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Application of Geographical Information System (GIS) and Remote Sensing (RS) Technologies to Clarify the Occurrence of Rift Valley Fever (RVF) In White Nile State, Sudan

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ABSTRACT

An attempt was made in this study in order to apply Geographical Information System (GIS) and Remote Sensing (RS) for disease mapping of Rift Valley Fever (RVF) in the White Nile State, Sudan. Rift Valley Fever (RVF) is an acute vector-borne zoonotic disease caused by an Arbovirus. Geographical Information System (GIS) is a computer based programme used to store and display digital data on a map representing earth surface. While, Remote Sensing (RS) is a method for acquisition of information about an object without physical contact.The results revealed that there was a relationship between occurrence of RVF and heavy total rainfall which was 382mm in 1973 and 782 mm in 2007 at Kosti station. The maximum temperature in the dry hot season was 43.1, 40.8 and 40.3 $^{\circ}C$ in 1973 and 41.9, 42.6 and 38.0 $^{\circ}C$ in 2007 for April, May and June respectively. In both two years the disease was reported there and the rainfall was more than the normal average. It is well known that the high temperature in summer followed by heavy rainfall might be responsible for occurrence of Rift Valley fever (RVF). The soil type is a clay soil in Kosti and Guda, however, in Tendalti is a sandy one. An assumption was made that the clay soil has a great impact on vector replication habitat. The elevation level above sea surface was 415, 378 and 372 meters for Tendelti, Guda and Kosti, respectively. As seen from the results, Kosti is the most depressed point in the study area, which made it the most prone for accumulation of rain water. The results confirmed the fact that Normalised difference Vegetation Index in Sudan increase when total rainfall increase. In conclusion, there was a relationship between the occurrence of Rift Valley Fever and heavy total rainfall, maximum temperature in summer seasons, soil type, elevation level and animal species. Furthermore, the epidemiological importance of the locality can be determined by landscape of the area and its natural foci disease as well as the extent and nature of contact of man and his environment. Based on that, more investigations regarding the relationship between the disease and the climatic indicators are required in order to enable the veterinary authorities to use the Early Warning System, regulate and restrict animal's movements, and explore the influence of herd immunity on the epidemiology of Rift valley Fever.

Keywords: Geographical Information System (GIS), Remote Sensing (RS), Rift Valley Fever (RVF), White Nile State, Sudan

INTRODUCTION

Rift valley Fever (RVF) is a mosquito-borne viral disease with a pronounced health and economic impact in domestic animals and human populations in much of sub-Saharan Africa (Megan and Bailey, 1989). The disease causes a high mortality and abortion in domestic animals. Rift Valley Fever (RVF) epidemics are closely linked to occurrence of warm phase of the Elnino Southern Oscillation (ENSO) phenomenon (Linthicum et al., 1999). The climatic determinants of the onset of RVF emergence are those which allow large numbers of the primary *Aedes mosquitoes* vectors (Davies, 2006).

Geographical Information System (GIS) is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, analyse, and display all forms of geographically referenced information. A Geographical Information System (GIS) can be used as a tool for any discipline which handles with data that can be connected with geographical locations, such as countries, regions, communities, or co-ordinates. The systems have been developing rapidly in the past and today there is a number of different software which is more user-friendly than in the past. Geographical Information System (GIS) is about to become tools for everyone. The need for using this system also in the field of veterinary medicine has been emerging during the last decades. Sanson et al. (1991) described the systems and possible applications in the field of veterinary medicine. Still, the most used application of GIS is to produce descriptive maps. However, the potential of GIS is much larger. Reviews in the field of environment and the field of animal health (Sharma, 1994) have been undertaken. GIS has been included indecision support systems for control of infectious diseases in animals (Sanson, 1994). The value of geo-referenced data in veterinary surveillance of both endemic and exotic diseases is immense. Recent examples in the literature show that these data have been used not only to identify areas with excess disease (Haine *et al.,* 2004) and target areas for further studies (Graham *et al.,* 2005) but also to produce hypotheses about means of disease introduction (Vigre *et al.,* 2005), identify the likely site of incursion of an exotic disease (Stevenson *et al.,* 2006) and for predictive modeling of alternative control strategies (Yoon *et al.*, 2006).

Remote Sensing is defined as the method of acquisition of information about an object without physical contact (Colwell, 1983). It means obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Washino and Wood, 1994). Thus, the use of the term remote sensing usually refers to the gathering and processing of information about the earth's environment, particularly its natural and cultural resources, through the use of photographs and related data acquired from an aircraft or satellite.

Statement of Justificatoins

Geographical Information System becomes an important tool which can be used by every one on his field specially on animal heath sectors, but its upright now we don't explore its great potentials in disease surveillance, investigation and control. Geographical Information System (GIS is) under used tool on animal health sector in Sudan.

There is scarcity of information and studies which correlate vector borne diseases, in general and particularly mosquito-borne diseases (e.g. RVF) to climate indicators to help in disease risk mapping and forecast the disease pattern in time and place (temporal and spatial distribution). Lack of geo-referenced data about RVF in animal in Sudan in spite of the disease occurrence since 1973 in the White Nile State. Eisa et al. (1980) described the wide spread of precipitating antibodies against RVFV almost in all over Sudan States except Darfur. In 2007 outbreak was declared in central states (White Nile, Gizera and Sennar) on October (WHO, 2007). A study by Hassan (2008) proved the presence of ImmunoglobulinG IgG in unvaccinated Ruminants in Sennar state. Hence this lack of geo-referenced data necessitates the use of remote sensing as proxy tool to fulfill this gap to offer data for studying the relation between geographical factors and the disease. In remote sensing studies the data on climate can be extracted from satellite image, hence remote sensing can resolve the problems of scarcity of geo-reference ground base climatic data.

Objectives

The aim of this research work is to correlate the occurrence of RVF with climatic indicators, environmental conditions, and any others anthropogenic factors which can determine the occurrence and spreading of the disease.

The specific objectives:

1- To determine the climatic indicators (Such as total rainfall, temperature, relative humidity and wind speed) of the disease.

2- To determine the environmental conditions which act as predisposing factors for the occurrence and spreading of the disease.

3- To use the findings of the study in order to provide recommendations for improving the prevention and control strategies.

MATERIALS AND METHODS

Study area

White Nile State falls within (Latitude 13° 30 to 12° North and Longitude 33°30 to 31° East). White Nile State is located in the center of Sudan. It is delimited by Khartoum State in the north, North Kordofan State in the west, South Kordofan State and the Upper Nile State in the south eastern and Al-Gazira and Sinnar States in the east. The total area of the state is 39701 square kilometers. The total population is 1,726,356. The most important crops are Durra, sesame, groundnuts, millet and wheat. Animal population is estimated as 7,875,673 heads. The most important towns are Kosti, Al-Dweim, Al-Kawwa and Rabak which is the capital of the State.

Geographical Information System (GIS) data

Geographical Information System (GIS) was used to study the environmental factors which have an impact on epizootics occurrence of Rift Valley Fever (RVF) in the White Nile State, through study the disease status in three localities (Tendelti, Kosti and Guda) so as to endeavour mapping for associated risk with the disease. Climatic data such as temperature, relative humidity, total rainfall and wind speed were obtained from Ministry of Environment, Forestry and Physical Planning. Information on animal species and density were collected from Ministry of Agriculture, Animal resources, Forestry and Irrigation, White Nile State, history of Rift Valley Fever investigated from records and previous studies. Elevation level, latitude and longitude were determined by using Global Positioning System (GPS). However, only field observations were made for soil type, land use, and presence of trees forest.

Remote Sensing data

Remote Sensing data used in the study was the LandSat Satellite Imagery. Free available landSat Images was obtained from the website (http://glct.umiacs.umd.edu.com) so as to study the Normalized Difference Vegetation Index (NDVI) trend in the region for the years of

1987, 2000 and 2006.

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}$$

NDVI= Normalized Difference Vegetation Index

NIR =Near Infrared Wavelengths,

VIS = Visible Red Wavelengths

The landsat Imagery used to construct the NDVI from the oldest available data (1987) and the most recent data (2006) so as to compare two different vegetation types in the study area. Richard's Equivalent was used for the NDVI in Sudan so as to know what the trend of the NDVI and the relationship between NDVI and total rainfall in the study area.

Data analysis

Microsoft Excels (2003) was used for analysis of climatic data. While, Arc GIS version 9.2 was used for displaying the data on maps. The total rainfall and its NDVI equivalent compared to detect the relationship between them. The NDVI increased when the total rainfall increased.

RESULT AND DISCUSSION

Geographical Information System (GIS)

History of Rift Valley Fever in the White Nile State

Rift Valley Fever reported first time in Sudan in Kosti Province in 1973 and the outbreak of 2007 also affected the region. In Guda the disease was not reported in 1973 but during the outbreak in 2007 the region was suspected there and a vaccination campaign carried there among cattle, sheep, and goats. In Tendelti there disease not yet reported among animals and humans.

Rainfall

The area of Kosti in 2007 was hardly affected with flooding after abnormal heavy rain season in White Nile State and bordering states in center of the Sudan Figure 1. It was obvious that the rain waters accumulated around Kosti and in the distance of the north of Kosti. This is due to the elevation in the land in the north and east. It appeared that the high land particularly the south border of White Nile State and the borders of Sennar (mountains) constitute an important source for the flood in the low land (White Nile). On the other hand, ecological variation was observed. Fore instance, the very heavy rainfall in Kosti area in 2007 and the monthly mean of total rainfall was 130 mm. It was more than two times of the normal climatic average (Figure 2). The average of the total rainfall and the distribution were different in the three localities and the highest average was recorded in Guda (suspected for RVF in 2007) and vaccination campaigns against RVF were carried out there. However, the disease was confirmed in Kosti in 1973 and the IgM antibodies for the RVFV had been detected in the animals in 2007. On the other hand, no previous report and vaccination campaign against the disease in Tendelti as well as the lowest average total rainfall was recorded. The annual total rainfall in Guda was 600-800 mm, in Tendelti was 200-400 mm and at kosti station was 200-700 mm.

Temperature

The highest average of minimum temperature at Kosti station was 23 °C in 2009 and 2010. While, the lowest average minimum temperature was 20°C in 1989. In the remaining years the minimum temperature was 22 °C. It is important to mention that the minimum temperature in 1973 and 2007 were similar. The highest average of maximum temperature was 37 °C in 1973 and 1990. While, the lowest average of the maximum temperature was 34 ºC in 1989. It is well known that the high temperature in summer followed by heavy rainfall might be responsible for occurrence of RVF.

Relative humidity

The highest average relative humidity was 48% in 2007, while the lowest average per month was 40% in 1990. The relationship between the relative humidity and total rainfall is presented in (Table1) which confirmed the fact that when the total rainfall increased then the relative humidity also will be increased.

The wind speed

The wind speed is shown in. The highest average per month of wind speed was 6 K/ Not in 1973. While, the lowest wind speed was 4 K/ Not in 1989, 1990, 2006, 2008 and 2009. The average per month of wind speed in 2007 was 5 K/not. The speed of the wind and its movement strongly affecting the mosquitoes dispersing.

Soil type

The soil type in Kosti and Guda is clay soil. However, the soil in Tendelti is sandy one. This variation has a great impact on the drainage; the clay land usually has bad levels of drainage compared to sandy soil.

Land use

There was a variation on the land use but the most obvious one is that in both of Kosti and Guda, the large areas of agricultural scheme using pump system irrigation method as well as large planed agricultural projects which produce (sugar cane, cotton, Sorghum and vegetables). The rain fed mechanized agricultural system and traditional agricultural activities were also observed. Tendelti is located about 100 kilometers west bank of the White Nile River. There was no irrigation system agricultural activities other than around the under construction dam on the seasonal stream (Khour-abu habel). This might induce change in this aspect as the objectives of the dam construction are to ease the accessibility of potable water for man and animal as well as to use the reserve waters in irrigated agricultural system at least the vegetables for local consumptions. Regarding the vegetation cover drastic change had took place in Kosti, Tendelti and Guda due to the excess trees cutting. These regions were in the Gum Arabic zone before deforestation in the last decades and it was spread for many different reasons such as extension of mechanized agricultural activities and fire wood needs. While, there was no replacements for the forests which were removed out.

Elevation level

The elevation level was 415 meters, 378 meters and 372 meters above sea surface level for Tendelti, Guda and Kosti, respectively. The difference in elevation is due to the land topology in the study area. It is generally from the plain landform exceptionally dispersing little hills in Algabalin locality.

The animal's species and density

The most reared animal species in Kosti are Sheep, Cattle, Goats and little numbers of camels. In Tendelti are sheep, cattle, goats and camels, respectively. In Guda (Alagablin Province) the Cattle are the most grazed animals among the livestock in the locality, sheep comes in the second rank then goats, and there was no camels.

Remote Sensing (RS)

Land cover

The results of Normalized Difference Vegetation Index (NDVI) are presented in Tables (2, 3 and 4) and Figures 6. The NDVI increased when the total rainfall increased. The NDVI equivalent was highest in Guda point and was ranged from 0.184 to 0.284, in Kosti Was ranged from 0.098 to 0.267 and in Tendelti was the lowest one and ranged from 0.098 to 0.141. As seen from the result particularly in Kosti the NDVI increases with the total rainfall increasing and there was association between epizootic of RVF and NDVI value Ranged from 0.145- 0.267.

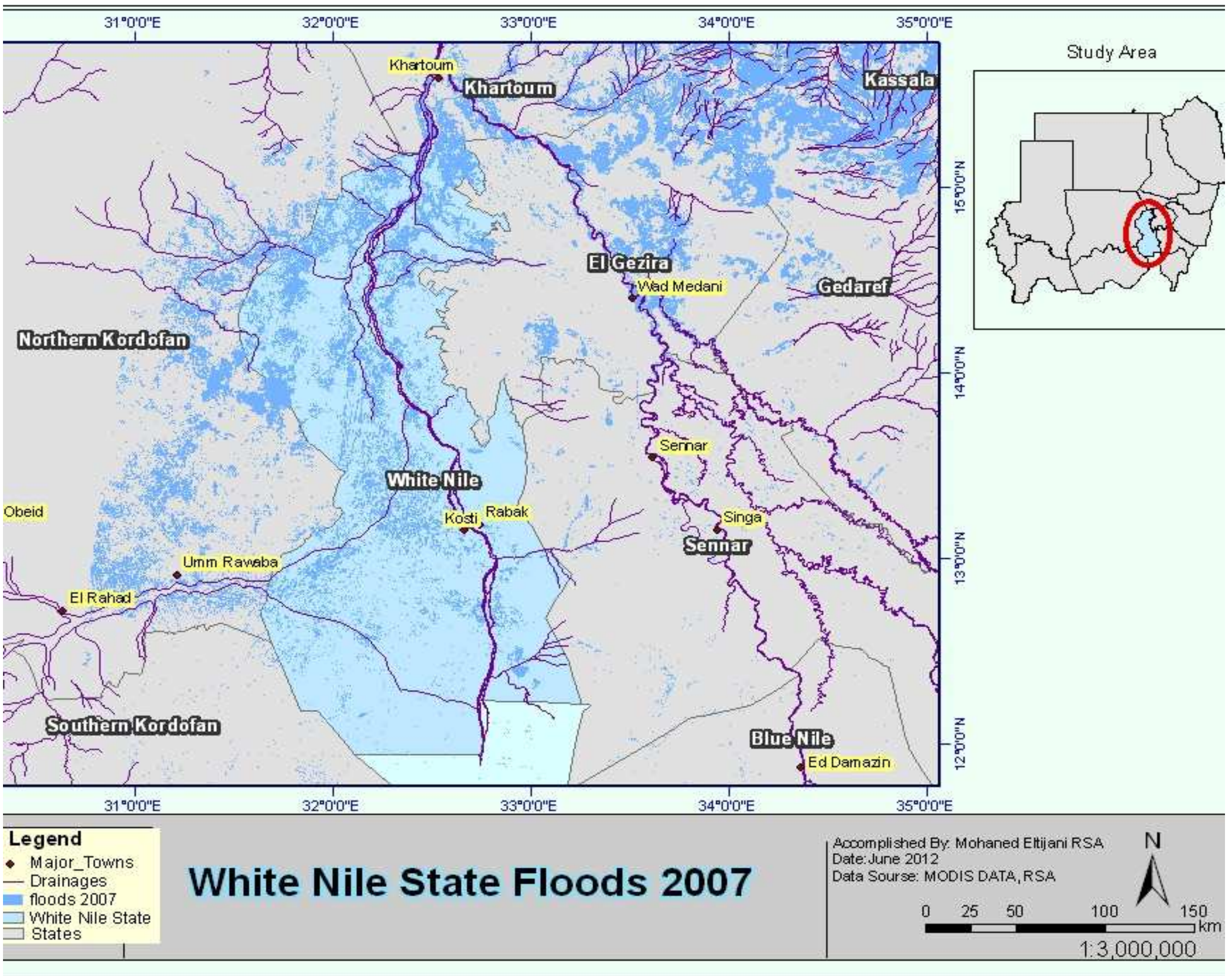

Figure1: Flood in White Nile State in 2007

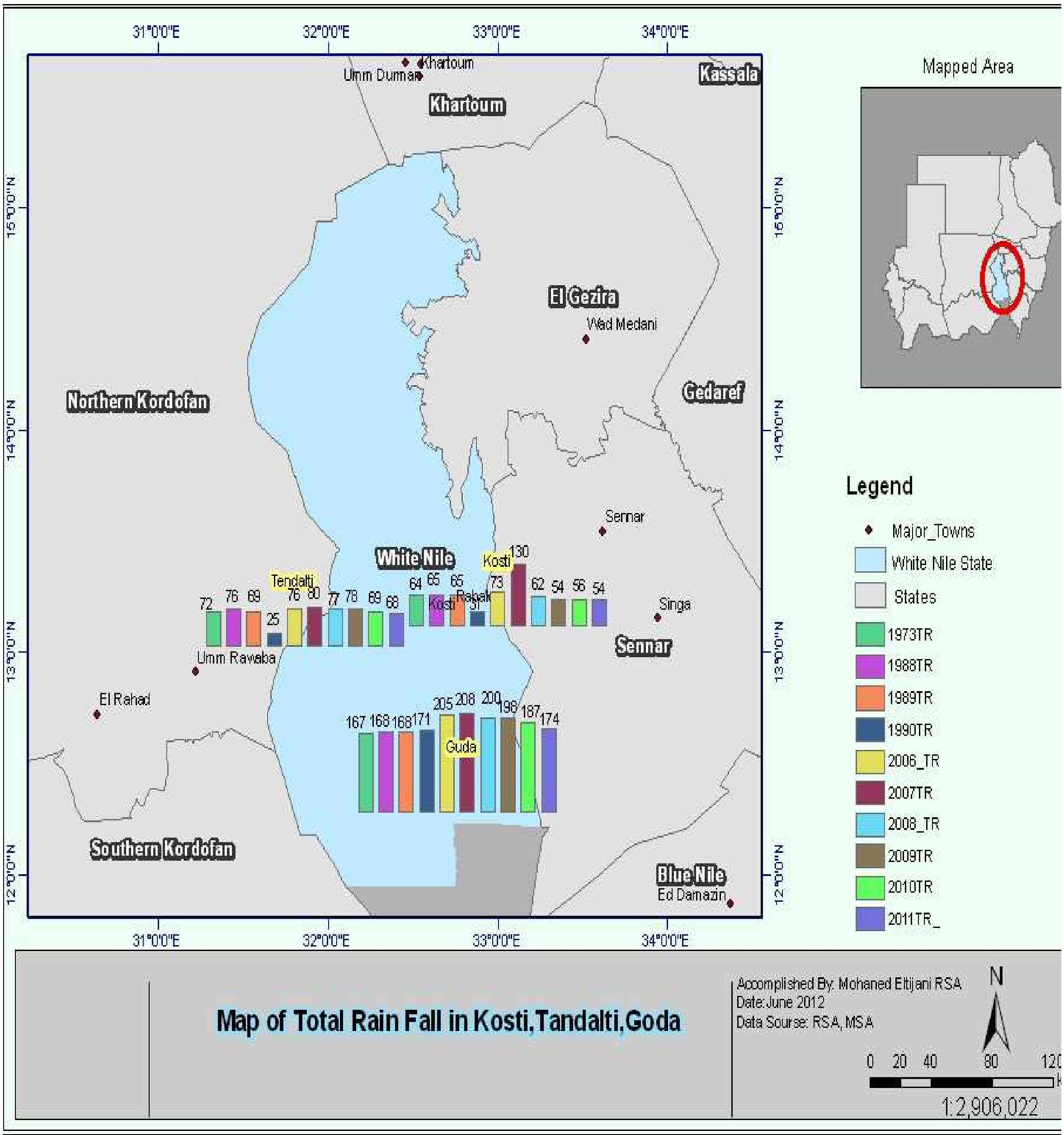

Figure 2: Total rainfall in Kosti , Guda and Tendelti For ten years (1973- 2011).

Year	**Total rain fall/mm**	**Max-t**	**Min-t**	**Relative humidity %**	**Wind speed K/not**
1973*	64	37	22	46	6
1988	66	36	20	43	4
1989	65	34	21	46	5
1990	31	37	22	40	4
2006	73	37	22	54	4
2007*	130	36	22	48	5
2008	62	36	22	47	4
2009	34	35	23	43	4
2010	56	38	23	46	5
2011	54	37	22	43	5

Table (1): Summary of the results of the climatic data at Kosti Station.

The climatic indicators are in month average.

Max-t = Maximum temperature

Min-t = Minimum temperature

K/not = Kilometer per Knot

Year	Total rainfall	NDVI
1973	382 mm	0.145
1988	386 mm	0.145
1989	391 mm	0.145
1990	183 mm	0.098
2006	427 mm	0.162
2007	786 mm	0.267
2008	372 mm	0.119
2009	429 mm	0.145
2010	400 mm	0.141
2011	324 mm	0.119

Table (2): Total rainfall and its Normalised Difference Vegetation Index (NDVI) equivalent at Kosti station for ten years (1973-2011).

NDVI=Normalised Difference Vegetation Index.

NDVI increase when the total rainfall increases.

Year	Total rain fall	NDVI
2001	278 mm	0.119
2002	304 mm	0.141
2003	277 mm	0.119
2004	197 mm	0.098
2005	302 mm	0.141
2006	288 mm	0.141
2007	319 mm	0.141
2008	308 mm	0.141
2009	312 mm	0.141

2010	287 mm	0.141

Table (3): Total rainfall and its Normalised Difference Vegetation Index (NDVI) equivalent in Tendelti (2001-2010).

NDVI= Normalized difference vegetation index.

Year	Total rainfall	NDVI
2001	667 mm	0.184
2002	768 mm	0.205
2003	770 mm	0.267
2004	767 mm	0.205
2005	822 mm	0.284
2006	751 mm	0.267
2004	832 mm	0.284
2008	800 mm	0.267
2009	788 mm	0.267
2010	790 mm	0.267

Table (4): Total rainfall and its Normalised Difference Vegetation Index (NDVI) equivalent in Guda (2001-2010).

NDVI= Normalised Difference Vegetation Index.

Discussion

This research work had been carried out in White Nile State to determine the relationship between occurrence features of Rift Valley Fever (RVF) and the eco-climatic indicators such as total rainfall, temperature, and landscape by application of Geographical Information System (GIS) and Remote Sensing (RS) technologies.

Our study on the ecology of RVF in White Nile State is in agreement with many previous studies on the relationship between RVF and impacts of eco-climatic factors. There was an association of epizootic of RVF with abnormal heavy rainfall. This was clear in the epidemic of the disease in White Nile State in 2007. The total rainfall was twice time above the normal climatic average at Kosti station. This finding agreed with Davies *et al.* (1985). They reported that in East Central Africa the epizootics and epidemics of RVF were associated with heavy rainfall seasons. The key factors in the association with virus activity appeared to be wide spread rainfall in several sites.

Moreover, Elfadil *et al.* (2004) stated that the outbreak of RVF in Saudi Arabia and Yemen in the year 2000/2001 was attributed to environmental conditions of Jazan region which is characterized by high rainfall (300-700 mm). This heavy rainfall should continue and persist for a long time, that large numbers of secondary vector populations build up. The same environmental condition occurred at Kosti station in 2007 where RVF was reported the first time in1973 by Eisa and Obeid (1977). Later in 2007 the Ministry of Animal Resources and Fisheries confirmed the presence of IgM antibodies of RVFV. In the last epidemic in 2007 the rainy season started early with heavy abnormal fall in June and persisted to October as unlike the previous years where the heavy rain confined from July to September.

The most important epidemiological temporal fact about RVF that the disease had been reported for the first time in Kosti province in June in 1973 at the beginning of the rainy season. However, in 1973 the total rainfall was 382 mm which did not exceed the normal climatic average. The rainy season had been started with heavy rainfall in May.

In both of two years (1973, 2007) temperature was very high in the dry hot season (the summer) from March to May and the highest temperature was 43.1and 43.2 °C on April in 1973 and 2010 respectively. All above findings most probably have an effect on the replication of RVF vectors, particularly *Aedes* mosquitoes the primary vector which has the ability to persist in the long dry spell buried deeply in the soil layers. After that dryness if the heavy rain took place the mosquito's egg rehydrated and hatches to give infected adult mosquito which are able to transmit the virus to susceptible hosts (Le Duc, 1989). Persistent of heavy rainfall made the suitable environmental conditions for the other secondary vectors of mosquitoes and other biting flies to build up. Furthermore, the spreading of RVF will be increased due to amplification of the virus in the susceptible ruminant host. If large numbers of susceptible host parasitized with mosquitoes in this infected place, then epizootic transmission may occur, and the aftermath may be an epidemic of RVF especially among the people who live in contact with animals (Le Duc, 1989).

Generally, precipitations and temperatures are affecting climatic factors in vector borne diseases. However, mosquitoes are considered to be the main vector of RVFV and its response with a high sensitive scale to the fluctuation and change of the climate more than many other arthropods species. This adaptability jeopardizing animal and man health. There are many who are debating the role of climate changes on the health. But certainly there is undoubted significant effect of climate on the epidemiology of vector borne diseases. Because the climate changes affects the host, vector efficacy and the viability of pathogen agent (Sophie and Eric, 2012).

Warmer temperatures may allow mosquitoes such as *Culex annulirostris* and *Aedes vigilax* to reach maturity much faster than in lower temperatures. The temperatures at Kosti station when the disease activities detected was hotter in summer and the minimum temperature was 22 °C. This degree is equal to many mosquitos' species for optimum replication temperature.

Among the factors mentioned for the re-emergence of vector-borne diseases, some of them are related to change of the environment such as land-cover or change in the weather patterns. The land cover change in White Nile State particularly in Kosti province since the mid of the last century, undergone drastic land use change (irrigation agricultural system) and the expansion which is going on up to now (sugar-cane cultivations) may induce an environmental change with an impact on the vectors and the host, or the virus transmission patterns. This aspect is required careful study to find preparedness and contingency plans for the control if the change leading to create a high risk zone. Keeping in mind that RVF had spread in Egypt in 1977 after Aswan dam project construction. Moreover, the RVF had been spread in *Gazan* region in Saudi Arabia after heavy rainfall season and dams construction (Elfadil *et al.*, 2004).

Crucial ecological factors that determine the epizootic of RVF in Sudan was the soil type. It seem that epizootic of RVF prevail on clay land soil type (kosti). This finding agrees with Anyamba et al. (2010). They found that the RVF in Kenya was associated with solonetz soil type (sort of clay soil). The clay land differ from sand land soil type in drainage, land surface moisture, and vulnerability to erosion. These differences have an effect on the land cover and mosquito's habitats. Other land feature difference was elevation; the most depressed point in the study area was Kosti (372 metres) over sea surface. The elevation differences help to create the suitable mosquito habitats. The flooding waters accumulate in the low land, then mosquito replicate there if the virus is present and when the pastoralist graze or bring their animals for watering, the disease may be transmitted to the susceptible host (Le Duc, 1989).

In Kenya the RVF was found to resurgence in flood vulnerable lands in an elevation less than 500 meters above sea surface level (Allen *et al.*, 2012). As mentioned above the elevation at Kosti station was 372 meters, this may explain the risk factor which are associated with land elevation. There are many anthropogenic factors which may interact with the environmental and ecological changes to make the conditions favorable for the RVF incidence. Keeping in mind that after the south section, the density of the animal in White Nile State may increase if the movement of animals ban by the South Sudan government. Beside that the expansion on the agricultural activities may lead to more susceptible host for RVF.

The animal movement may acquire crucial role on the spreading of RVF if the environmental conditions are suitable for the establishing of the infection in new environment. The disease was not reported in Tendelti, although the animals especially the camels migrate to south Sudan in the dry season. They are exposed to mosquitoes which may transmit the viral infection particularly the south Sudan considered as an endemic area since 1936 (Eisa *et al., 1980)*. The camel may transmit the infection to Kosti with out showing clinical disease. However, in Tendelti the disease was not reported, although the migration of animals and this may be attributed to the variation in the environmental conditions.

Our findings proved the importance of Normalized Difference Vegetation Index (NDVI) as a risk factor for the incidence of RVF in the Sudan. In savannah complexes of East Africa, the RVF was associated with NDVI Value of 0.15-0.40 with annually mean rainfall of 200- 800 mm. A higher NDVI has shown a strong association with the RVFV period particularly in Kenya (Anyamba *et al.,* 2009).

The study area located in savannah complex of the central Sudan and the RVF has an association with the value of NDVI of 0.141-0.267 at Kosti station. This result is in complete agreement with the work of Peters and Linthicum (1994).This may explain the importance of the NDVI in early warning detection and prediction systems. Because the highly resolution satellite imagery can enabling study of the Normlised Difference Vegetation Index (NDVI), total rainfall , Elnino, Inter-Tropical Convergence Zone (ITCZ) and Basin Excess Rainfall Monitoring Systems (BERMS).

Based on that, Kosti is a high risk area due to prevailing of the suitable environmental conditions such as the rainfall fluctuation, the soil type, land use system, and the different species of ruminant's host. Guda can be classified as risk zone although there were some climatic indicators which exceed those recorded in Kosti. The disease was not reported there in 1973, but the outbreak in 2007 many cases among human admitted to Kosti Teaching Hospital were proved to be positive for RVFV by ELISA and PCR (WHO, 2007) traced back to the pastoralist community from Guda. This discrepancy might be due to the weak of investigation and diagnosis when the out break hit the White Nile State in 1973.

Daubney (1931) observed that the endogenous African breeds have natural resistance to the RVF. This resistance may be due to genetic factors. The diseaseis not present on its clinical form in many instances, except the storm of abortion in the pregnant females, and high mortality rate of newborn. In pertain to the herd immunity and the epidemic of RVF in the indigenous breeds in Africa the animals may acquire their resistance to the clinical disease according to the continuous contact with the virus in natural pastures. The RVFV was found in its cryptic cycles low level activities in South Sudan. Described positive serum samples for RVFV, among different ruminant host from South Sudan. In preliminary survey for precipitating antibodies by Eisa (1984) reported different rates of the positive sera samples of precipitating antibodies against RVFV among ruminants and other domestic animals (equine) all over Sudan states except Darfur state, without obvious clinical disease in the animal at that time in Sudan this may explain the state of cryptic cycle activity of the virus .

A Study by Hassan (2008) revealed that the IgG antibodies prevalence rate during 2008 in Sennar State ranged from 4.2% to 20.8%. Based on that the RVF may pose a great hazard in a vast area in different Sudanese State especially White Nile, Sennar, and Gizera States. We forewarn that if the borders between Sudan and South Sudan are not secured and well monitored a destructive outbreak may take place if the favorable environmental conditions prevail. On the other hand, if the pastoralist deprived from grazing in South Sudan pastures the acquired immunity level of livestock may decrease because in South Sudan the environmental conditions are favorable for the virus activity are more common. Finally, regarding herd immunity there is a suggestion that in the region where the epidemic of RVF occurred in humans who are suffering from chronic endemic Malaria, Schistosomiasis, and the Human Immunodeficiency Virus (HIV), all these diseases made a compromised immune system (Immunosuppressive diseases). The out come of RVFV infection among those populations who are affected by immuno-suppressive diseases render them more susceptible to RVF. Kosti is known by its endemicity for chronic parasitic diseases such as Fasciolosis and Schistosomiasis and this may increase the susceptibility of the animals for RVF.

CONCLUSION

The epidemiological significance of a locality in incidence of Rift Valley Fever (RVF) is determined by the following factors:

a) Climatic factors such as high rainfall, high average maximum temperature in dry hot seasons (summer), land elevation level above sea surface and the soil type.

b) Animal species and movement of animals.

c) Land use, human behavior and mobility, knowledge and perception of disease risk, and socio-economic conditions. Generally, previous studies in spatial epidemiology have ignored or given less emphasis to the latter set of factors (i.e., land use and human behavior).

The challenge in landscape epidemiology is to integrate dynamically these different factors, with an emphasis on their interactions and not just on their spatial over lay, by identifying a set of propositions on factors controlling these interactions. This study contributes to a general understanding of spatial variations of risk to Rift Valley Fever (RVF) and clearly outlines the environmental factors that are created by humans which could lead to future urban outbreaks of Rift Valley Fever for the first time with potentially devastating consequences (irrigation system schemes and water harvesting projects).

RECOMMENDATIONS

1. There is an urgent need to highlight the importance of studies which disclose the association between epidemics of Rift Valley Fever and environmental conditions which could work as risk factors to enable more efficient and effective strategy control.
2. Further study is needed to identify the role of the main vectors in the country and the environmental conditions which create conducive habitats for mosquitoes and increase the vectors capacity to transmit the virus among animals and human initiating out-breaks.
3. Improve the surveillance system for the RVF disease in the country.
4. Enhance the capacity of the veterinary authorities in the country to implement an early warning system using Geographical Information System (GIS) and Remote Sensing (RS).
5. The regional and international cooperation is needed as the only way to fight the disease expansion since the disease does not respect geographical borders of the countries.
6. It is well known that any agriculture development project may induce drastic change on the environment condition on its area or around. The agricultural schemes and water harvesting are an examples of that sort of developmental projects should be urgently studied to evaluate their effect on the environment condition and the epidemiology of vector-borne diseases in general and Rift Valley Fever particularly and all water related diseases.
7. For better understanding of the associated risk with Rift Valley Fever epizootics/epidemics in Sudan a thoroughly statistical epidemiological studies are needed

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