Use of Bio-Physical Indicators to Map and Characterize Coping Strategies of Households to Rift Valley Fever Outbreaks in Ijara District-Kenya

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Abstract: *Extended and above normal rainfall in the study after a warm phase of El Niño creates conditions favorable for an outbreak of Rift Valley Fever (RVF). We used geospatial techniques together with focus group discussions to map and characterize bio-physical indicators influencing the outbreak of Rift Valley Fever (RVF) in Ijara District, Kenya. By applying geo-statistical tools, a generalized linear model was used to characterize and differentiate RVF indices in the study area. Our results indicate that the occurrence of RVF is diametrically distributed between high and low risk areas approximately half-way across the study area. Households have put in place coping mechanisms and are able to cope with RVF outbreaks. However, communities living in high risk areas were found to have more strategic coping mechanisms while those at low risk areas use ad hoc coping strategies. Communities at high risk areas would therefore cope better with adverse climate variability and extended disease burden compared to those at low risk areas who have minimal knowledge of coping strategies.*

Keywords: RVF, Coping Strategies, Geo-statistical.

1. Introduction

Coping refers to the ability of people, organizations, systems or communities, using available skills and resources to face and manage (or strategies towards) adverse conditions arising from endemic and epidemic diseases, emergencies or disasters. Coping strategies are engaged as a livelihood diversification by many rural communities; pastoralists and agro-pastoralists in the arid and semi-arid regions at certain periods of the year to avert extensive losses in their livelihoods. Factors that cause the need for development of coping strategies are the unreliability and uncertainty of climate, and increased disease burden that would greatly impact ecosystem services. [1]; [2].

Ijara District, Kenya is part of the Arid and Semi-Arid Lands (ASAL) which is mainly inhabited by pastoralists. The pastoralists who mainly keep livestock have overtime had a livelihood dependent on the intricate knowledge they have gained to adapt and sustain equilibrium in the natural and socio-economic environment [3].

Previous studies [3];[4] show that the extent and exercise of knowledge however is dependent on coping strategies/ household characteristics for timely decisions in climate uncertainty and outbreak of diseases, diversity of livestock, mobility, diversification of livestock species and breeds, maximization of stock numbers and splitting or redistribution of herds.

This study focuses on characterization of some of the coping strategies that households have practiced over time to mitigate against adverse climate conditions and by extension, the risks associated with Rift Valley Fever (RVF) outbreaks. RVF is a severe viral disease that has been observed to cause huge socio-economic losses including death of both humans and animals in hundreds of thousands [5]; [6]. There are some bio-climatic and bio-physical indicators that have been found to be related and also to be drivers of the RVF disease. By way of geo-statistical analysis these risk factors were analyzed to develop a risk map that depicted areas which are at high risk or low risk of RVF outbreak within our study area. Coping strategies at these areas were elicited by way of focus group discussions.

2. Literature Review

RVF causes fever in both livestock such as cattle, buffalo, sheep, goats and humans. The disease is associated with mosquito-borne epidemics during years of prolonged and above normal rainfall with extensive localized flooding. The flooding allows buried mosquito eggs, usually of the genus Aedes, to be brought to surface to hatch. The eggs having been infected from previous RVF outbreak hatch into mosquitoes that transfer the virus to the livestock. As other genus of mosquito populations and those that are uninfected build up, the virus spread is amplified once they attack the infected livestock. and. Humans are also likely to be infected also especially when they are exposed to blood or other body fluids from RVF infected animals. Exposure of this kind may happen in the cause of tending to delivering animals, slaughtering, sickly or ingesting RVF contaminated meat or milk [7]; [8].
RVF primarily affects livestock and can cause deaths in large numbers; a situation referred to as an epizootic as was the case in 1950/51 where there was an estimated death in hundreds of thousands of sheep. The RVF virus can at times lead to an epidemic among people exposed to animals with RVF. However, infected people may not immediately exhibit RVF symptoms while others have been observed to

experience mild illness associated fever and liver abnormalities. Some people experience more severe symptoms like fever, weakness, back pain, dizziness, and others suffer extreme weight loss. In some advanced cases victims suffer hemorrhagic fever and encephalitis that at times lead to seizures, coma, and eye disease or blindness [8].

The climatic factors which predispose the emergence of RVF during inter-epidemic periods have been well documented [9]. Epidemics always follow heavy and prolonged, often unseasonal, above normal rainfall. From the 1997/98 outbreak more research has been put to understand the disease drivers and dynamics surrounding the RVF disease and outbreak. A good understanding of primary indicators in the development of early forecasting systems can greatly help in putting the necessary measures to minimize or avert impending epidemics [9].

RVF outbreaks occur several years apart, irregularly in the arid and semi-arid areas where farmers have little ability to identify the symptoms and worse still lack the capacity of buying the vaccine and in time before the outbreak [10]. At onset of RVF outbreak, some households resort to selling most of their livestock to avert losses. This inevitably causes the actual prices for the livestock to plunge due to oversupply. This greatly undermines the household's coping strategy to fend for family and diminishes the ability to restock the same number of livestock after the outbreak.

Global climate change comes with varied environmental stresses/ shocks that make communities vulnerable. Some researchers ([14][15];[16][17];[13];[15]) observe that different shocks require different coping reactions and strategies. This has been seen in many communities where there is difficulty in differentiating active coping strategies and weak coping strategies.Weak coping strategies may offer instant solution in light of impending need but in the long run they are seen as a poverty trap that a family/ community might fall into. The ability of a household to adopt active coping strategies will mainly depend on the household to differentiate those that are poverty driven and those that comes from shocks. There is a need therefore to quantify and characterize coping strategies amongst pastoral and agro-pastoral households. This will greatly assist in understanding how households respond to external shocks such as climate change and disease outbreaks [2].

3. Methods and Materials

Figure 1 shows the study area which falls in the North Eastern part of Kenya. Ijara is one of the eleven districts in the province and is regarded as Semi Arid region. The rresearch design and methodology for this study involved identification and mapping of bio-physical factors that are considered significant to the outbreak of RVF. The mapped regions provided a means identifying areas that are at risk of the RVF outbreaks. Through focused group discussions (FGD), we characterized coping strategies within areas that have a high potential of RVF out breaks, see Figure 1. Characterization was done by employment of in-depth participatory epidemiology techniques and methods. Participatory Epidemiology (PE) uses a combination of practitioner communication skills and participatory methods

to improve involvement of animal keepers in the understanding and analysis of their livelihoods, animal disease problems, design, implementation and evaluation of disease control programmes and policies [18].

Contrary to conventional data collection methods, PE has gained popularity due to the ease of implementation. Wit limited research time, financial resources and well trained personnel it is possible to determine common issues and come up with general perceptions for action oriented research to challenges facing a community. The approach used in our study involved semi structured focus group discussions designed around guided conversational themes.

We employed R statistical software[19] and ArcGis10x[20] for analysis. The R package provided a platform for identification of the bio-physical variables deemed significant to the outbreak of the RVF cases in the study area. These variables were consequently used as input in ArcGis10x where friction data of the combined variables was created. The friction data output was a risk map which was then reclassified to depict areas of high risk and low risk across the study area. Locations with relative high and low probability of RVF outbreak could then be identified.

The risk map areas informed specific locations where focus group discussions could be held in order to characterize coping strategies within a community. FGDs were held in both high and low risk areas in, with group sessions being recorded in field book and flip chart, a voice recorder, hand held GPS and photos. Data from each group was then tabulated in Microsoft Excel 2010 to decode and understand the coping strategies amongst the different communities.
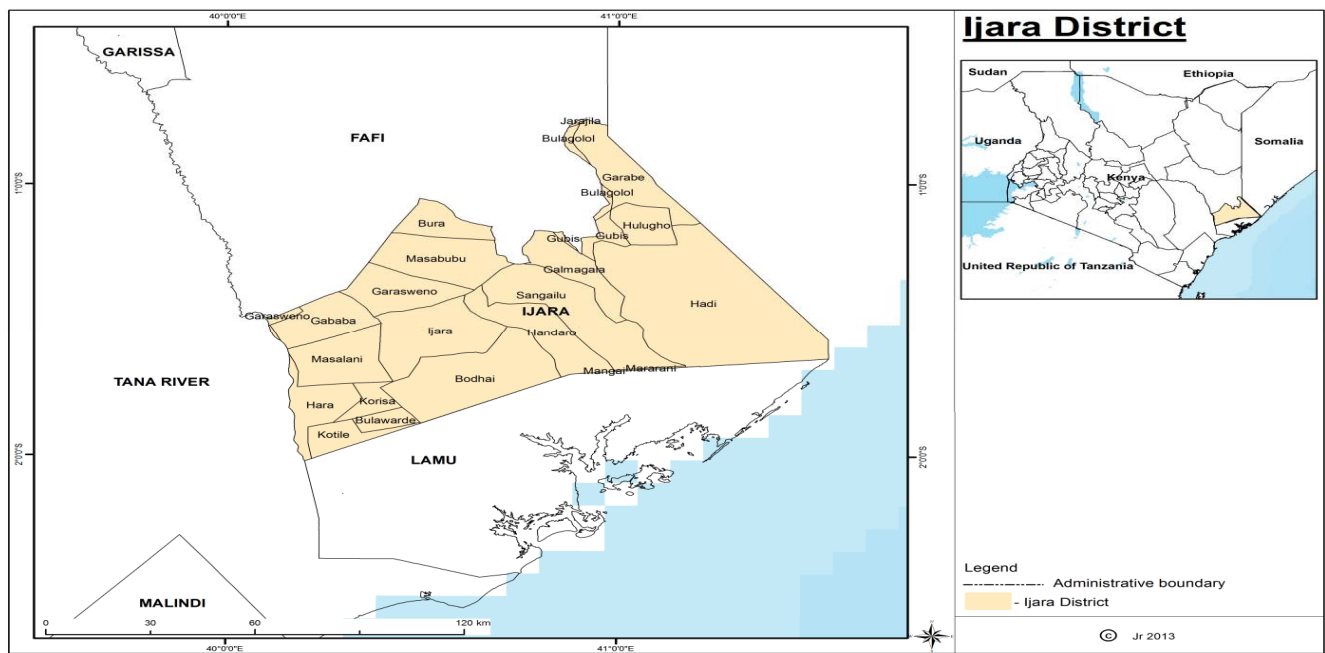
Figure 1: Study Area- Ijara District is one of the eleven districts in North Eastern Province, Kenya

3.1 Characterization of the Study Site

Latest bio-physical data which included land cover, soil and elevation was prepared in ArcGIS to ensure homogeneity in terms coordinate systems and resolution. Land cover data was obtained from the Global Land cover (GlobCover) 2009 database. The land cover classes considered for this analysis were twenty two in total, consistent with the UN Land Cover Classification System [21].

Soil data was obtained from the Harmonized World Soil Database (HWSD) which is a comprehensive database of the world for all soil types in accordance with the current FAO classification system [22], while elevation data was obtained from the Shuttle Radar Topographic Mission (SRTM) 90m [23]. The rainfall data used in this study was obtained from TRMM for the period December 1997 to July 2013. The data is a satellite product of NASA and JAXA services that was launched in November 1997 to provide rainfall data at a resolution of 0.25degrees [24][25][26][27].

Records of RVF outbreak cases as confirmed by the Department of Veterinary Services (DVS) for the period 1912 to 2007 were obtained from the DVS and Centers for Disease Control (CDC), [28]. All the outbreak cases can be traced to the province, district and division of outbreak but hardly geo-referenced to the epicenter of the outbreak. An inventory of all confirmed RVF outbreak cases traced and reported in all locations and hospitals were aggregated to the division level. The division was therefore used as the unit of analysis. Irrespective of the number of cases, both in human and animals a division reported, it was resolved that a division with an outbreak was a 'case' and no outbreak as 'no case'. It was further noted that even if a division reported a single outbreak over 30 years then it was evidence enough that the division has conducive ecological conditions to facilitate a future outbreak.

The division being the unit of analysis, a summary statistics on the bio-physical indicators was performed in ArcGIS spatial analysis tool so as to determine the feature type that most dominant. The dominant feature was then assigned to the particular division. An entry of all the divisions by case and bio-physical data was then prepared for input for further analysis in R statistical software.

3.2 Geostatistical Analysis

The aim at this stage was to determine the factors that affect the probability of occurrence of RVF. The R package has the capability to support analysis of discrete data and continuous data. In our study, discrete data reported incidences of RVF outbreak in each of the divisions while continuous data was the biophysical data. The Generalized Linear Models (GLMs) offers a weighted linear regression that can be used to obtain parameter estimates of non- linear observations as is the case in RVF outbreaks. There are a variety of GLMs as the 'normal', 'binomial', 'poisson' and 'gamma'[29]. This particular feature of the software allows for the identification of the bio-physical indicators deemed significant for the RVF outbreak in the divisions that reported RVF cases. A GLM with a Logit link was used for this analysis. This model was chosen since it suited our study as the cases of RVF at the division level were binomial; that is the presence (1) or absence (0) of reported case of RVF. The logit link in the model allows for regression of presence or absence to the explanatory variables, the bio-physical data that are qualitative.

We used four stage approach was where all the bio-physical data were run using the model to determine the significant indicator. An auto-correlation test was run at this stage to check for bio-physical data that significantly influenced each other. Single data were then run using the model to determine the class within which the biophysical data was deemed significant in the occurrence of a RVF case.

Paper ID: SEP14136

1044

3.3 RVF Risk Map

From the geo-statistical analysis it was possible to make observations on which of the bio-physical data and of which type are quite significant to the outbreak of RVF. The bio-physical data were then pre-coded with a numerical risk index (1, 2, 3.....), where 1 indicated areas that had a higher probability of RVF risk, 2 for lower risk probability and so forth within the ArcGis10x environment. Map algebra was then invoked in ArcGis to combine all sets of data. The resultant output is the 'friction map' or probability map of RVF risk.

A final risk map was then generated by reclassification of high and low risk RVF outbreak incidences. The high and low risk divisions in the area of study used then used to identify specific areas where focus group discussions would be held. The actual location where the FGDs were carried out was agreed upon with the help of key informants within the study area.

3.4 Focus Group Discussions

The purpose of focused group discussions (FGDs) was to characterize coping strategies that households used over the years to cope with external shocks. In this study, FGDs was a discussion of at most 10 local people, the interpreter and moderator. The discussion generally started by way of prayer, introduction of all those in attendance then the moderator would set the agenda for discussion. This was then followed by the development of seasonal calendar of the past and current climate perceptions of the community. Seasonal calendars helped the FGD participants contextualize occurrences within a calendar year.

Once the seasonal calendar had been agreed on amongst the FGD members, the discussion proceeded on into a guided discussion for a maximum of an hour. A checklist was used to elicit issues that were pertinent to livelihoods such as common livestock diseases that have most impact and those that they deemed to be climate driven. The checklist also included some of the coping strategies that the community has used, barriers that deter coping, and measures that have been put prior to and after a disease outbreak. The issues raised were noted, and a pair wise comparison used to determine what was importance or of most impact to their livelihoods. The ranking was then used to determine the order of priority with the first ppriority given to issues at the top and the last allocated those with lowest impact or influence on livelihoods. The discussion amongst the FGD members was allowed to proceed until a consensus on a single issue was arrived at. Items that went into pairwise comparison were kept to a maximum of 9 at any time. The discussion was then wrapped up by thanking all those in attendance, commentary on any other issues directly or indirectly related to the agenda, followed by a photo and determination of the GPS position for each group.

3.5 FGDs Data Analysis

The data obtained from FGDs was then tabulated into Excel together with the seasonal calendar and other attribute data such as local names. Climate related diseases from community perceptions were also tallied to corresponding calendar times. The rest of the issues that came up from the guided conversation were also tabulated with their respective rank positions. The tabulated results gave different insights in terms of priority and action as to how the communities approached different issues.

4. Results and Discussion

Most of Ijara district is covered by rain fed croplands (6%), and mosaicked open or closed grasslands and shrub lands (48%), and broad leaved forest vegetation. The urban and bare areas cover a very small area of the whole district, barely 1% (Figure...).

Figure 2 shows the main soil types in Ijara district. These are solenetz, planosols and vertisols and have coverage of approximately 42%, 38% and 17% respectively with the main soil texture types being clay, loam, and sandy. The heavy clayey soil is approximately 60% and 38% of clay loam of the district. The elevation within the district varies between 0–90m above sea level with a gradient rise from south eastwards to the north. Majority of the area is fairly flat with many areas having a maximum of 0–15% slope rise covering 72% of the whole district.

Out of 47 districts, more than Over 30 have have reported RVF outbreaks, which is over 63% of all the districts. It is also observed that the number of RVF outbreaks in the last 3 decades has had high impact outbreaks across many divisions with more areas reporting the diseases. The peaks in this period of outbreaks starting from recent are 2006–2007, 1997–1998, and 1989–1990.

TRMM has a low resolution available at 0.25 degrees for the period December 1997 to July 2013 in netdcf. Our results show that the easterly part of Ijara is wetter compared to the west with rainfall of over 2mm per day, Figure3. The late 2006 early 2007 RVF outbreak coincides with these prolonged rainfall periods.
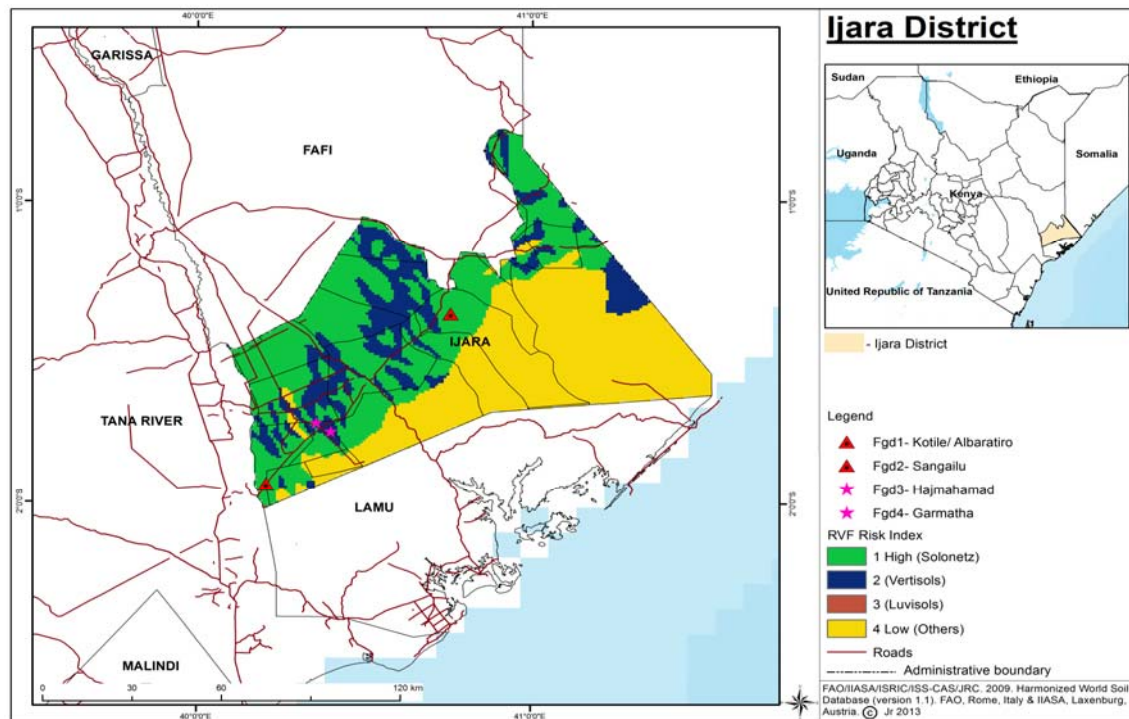
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Figure 2: FGD location. High Risk Areas are halfway northwards of the district. Low risk areas having 'other' soil types are midway south and to the east.
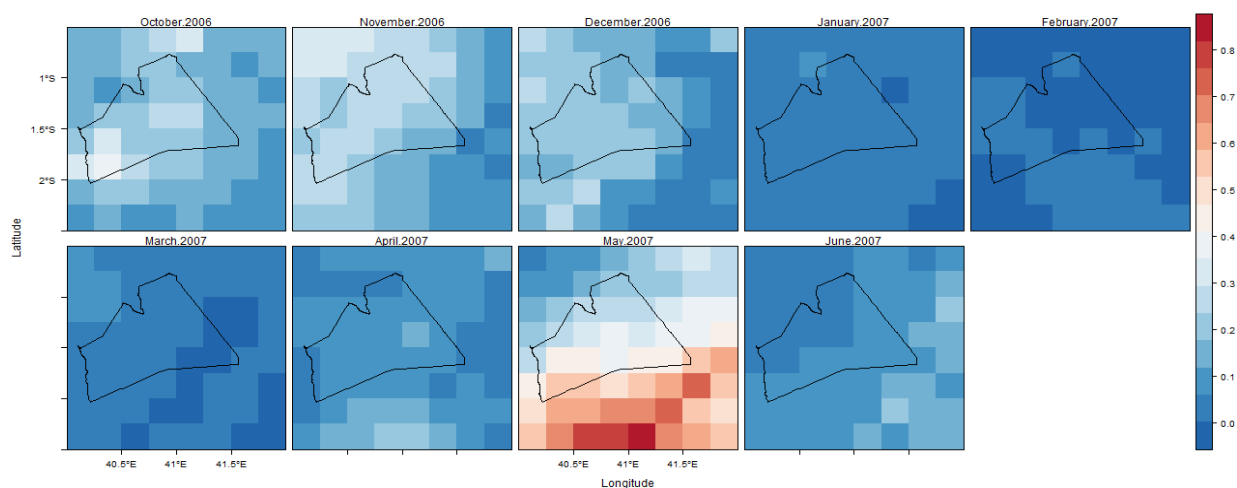

Figure 3: Rainfall distribution over Ijara District (October 2006 – June 2007 in mm/ day). The heavy rains start in October to December and continue in the first quarter of 2007. Short rains period in April-June 2007 had a higher amount of rainfall compared to the previous year.

The longest section across Ijara was just over one degree in distance thus resolving the analysis to this level was a compromise to variability anticipated. Hence, as much as rainfall was quite significant (0.04) to the model it was dropped from further analysis. Land cover was also significant (0.15) but data available was for the period 2009 only, and that would not be reflective of the vegetation cover during the 2006–2007 outbreaks.

The data was retained for further analysis in the GLM were soil and elevation, see equation 1.

Glm (model;Cases = Soil + Elevation, family= binomial(link = "logit"))

Eqn. 1. GLM Model

The output model shows that when the vertisols, solonetz, and luvisols were compared to the other soils they had a higher correlation coefficient to the occurrence of RVF cases, see Table 1. The solonetz and luvisols had almost the same coefficient (1.2) while vertisols were lower (0.66). Areas of elevation between 1000–2000m were also compared to areas below 1000 and those above 2000m. The areas below 1000m had a higher coefficient (2.74) to those at a higher altitude (-1.99), see Table 1. This result helps confirm that the RVF cases that occurred in these areas could best be explained by these soil types and the elevation.

Table 1: Bio-physical Risk Factor Coefficients from GLM model

Variable	Levels	Generalised linear model	
		Coefficients (β)	Standard Deviation (SE) of (β)
Soil type	Vertisols	0.66	0.31
	Solonertz	1.19	0.44
	Luvisols	1.21	0.58
	Others	0.00	-
Elevation	0 -1000	2.74	0.38
	>1000-<2000	0.00	-
	>2000	-1.99	0.48

From the results, solonetz, vertisols and luvisols covered half of the study while the other soil types cover the rest of the district. Areas that had solonetz and altitutedes of less than 1000m were areas of highest risk, while regions with vertisols and luvisols followed in decreasing risk respectively. Specifically, areas with other soil types in the district have a lower risk, see Figure 2. Four focused group discussions (FGD1–4) were successfully held in Ijara District, two at both high risk locations (Sangailu and Kotile) and at low risk locations (Hajmahamad and Galmatha; also known as Falmata) divisions, see Figure 2.. The local communities' perception in both high risk and low risk of RVF outbreak areas agreed with our analysis.

Coping strategies are considered as those initiatives taken by households prior to the onset of a season as to reduce risk of livestock loss. Our results indicate that mechanisms for all four groups are closely related. These ranged from in order of separation of infected animals, prayer, early treatment of sickly animals, vaccination, early deworming, and splitting or sharing livestock to friends and family in other areas to reduce impact. Barriers that impeded households or a community from devising coping strategies were identified as lack of the requisite knowledge to diagnose early symptoms of disease outbreak and inaccessibility to veterinary services. In some instances, as reported from FGD2, some drugs seem to no longer work or are ineffective when administered to the livestock. For example, FGD3 reported that animals had developed immunity against some drugs used in the treatment of trypanasomiasis. The spread of RVF after the outbreak was also too fast as mentioned in FGD4 to allow for adequate diagnosis and treatment.

From the FGDs it was observed that actions taken by communities in the high risk areas were strategic as they took actions like vaccination, controlled animal movement with awareness to changing climate and disease incidence. Those in low risk areas used reactive, ad hoc coping strategies like treatment of sick animals' as opposed to vaccination. It was thus observed that those communities in the high risk areas would cope better with adverse climate variability and extended disease burden compared to those communities in the low risk areas who lack knowledge of some of those strategies.

5. Conclusion and Recommendation

The study intended to establish whether there was a difference in exercise of strategies by communities in subsequent RVF outbreaks. This study has demonstrated how geospatial techniques and tools can be used to characterize and understand coping strategies exercised by communities in Ijara district against RVF outbreaks. Through the identification of bio-physical factors that are most significant to the outbreak of RVF and geo-statistical analysis, a generalized linear model (glm) was used to differentiate the RVF risk index across Ijara district.

The type of soils dominant is a region was identified as significant factor occur in most of the flat areas. During periods of extended rainfall, the solonetz, vertisols and luvisols soil type have the capacity retain water for long creating a conducive environment for mosquitoes to breed. these potential hotspots for RVF. The correlation coefficient of these soil types to occurrence of RVF is 2.74 in the high risk areas as opposed to the of -1.99 for low risk areas.The high and low RVF risk areas were approximately split halfway across the whole district, northwards and southwards respectively.

Further, our results show that communities in the high risk areas have strategic measures such as vaccination, controlled animal movement with awareness to changing climate and disease incidence. Those in low risk areas used reactive, ad hoc coping strategies like treatment of sick animals as opposed to vaccination. Thus communities in the high risk areas are more likely to cope better with adverse climate variability and extended disease burden compared to those communities in the low risk areas who lack knowledge of some of those strategies.

The rainfall data used in this research was of moderate resolution. Higher resolution rainfall data over a longer time period would greatly assist in corroborating these results. Other geo-statistical models that are able to consider dynamic factors like NDVI (at a low resolution approx. 5km or less) should be explored. This will make it possible to refine the RVF risk map as outbreaks especially those sporadic can be factored into the model.

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Paper ID: SEP14136

1048