B., Haworth, M., Coleman, G., & Soares Magalhaes, R. J. (2016). Use of big data in the surveillance of veterinary diseases: Early detection of tick paralysis in companion animals. *Parasites and Vectors*, *9*(1). https://doi.org/10.1186/S13071-016-1590-6

[42]. Hernández-Jover, M., Phiri, B. J., Stringer, L., & Martínez Avilés, M. (2021). Editorial: Developments in Animal Health Surveillance. *Frontiers in Veterinary Science*, *7*, 1233. https://doi.org/10.3389/FVETS.2020.637364/BIBTEX

[43]. Jaya, I. G. N. M., & Folmer, H. (2022). Spatiotemporal high-resolution prediction and mapping: methodology and application to dengue disease. *Journal of Geographical Systems*, 1–55. https://doi.org/10.1007/s10109-021-00368-0

[44]. Karimuribo, E. D., Mutagahywa, E., Sindato, C., Mboera, L., Mwabukusi, M., Njenga, M. K., Teesdale, S., Olsen, J., & Rweyemamu, M. (2017). A Smartphone App (AfyaData) for Innovative One Health Disease Surveillance from Community to National Levels in Africa: Intervention in Disease Surveillance. *JMIR Public Health Surveill 2017;3(4):E94 Https://Publichealth.Jmir.Org/2017/4/E94*, *3*(4), e7373. https://doi.org/10.2196/PUBLICHEALTH.7373

[45]. *Kenya's Sheep and Goat Meat Market Report 2023 - Prices, Size, Forecast, and Companies*. (n.d.). Retrieved March 9, 2023, from https://www.indexbox.io/store/kenya-sheep-and-goat-meat-market-report-analysis-and-forecast-to-2025/

[46]. *Kenya - Food Security Outlook Update: Sat, 2022-12-31 | Famine Early Warning Systems Network*. (n.d.). Retrieved March 9, 2023, from https://fews.net/east-africa/kenya/food-security-outlook-update/january-2023

[47]. Lesmanawati, D. A. S., Veenstra, P., Moa, A., Adam, D. C., & Macintyre, C. R. (2020). A rapid risk analysis tool to prioritise response to infectious disease outbreaks. *BMJ Global Health*, *5*, 2327. https://doi.org/10.1136/bmjgh-2020-002327

[48]. *Livestock Population - Kenya National Bureau of Statistics*. (n.d.). Retrieved March 25, 2023, from https://www.knbs.or.ke/livestock-population/

[49]. Maciej Serda, Becker, F. G., Cleary, M., Team, R. M., Holtermann, H., The, D., Agenda, N., Science, P., Sk, S. K., Hinnebusch, R., Hinnebusch A, R., Rabinovich, I., Olmert, Y., Uld, D. Q. G. L. Q., Ri, W. K. H. U., Lq, V., Frxqwu, W. K. H., Zklfk, E., Edvhg, L. V, … فاطمی, ح. (2013). Synteza i aktywność biologiczna nowych analogów tiosemikarbazonowych chelatorów żelaza. *Uniwersytet Śląski*, *7*(1), 343–354. https://doi.org/10.2/JQUERY.MIN.JS

[50]. McGreevy, P., Thomson, P., Dhand, N. K., Raubenheimer, D., Masters, S., Mansfield, C. S., Baldwin, T., Magalhaes, R. J. S., Rand, J., Hill, P., Peaston, A., Gilkerson, J., Combs, M., Raidal, S., Irwin, P., Irons, P., Squires, R., Brodbelt, D., & Hammond, J. (2017). VetCompass Australia: A National Big Data Collection System for Veterinary Science. *Animals 2017, Vol. 7, Page 74*, *7*(10), 74. https://doi.org/10.3390/ANI7100074

[51]. Merianos, A. (2007). Surveillance and response to disease emergence. *Current Topics in Microbiology and Immunology*, *315*, 477–509. https://doi.org/10.1007/978-3-540-70962-6_19

[52]. Mremi, I. R., Rumisha, S. F., Sindato, C., Kimera, S. I., & Mboera, L. E. G. (2022). Comparative assessment of the human and animal health surveillance systems in Tanzania: Opportunities for an integrated one health surveillance platform. *Global Public Health*, *0*(0), 1–17. https://doi.org/10.1080/17441692.2022.2110921

[53]. Mworia, J. K., Kinyamario, J. I., & Githaiga, J. M. (2008). Influence of cultivation, settlements and water sources on wildlife distribution and habitat selection in south-east Kajiado, Kenya. *Environmental Conservation*, *35*(2), 117–124. https://doi.org/10.1017/S0376892908004670

[54]. Njenga, M. K., Kemunto, N., Kahariri, S., Holmstrom, L., Oyas, H., Biggers, K., Riddle, A., Gachohi, J., Muturi, M., Mwatondo, A., Gakuya, F., Lekolool, I., Sitawa, R., Apamaku, M., Osoro, E., Widdowson, M. A., & Munyua, P. (2021). High real-time reporting of domestic and wild animal diseases following rollout of mobile phone reporting system in Kenya. *PLoS ONE*, *16*(9 September), 1–13. https://doi.org/10.1371/journal.pone.0244119

[55]. Okello, I., Mafie, E., Eastwood, G., Nzalawahe, J., Mboera, L. E. G., & Onyoyo, S. (2022). Prevalence and Associated Risk Factors of African Animal Trypanosomiasis in Cattle in Lambwe, Kenya. *Journal of Parasitology Research*, *2022*. https://doi.org/10.1155/2022/5984376

[56]. Omondi, G. P., Gakuya, F., Arzt, J., Sangula, A., Hartwig, E., Pauszek, S., Smoliga, G., Brito, B., Perez, A., Obanda, V., & VanderWaal, K. (2020). The role of African buffalo in the epidemiology of foot-and-mouth disease in sympatric cattle and buffalo populations in Kenya. *Transboundary and Emerging Diseases*, *67*(5), 2206–2221. https://doi.org/10.1111/TBED.13573

[57]. Ottichilo, W. K., De Leeuw, J., Skidmore, A. K., Prins, H. H. T., & Said, M. Y. (2000). Population trends of large non-migratory wild herbivores and livestock in the Maasai Mara ecosystem, Kenya, between 1979–1997. *African Journal of Ecology*, *38*(3), 202–216.

https://doi.org/10.1046/j.1365-2028.2000.00242.x
[58]. Rosenberg, R. (2015). Detecting the emergence of novel, zoonotic viruses pathogenic to humans. *Cellular and Molecular Life Sciences*, *72*(6), 1115–1125. https://doi.org/10.1007/S00018-014-1785-Y
[59]. SONENSHINE, D. E., LANE, R. S., & NICHOLSON, W. L. (2002). TICKS (Ixodida). *Medical and Veterinary Entomology*, 517–558. https://doi.org/10.1016/B978-012510451-7/50026-8
[60]. Thumbi, S. M., Njenga, M. K., Otiang, E., Otieno, L., Munyua, P., Eichler, S., Widdowson, M. A., McElwain, T. F., & Palmer, G. H. (2019). Mobile phone-based surveillance for animal disease in rural communities: Implications for detection of zoonoses spillover. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *374*(1782). https://doi.org/10.1098/rstb.2019.0020
[61]. Tyrrell, P., Russell, S., & Western, D. (2017). Seasonal movements of wildlife and livestock in a heterogenous pastoral landscape: Implications for coexistence and community based conservation. *Global Ecology and Conservation*, *12*, 59–72. https://doi.org/10.1016/J.GECCO.2017.08.006
[62]. *Understanding the socioeconomic impact of Foot-and-mouth Disease control in Kenya | The Cattle Site*. (n.d.). Retrieved March 9, 2023, from https://www.thecattlesite.com/articles/4396/understanding-the-socioeconomic-impact-of-foot-and-mouth-disease-control-in-kenya
[63]. Voeten, M. M., & Prins, H. H. T. (1999). Resource partitioning between sympatric wild and domestic herbivores in the Tarangire region of Tanzania. *Oecologia*, *20*(2), 287–294. https://doi.org/10.1007/s004420050860
[64]. Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International*, *86*, 14–23. https://doi.org/10.1016/J.ENVINT.2015.09.007