Research Article ISSN 2767-5416

Journal of Medical Clinical Case Reports

Mathematical and spatial epidemiology to rift valley fever and its association with climate in Sudan : Prospective study

Mohamed E.A.Mansour

Central Veterinary Research Laboratory (CVRL), Sudan.

***Corresponding author**

Mohamed E.A.Mansour,
Central Veterinary Research Laboratory, (CVRL),
Madani street, Kilo (10),
Soba, P.O.Box8067,
Postal code: 12217,
Khartoum, Sudan.

Submitted : 25 Jun 2024 ; Published : 10 July 2024

Citation: Mohamed E.A.M., (2024). Mathematical and spatial epidemiology to rift valley fever and its association with climate in Sudan: Prospective study. J Medical Case Repo, 6(3):1-7. DOI : https://doi.org/10.47485/2767-5416.1084

Abstract

Rift valley fever (RVF) is transboundary zoonosis that impacts on health and trade. It caused by RNA virus that belongs to family Bunyviridae, genus Phlebovirus. It characterized by abortion in small ruminants following heavy rain falls. Also the virus is stable and survives in mosquito vector. Also, it is transmitted by contact with infected tissues and undercooked milk. RVF symptom is influenza like illness, in a severe cases bilateral blindness and encephalitis occurred. Its case fatality rate is very low (CFR=1%), however, it is reported to be as 50% in man. The objectives were to understand RVF epidemiology, analyze its climate and spatial patterns. The method used was to examine dependent and independent variables. The univariate analyses showed significant association between RVF and rain falls, vegetation cover, temperature and ElNino, respectively. The multivariate analyses found significant association between rain fall and vegetation index and RVF. This means rain fall and vegetation index were risk factors for RVF occurrence. Also, likelihood of transmission was calculated as 2.42 where infectiousness that an individual can infect another one. RVF basic reproduction number (R0) was estimated as 0.003. The study discussed RVF likelihood as (1.08%±2SD) decrease in RVF prevalence during year 2025; however no RVF outbreak is expected. The study concluded overall RVF prevalence was 34%. It recommended regression analyses is a very good to predict RVF, however vector ecology is essential. Therefore, this improves RVF management.

Keywords: RVF, epidemiology, predictive analyses, climate, Sudan

Introduction

Rift valley fever (RVF) is transboundary zoonosis that impacts on animal and man health. It is mainly occur in small ruminants like sheep and goat and also large animals. It belongs to family *Bunyviridae*, genus *Phlebovirus*(Calisher, c.h. & karabatsos, n, 1989). It is characterized by high rate of abortion in pregnant animals following heavy rain falls accompanied with disease in human (G.H., 2004). It can be transmitted by direct contact with infected fluids and tissues or/and raw milk ingestion. *Aedes Egyptiae* is disease principle vector (Iranpour, M *et al*.,2011). It survives in inter-epidemic periods and transmit the virus via vector contaminated eggs to its progenies; whereat it lives in land depression (dambos) and spill over virus when conditions were suitable (OIE, 2014). Also RVF was found to be associated with ElNino phenomenon in Eastern Africa, where at Indian oceanic temperature rises; it leads to evaporation and cloud accumulation, then heavy rain in East Africa. RVF outbreak was predicted to occur in Kenya and Sudan in 2008 through weather monitoring via satellite imagery (Anyamba A *et al*.,2001). Geological data are essential to estimate RVF, where its epidemiology is related to vector habitats. Also outdoor sleeping makes people at risk due to mosquito abundance. Also it can transmit the virus from animal host to human indirectly. In human, most of RVF symptoms are influenza like illness and in a serious cases, meningitis and blindness whereas hemorrhagic fever, jaundice beside hepatic disease was pathognomonic to RVF. It can cause systematic infection (MadaniI T.A *et al.*, 2003). Climate, like rain falls, humidity and vegetation index were found to be associated with RVF incidence. In addition, RVF was reported in African continent and recently in year 2000 it had been reported in Arabian Peninsula and Madagascar (Shoemaker, t *et al*., 2000). This made huge impact due to livestock trade ban from Africa to gulfs and Arabian countries (Meegan, j.m. & bailey, c.l, 1989). However, RVF outbreaks and foci are frequently reported in the Sudan. Thus, this study is an endeavor to carry out predictive analyses to disease prevalence and its association with weather. Also to evaluate spatial epidemiology of the disease and how to effectively manage and control it.

Objective

1. To estimate RVF prevalence in study population in the Sudan.
2. To assess environmental risk factors and its association with RVF.
3. To evaluate RVF basic reproduction number and predictive analyses in this study.
4. To understand spatial epidemiology of RVF.
5. To estimate transmission, off spring and time generation distribution of RVF.

Research Hypotheses

The study question was that what factors that affect RVF occurrence and epidemiology were and how can we measure it. This study assumed arithmetic mean value for sample and populations were equal given that they were randomly distributed. Probability distribution for RVF was predicted as 0.36. What if sample and population were differing, then we did accept type II error (β=0.01) whereat in 100 sample we were confident that 95% of sample had an effect on population and only 5% had no effect (Cohen, J., 1992). Then after we did reject null hypotheses and accept alternative on which in fact is true.

Material and Method

Data Collection

Data were collected about RVF climate information about different districts in Sudan during 1973 to 2007. Then, it was analyzed to determine RVF prevalence in study area. Also, previous reports and information about RVF outbreaks and cases in suspected population were used for this study respectively. Literature and publications about RVF used figure1.

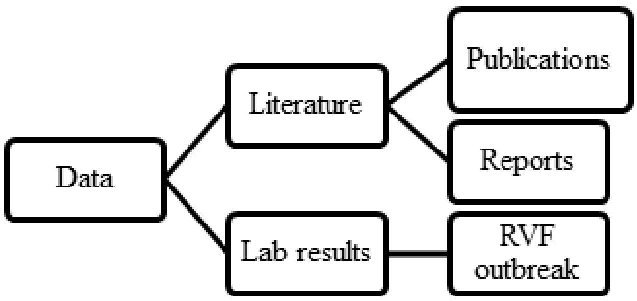

Figure 1: figure explains RVF data collection

Study Area

This study was carried out in areas where RVF were reported (Khartoum, Gezira, White Nile, Sennar and Blue Nile and Gedarif states) where climate are suitable for incidence and new cases to occur. Those districts are characterized by high rain fall and irrigation schemes.

Study Population

The current study was focused on small ruminant's population like goat and sheep as target population. Sudan had 50.1 million sheep and 42.1 million goats in 2006 (Central Bank of Sudan, 2004). Beside large animals like camel and cattle were considered in this study, however small ruminants are more susceptible to RVF than large animals but they can act as carrier or/and reservoir.

Sample Size and Study Design

Sample Size Determination

Sample size was determined by using the following formula according to sampling method used to estimate RVF prevalence in study population (Thrusfield, M., 2007).

$$\text{Sample size (n)} = \frac{1.96 * Pexp(1 - Pexp)}{d^2} \quad (1)$$

Where at

n = required sample size

Pexp = expected prevalence

d = desired absolute precision

Thus, 176 samples were required to detect 34% expected RVF prevalence given that population was randomly distributed. The study design was longitudinal study where in new incidence and cases are considered to evaluate trend of the disease. However, Sample size (n=100) used in analyses.

RVF Analyses Model

This study done to estimate RVF epidemiology. Also, prevalence, risk factors and spatial pattern were determined. The final model is to understand RVF epidemiology and how to reduce its prevalence in study area.

Mathematical Analyses for RVF Transmission

Reed frost analyses will be demonstrated to evaluate RVF epidemic curve during study period. RVF outbreak transmission was estimated by determining disease off spring and time generation distribution.

Spatial Pattern to RVF

Information about weather to design spatial map analyses for RVF outbreak in suspected area was used. Qgis software version 3.16, Hannover used in this study (Post gis-project, 2013).

Off spring and time generation distribution

The off spring distribution *p*(y) of RVF was calculated as probablity of secondary infection (y) that were caused by index case where was equal to y. Also time generation distribution was estimated by determining time when an individual was able to infect another one (Nicholas C. Grassly and Christophe Fraser, 2008).

RVF basic Reproduction Number (R0)

The basic reproduction number was determined by using the following formula (Becker NG *et al.,* 2006).

$$R0 = \beta\tau \quad (2)$$

Where at

R0 : Basic reproduction number

B : infection producing contact per unite time

T = mean infectious period

If R0>1, outbreak will spill over, and if R0<1 it will die out

Space time map Analyses for RVF

This study estimated RVF model in study population by buffering study area with time factor where at RVF was reported from 1973 to 2007.

Statistical Analyses

Descriptive statistics, univariate, multivariate and mathematical analyses were done. RVF was dependent variable and environmental risk factors (rain fall, temperature, vegetation cover and ElNino phenomenon) as independent variables. Analyses done in Microsoft excel spreadsheet by using analyses tool pack (Sokal *et al*., 1995). Also, statistical analysis software PSPP version 1.4 used in this study (gnu, 2020).

Result

Frequency Table

39 and 61 were frequency of RVF disease and no disease in this study, Figure2.

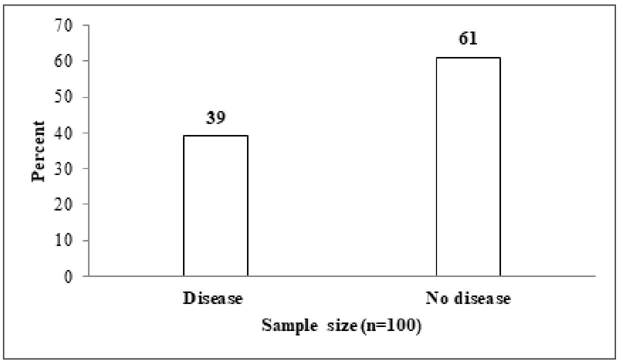

Figure 2: Frequency table to RVF outbreak

Descriptive Statistics

This study showed RVF (R0) probablity distribution, mean value and standard deviation were 0.01, 0.34 and 0.004 respectively Tables 1.

Table 1: Descriptive statistics for RVF and risk factors

Variable		N=100	Mean ± 2 SD	Minimum	Maximum
Climate					
	Temperature	100	0.59 ± 2*2.87	0.29	29.021
	Rain fall	100	418.± 2*46.78	398.20	796.41
	vegetation cover	100	1.02 ± 2*0.07	0.53	1.056
	ElNino	100	0.59 ± 2*2.88	0.29	29.17
RVF					
	RVF R0	100	0.34 ± 2*0.05	0.01	0.36

Univariate Analyses of Environmental Risk Factors

This study showed there was significant association between temperature, rainfall, vegetation index and ElNino phenomenon and RVF infectivity, (*P*-value<0.05). Also, there were relatively very small correlation between them (R^2=0.006), (R^2=0.07), (R^2=0.12), (R^2=0.03) respectively, Table2.

Table 2: Univeraite analyses of environmental risk factors and its association with RVF

Variable		RVF		Chi square	df	P-value
		Disease	No disease			
Temperature	Low	31(44.30%)	39(55.70%)	27.4	1	0.00**
	High	30(100%)	0(0.00%)			
Rainfall	Low	11(22.00%)	39(78.00%)	63.93	1	0.00**
	High	50(100%)	0(0.00%)			
Vegetation index	Low	61(98.40%)	1(1.60%)	95.86	1	0.00**
	High	0(0.00%)	38(100%)			
ELNino	Low	25(39.10%)	39(60.90%)	35.96	1	0.00**
	High	36(100%)	0(0.00%)			

Significance level, * = P<0.05, **= P<0.01, and P< 0.001

Multivariate Regression Analyses

There were significant association between, rain fall and vegetation index and RVF, (P-value<0.05), while temperature and ElNino phenomenon were not, (P-value>0.05) and there was relatively small correlation between them and RVF (R^2=0.23), the co-efficient formula was (RVF= one temperature + 2.52 rainfall- 0.09 vegetation index + 4.61 ElNino) Table 3.

Table 3: Multivariate analyses of climate risk factors and its association with RVF

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Exp(B)	95% Confidence Interval for B	
	B	Std. Error	Beta				Lower Bound	Upper Bound
RVF (Constant)	0.08	0.03	0	2.95	0.00		0.03	0.14
Temperature	0	0.04	0	-0.06	0.95	1	-0.09	0.08
Rainfall	-0.08	0.04	-0.08	-2.17	0.03*	2.52	-0.15	-0.01
Vegetation index	0.92	0.03	0.91	28.09	0**	-0.09	0.85	0.98
ElNino	-0.01	0.05	-0.01	-0.11	0.91	4.61	-0.1	0.09

Significance level, * = P<0.05, **= P<0.01, and P< 0.001

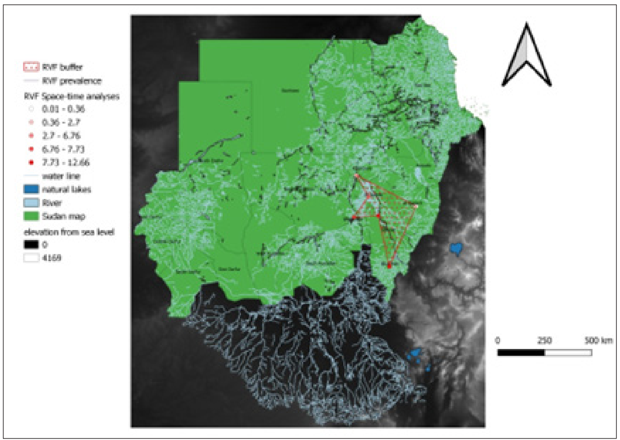

Figure 3: RVFgeographical distribution and its correlation to climatic factors

Figure 4: Space time map analyses for RVF from 1973 to 2007

Predictive Analysis

This study showed RVF probablity as 0.2 given that population was randomly distributed during study period. Also, RVF curve was increasing and get steady and then made plateau. The cut off value for RVF outbreak was estimated as (0. 34± 2SD). For example in year 2025 the likelihood for RVF prevalence was calculated as 1.08% decrease in RVF rate , this means the expected prevalence will be 33.08% , however, RVF outbreak is not likely to occur given that population is randomly distributed.

RVF Spatial Epidemiology

This study showed RVF probablity distribution was estimated as 0.34 given that population is randomly distributed. The lowest RVF probablity was 0.36 and highest was 12.66 in study area, Figure 3.

Space Time Analyses for RVF

This study found estimated overall RVF prevalence as 5.76% given that population is randomly distributed during 1973 to 2007, Figure 4.

RVF off spring and time generation Distribution

This study found that RVF off spring and time generation probability were estimated as 0.03 and 0.02 given that population is homogenous and randomly distributed.

Figure 5: RVF spatial pattern analyses

Basic Reproduction Number R0

This study showed that 10^{th} animal in a given sheep flock as RVF first case determined to infect secondary case given that RVF infection producing contact per unit time was 0.01 and mean infectious period was 0.34. Thus, R0 was estimated as 0.003 where at RVF outbreak was expected to die out, Figure 5.

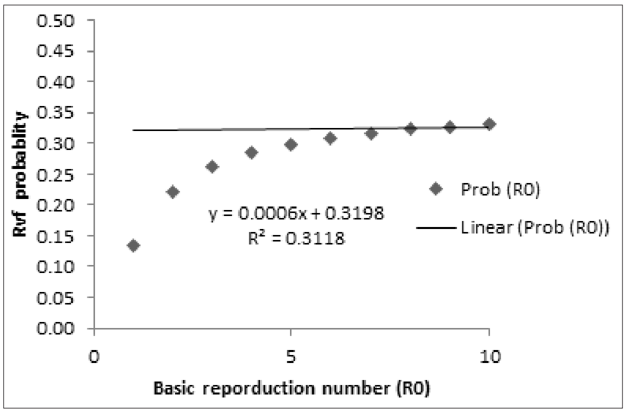

Figure 6: RVF probablity and basic reproductive number

RVF Transmission Analyses

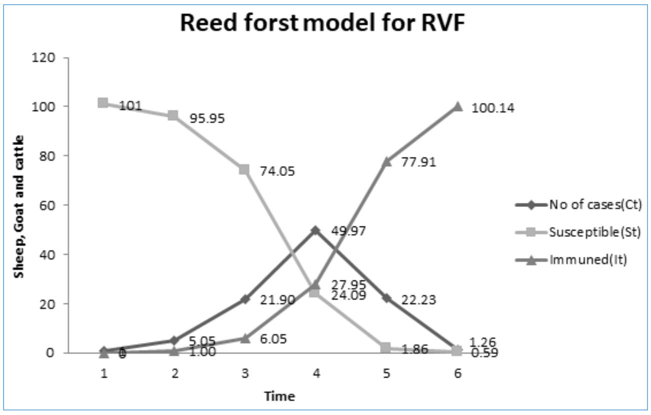

Figure 7: Reed forst analyses for RVF epidemic curve

Discrete data about RVF were examined by using Reed frost analyses. It is epidemic curve to study population. It was stochastic analysis and it was demonstrated by simple graphical representation Figure 7. It was evaluated behavior of epidemic over time, wherein infectiousness was essential to understand transmission rates of RVF outbreak, Figure 6 .Also, this study calculated that average of RVF transmission probability (Prob R0) was estimated as 0.62. it was done by multiply cut-off value (0.31) by 2. Further, transmission likelihood was evaluated as 2.42 whereat an individual was able to infect secondary case; given that contact pattern was known in population that was randomly distributed. The mean of RVF off spring probability was 0.97 and time generation probablity was 0.03, Figure 8.

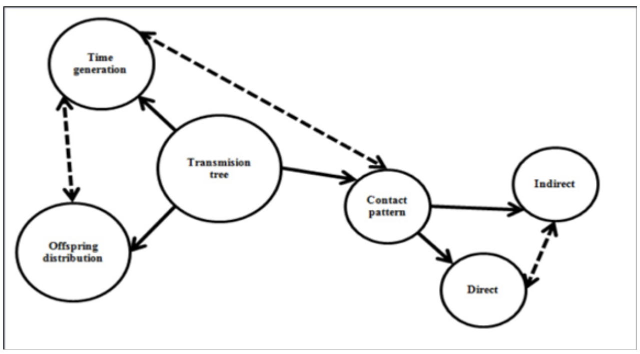

Figure 8: Transmission tree for RVF and it relation to off spring and time generation

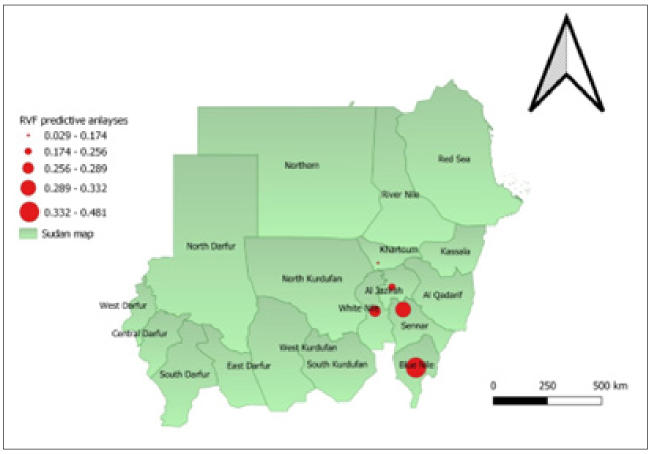

Figure 9: RVF predictive map analyses

Sensitivity Analyses

RVF sensitivity was calculated to determine its prevalence in this study. all factors were included to estimate real situation of RVF. The cut-off value was (0.34 ±2SD) and lowest value was 0.17 and highest value was 0.48, Figure 9.

Uncertainty Analyses

This study found RVF (R0) probability distribution ranged from 0.01 to 0.36 given that population was randomly distributed. Also, RVF (R0) was estimated to be less than one (R0=0.21) whereat RVF outbreak will not spill over in study area given that 99% we were confident 100 samples had an effect on population and only 0.01% had no effect.

Discussion

Rift valley fever is arthropod-born disease that infects small ruminants and human. It has impact and consequence in public health and hygiene and also it can cause economic loss due to livestock trade ban. It has been reported in many countries in Eastern African community like Sudan, Kenya, Tanzania, and Eretria, Djibouti and other countries. This study discussed that weather and RVF outbreak in Sudan was important. The first report of RVF outbreak was done by (EISA, 1984), in Whit Nile state where involved RVF surveillance in suspected animal. Also, it had been reported in year 2007 where it did break out in animal population accompanied with man disease where ictrus and eye disease where reported. Also, RVF was reported in Sudan in animal population (World Organisation for Animal Health, 2019). Lack of coordination between medical and veterinary authority also contribute to spreading of infection and affect disease dynamic. This study was reported that probablity distributions for RVF (R0) in study are estimated to range from 0.01 to 0.36 where at population was randomly distributed. The overall estimated prevalence was 34% in suspected animal population in the study. This was in agreement with study that found similar percentage of RVF among farmers and people working in animal production in Sudan (Ayman A *et al*., 2020). Although other studies showed that RVF prevalence estimated as 9.3% (95%CI 8.1-10.6) in animals (Jean T *et al*., 2023). This discrepancy in prevalence is claimed due to many factors like for example sample size, required absolute precision and laboratory testing properties.

This study found RVF transmission or contact pattern was evaluated as 2.05 where at an infectiousness can occur from individual to another. This had determined by RVF off spring and time generation probablity where transmission tree can be depicted. Sometimes, however, it is difficult to detect the contact pattern in particular when time generation distribution is relatively very small to detect. Prediction analyses showed that in best case scenario RVF basic reproduction number was estimated to be less than one (R0=0.003) where an outbreak cannot occurred, however other studies found that even though R0 less than one outbreak is expected due to off springs and size distribution (Jagers P, 1975). For example in year 2025 RVF likelihood is decreasing by 1.08% and there is increment in RVF reproduction number (R0=0.36), however no outbreak is expected to occur given that population is randomly distributed. Thus, there is decline in RVF prevalence among suspected population by approximately about one percent but R0 is increasing, but no serious outbreak was expected to happened, though RVF foci is expected in at risk population. Therefore, increasing herd immunity and vector control can reduce the disease. The univariate analyses found that significant association with temperature, rain fall, vegetation cover and ElNino phenomenon. Thus, study assumption whereat sample and population were differing given they were distributed at random, and RVF was found to be dependent on weather. Then we did accept type II error wherein 100 sample we were confident 95% had an effect on population and only 5% had no effect. Then, we did reject null hypothesis, where there was no difference and did accept alternative one which is true in fact. Other study was found to be in agreement with this report whereat RVF climate condition is very necessary to RVF occurrence (Faburay, 2015). Also, another study found that topographic wetness index (TWI) and enhanced vegetation index (EVI) were significantly related to RVF, whereas, precipitation and human density were not significantly associated (Carson T et al., 2023). Also, more up to date information are important to improve this study to better predict RVF epidemiology in Sudan. Beside, rigorous disease management and surveillance planning to have thorough knowledge about disease epidemiology and then reduce its prevalence and increase the production.

Conclusion

The study concluded that the overall RVF prevalence was estimated by 34% in this study. The univariate analyses found that temperature, rain fall and vegetation cover and ElNino phenomenon were associated with RVF;whereat in multivariate analyses only rain fall and vegetation index were significant.

Recommendation

The study recommended that multivariate regression analyses are a very good tool to predict RVF outbreak in the Sudan. Therefore, this can improve management and control of the disease. Also, vector ecology was needed to improve the final epidemiological model in the study area.

Acknowledgement

The author of this article wants to acknowledge the director of central veterinary research laboratory, CVRL Sudan to accept publication of this work.

Conflict of Interest

There is no conflict of interest in this work.

Author’s Contribution

Mohammed E.A.M had collected managed, analyzed data and also had written the manuscript for this work.

Funding Information

No fund was allocated for this work.

Ethical Approval

This work had been done after ethical approval from CVRL; Sudan where it represents governmental authority that this work does not cause harmful impact on animal welfare and animal health regulation and principle.

Bibliography

1. Anyamba A, Linthicum KJ, Tucker CJ. (2001). Climate-disease connections: Rift Valley Fever in Kenya. Cad Saude Publica., 17.
2. Ayman Ahmed, Yousif Ali, Adel Elduma, Mawahib Hassan Eldigail, Rehab Abdallah Mhmoud,Nouh Saad Mohamed, Thomas G. Ksiazek, Isabelle Dietrich, Scott C. Weaver. (2020). Unique Outbreak of Rift ValleyFever in Sudan, 2019. *Emerging Infectious Diseases, 26*(12), 3030-3033.
3. Becker NG, Glass K, Barnes B, Caley P, Philp D, McCaw JM, et al. (2006). The reproduction numberUsing Mathematical Models to Assess Responses to an Outbreak of an Emerged Viral Respiratory Disease. *National Centre for Epidemiology and Population Health*.
4. Calisher, c.h. & karabatsos, n. (1989). Arbovirus serogroups: definition. In: monath, t.p., (ed.). *The Arboviruses:Epidemiology and Ecology, Vol. I*(19–57).
5. Carson Telford ,Luke Nyakarahuka , Lance Waller, Uriel Kitron,and Trevor Shoemaker. (2023). Geostatistical Modeling and Prediction of Rift Valley Fever Seroprevalence among Livestock in UgandaGeostatistical Modeling and Prediction of Rift Valley Fever Seroprevalence among Livestock in Uganda. *Am J Trop Med Hyg, 108*(4), 712–721.
6. Central Bank of Sudan. (2004). Annual Report. No. 44. Khartoum- Sudan.
7. Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159.
8. EISA, M. (1984)). Preliminary survey of domestic animals of the Sudan forprecipitating antibodies to Rift Valley fever virus. *J. Hyg., Camb*., 93, 629-637.
9. Faburay, B. (2015). The case for a “one health” approach to combatting vector-borne diseases. *Infect. Ecol. Epidemiol*, 5, 1–4.
10. G.H., G. (2004). Rift Valley fever. Rev. sci. tech. Off. int. Epiz, 23(2), 613–623.

11. gnu. (2020). Retrieved 6 2, 2024, from http://www.gnu.org/copyleft/.
12. Iranpour, M.; Turell, M.J.; Lindsay, L.R. (2011). Potential for Canadian mosquitoes to transmit Rift Valley fever virus. J. Am. Mosq. *Control Assoc*, 27, 363–369.
13. Jagers, P. (1975). Branching Processes With Biological Applications. *Wiley, London, 1*(282).
14. Jean Thierry Ebogo-Belobo , Sebastien Kenmoe, Ngu Njei Abanda, Arnol Bowo-Ngandji, Donatien Serge Mbaga, Jeannette Nina Magoudjou-Pekam,Ginette Irma Kame-Ngasse, Serges Tchatchouang, Elisabeth Zeuko'o Menkem, et al. (2023). Contemporary epidemiological data of Rift Valley fever virus in humans, mosquitoes and other animal species in Africa: A systematic review and meta-analysis. *Vet Med Sci, 9*(5), 2309–2328.
15. MadaniI T.A., AL-Mazrou Y.Y., AL-Jefferi M.H., Mishkhas A.A., AL-Rabeah A.M., Turkistani A.M., AL-Sayed M.O.,Abodahish A.A., Khan A.S., Ksiazek T.G. & Shobokshi O. (2003). Rift Valley fever epidemic in Saudi Arabia:epidemiological, clinical, and laboratory characteristics. *Clin. Infect. Dis*., 37, 1084–1092.
16. Meegan, j.m. & bailey, c.l. (1989). Rift Valley fever. In: monath, t.p., (ed.). *The Arboviruses: Epidemiology and Ecology*, Vol. IV, 51–57.
17. Nicholas C. Grassly and Christophe Fraser. (2008). Mathematical models of infectious disease transmission. *Nature:Microbiology*, 6, 477-487.
18. OIE. (2014). Rift valley fever. Version adopted by the World Assembly of Delegates of the OIE in May 2014.
19. Post gis-project. (2013). *Spatial support for postgresql*. Retrieved 3 20, 2024, from http://postgis.refractions.net/.
20. Shoemaker, t., boulianne, c., vincent, m.j., pezzanite, l., al-qahtani,m.m., al-mazrou, y. and others. (2000–01). Genetic analysis of viruses associated with emergence of Rift Valley fever in Saudi Arabia andYemen. *Emerging Infectious Disease*, 8, 1415–14520.
21. Sokal, Robert R., and F. James Rohlf. (1995). The Principles and Practice of Statistics in Biological Research (2nd ed. New York: W. H. Freeman ed.).
22. Thrusfield, M. (2007). Veterinary Epidemiology, 3rd edition. Victoria, Blackwell Science.
23. World Organisation for Animal Health. (2019). Rift Valley fever, Sudan. Follow-up report no. 1.