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Modeling Rift Valley Fever over Egypt in Relation to Weather Conditions

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Abstract

Rift Valley Fever (RVF) is considered as one of the biggest threats for both human and livestock. The disease has significant economic importance due to losses and abortion in infected animals and public health hazard to human. The main purpose of this investigation is to explore the relationship between RVF outbreaks and weather conditions throughout different governorates in Egypt. Therefore, 450 serum samples were collected from sheep and goat for four selected governorates during 2013. Three represent delta region (Kaliobia, Dakahlia, Sharkia) and another one represents north-west coast of Egypt (Marsa Matrouh). Different meteorological parameters have been downloaded and collected for the same locations and year, from NASA website. It was noticed that, number of outbreaks for both animals is decreasing gradually from January to December for all governorates. The maximum occurrence of this disease is happening mainly in January and February. In the same time, the highest RVF outbreaks were reported at El-Sharkia governorate comparable to other ones. In addition, the number of cases had increased and concentrated during the first half of the year compared to the second one. In the same time, outbreaks were increased in sheep than goat at different governorates. Most of governorates did not record any outbreak during the second half of the year; especially for goat. One may notice that, these outbreaks were negatively correlated with solar radiation, maximum, minimum, mean and dew point temperature, but positively correlated with rainfall, wind speed and relative humidity. Using monthly RVF outbreaks and meteorological data, the regression equations were developed for each animal in the selected governorates during 2013. Through statistical calculations, these equations proved that, it could be used with high confidence and accuracy to predict the number of RVF outbreaks in relation to meteorological and weather condition over different governorates in Egypt.

1. Introduction

Daily, monthly and seasonally changes in weather conditions are highly affecting all life activities. Therefore, study the correlation and regression between rift valley fever (RVF) outbreaks and weather will be considered as one of the promising study, especially in Egypt.

RVF is an acute, mosquito-borne viral disease that has a significant threat to humans and livestock. Rift valley fever virus is a member of the Phlebovirus genus family Bunyaviridae, which has been isolated from at least 40 mosquito species in the field and other arthropods (Sindato et al. 2012 and Routray, 2017). The disease affect a variety of animal species including ruminants and camels, causing mortality in young animals and abortions in adults (Nanyingi et al. 2015).

The disease is endemic mainly in sub-Saharan Africa, but it has also been seen in North Africa, and may have become established in Egypt (Gerdes 2004), where Egypt's climate is characterized by hot dry summers and mild winters prevail with relatively low, irregular, and unpredictable rainfall. Egypt is one of the potential vulnerable countries to the effect of global warming (World Bank, 2009). In August 1977, an epizootic identified as RVF occurred (Meegan 1979) in Egypt. The disease was recognized in it after the flooding of the Aswan dam and subsequent irrigation of vast areas. Livestock animals especially sheep became ill, died and abortion in adult animals. Moreover, many outbreaks of RVF occurred in Egypt during 1993, 1994, 1997 and the last one 2003 (Arthur et al. 1993, Moutailler et al. 2008).

RVF can be transmitted initially through aerosol and subsequent through the mosquito vector. RVF can remain dormant in Aedes spp. mosquito eggs in dry soil for several years. The mosquito's population is rapidly increase and the eggs enable to passage from one area to another during the period of heavy rainfall. Consequently, the spreading of the virus between animals increase (Linthicum et al. 1984, Mpeshe et al. 2014).

Climate change plays an important role in increasing the frequency of extreme weather events, hence has a significant effects on the seasonal activity of many vector species. It is therefore expected that global climate change will alter the distribution and increase the risk of some vector-borne zoonosis, including RVF, leading to significant changes in the geographical distribution and frequency of RVF epidemics at irregular intervals of 5 to 35 years (McMichael et al. 2006).

The change in global temperature effect on biology of the vector such as feeding rate and egg production, and the length of the development cycle and the extrinsic incubation period. Therefore, this may increase the vector capacity and the transmission rate of the virus (Martin et al. 2008, Hartman, 2017).

Most domesticated animals perform optimally at temperatures between 10 and 30°C, and temperatures above the maximum limit would suppress feed intake, milk production, reproductive performance, immunity and endocrine function (Das et al., 2016). At temperatures above 30°C, cattle, sheep, goats, pigs and chickens would reduce their feed intake by 3–5% for each unit increase in temperature (National Research Council (NRC), 1981). In addition, when temperature rises above the biological maximum threshold for a species, it may decrease the vector population. Sustained climate shifts may lead to changes in the RVF burden in endemic areas and new outbreaks in areas of similar conditions. The occurrence of RVF may be endemic and/or epidemic depending on climatic changes of different geographic regions. Epidemic areas as described by Martin et al (2008) are characterized by plateau grasslands with relatively high rainfall as in East Africa or semi-arid zones as in Saudi Arabia and West Africa or irrigated zones as in Egypt and Yemen.

Diagnosis of RVF is based on the epidemiological factors including abnormal heavy, clinical symptoms and signs, occurrence of storm abortions in small ruminants and serological diagnosis using ELISA (Ezatkhah et al. 2015, Kanouté, 2017). RVF antibodies may not be detectable during the first few days of disease and since the viremia often reaches high titers for several days, detection of viral genome or antigen may be the method of choice (Fagbo et al. 2014) {Sang, 2017 #62}. Moreover, ELISA is the most specific, sensitive and useful tool to detect infected animals in endemic areas or during an epizootic.

There are three primary aims of this study:

i. To correlate between weather parameters and RVF outbreaks occurrence in Egypt.
ii. To develop regression equations, for different governorates, to correlate between RFV outbreaks in sheep and goat and different climate variables.
iii. To help and give enough time and opportunity to the farmers and veterinary authority to take the precaution for the expected outbreaks, or at least minimize its effect.

2. Materials and Methods

2.1. Area of Study

Four governorates were selected; Marsa-Matrouh, El-Dakahlia, El-Kaliobia and El-Sharkia, to investigate this research over Egypt. Table 1 and figure 1 illustrate the geographical locations (latitude and longitude) of those governorates.

Table 1. *Latitudes and longitudes for selected governorates.*

Governorate	Latitude °N	Longitude °E
Marsa-Matrouh	31.333	27.217
El-Dakahlia	31.030	31.230
El-Kaliobia	30.280	31.110
EL-Sharkia	30.240	31.350

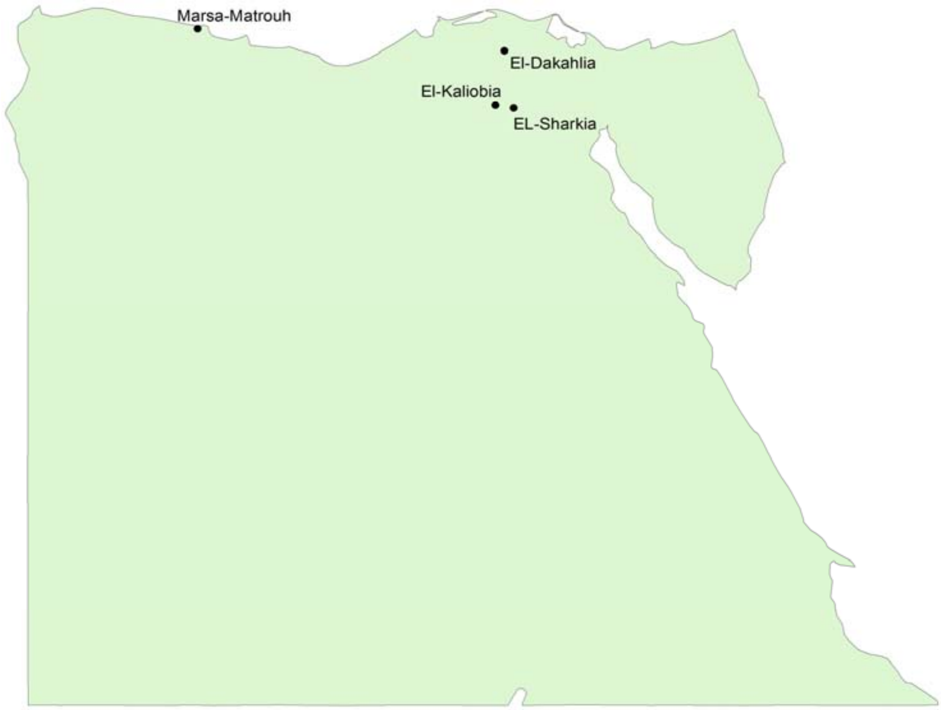

Figure 1. *Locations of the selected governorates.*

2.2. Meteorological Data

Daily weather data, year 2013, for many meteorological parameters have been downloaded from NASA Surface meteorology and Solar Energy: Daily Averaged Data website (http://power.larc.nasa.gov/). These selected meteorological variables are shown in table 2. These daily data were used to compute its monthly means values over the four governorates.

Table 2. *Meteorological variables acronyms, description and its units.*

Variables	NASA Power variable Description and Units	Unit
S	Daily insolation incident on a horizontal surface	$MJ/m^2/day$
T_X	Maximum air temperature at 2 m	°C
T_n	Minimum air temperature at 2 m	°C
T_2	Average air temperature at 2 m	°C
T_d	Dew point temperature at 2 m	°C
RH	Relative humidity at 2 m	%
R	Average Precipitation	mm/day
W	Wind speed at 10 m	m/s

2.3. Rift Valley Fever (RVF) Data

A total 381 and 259 serum samples were collected from sheep and goats at the governorates, three represent delta region (Kaliobia, Dakahlia, Sharkia) and another one represent north-west coast of Egypt (Marsa Matrouh) during 2013. A total 450 samples were collected from animals which were apparently healthy and/or had history of abortion in different seasons. In addition, 190 samples were collected from clinically affected animals, showed fever and abortion. All serum samples were collected randomly from movable herds and individual affected cases and preserved at -20°C.

2.4. Correlation and Regression Analysis

This procedure will be used to develop the regression analysis, which identifying the relationship between RVF outbreaks, and different meteorological parameters. This relationship will be the base to develop a multiple regression and prognostic model. Therefore, total RVF outbreaks and monthly average meteorological data, during year 2013, will be used to determine the correlation and the best regression equation that represent the effect of each meteorological variable and RVF outbreaks in Egypt for the selected animals.

The generated empirical multiple regression model defined as:

$$Y = a_0 + a_1 X_1 + a_2 X_2 + \cdots\cdots\cdots + a_i X_i \quad (1)$$

Where Y is the number of RVF outbreaks, a_0 is the constant and equals zero in this study. X_1, $X2 \ldots X_i$ are the key meteorological factors, and $a_1 \ldots a_i$ are referred to as the model parameters. In addition, the confidence interval was set to 95% during the course of this study.

2.5. Evaluation of Regression Equation

To evaluate the performance of the developed regression model in predicting RVF outbreaks for each animal in the selected locations, the Mean Percentage Error (MPE%) between the measured and predicted RVF values, was calculated as follow:

$$\mathrm{MPE} = \sum_{i=1}^{n} \left(\frac{(P_i - O_i)}{O_i} \times 100 \right) \quad (2)$$

Where P_i and O_i are representing the predicted and observed values respectively. Also, MPE is known as mean percentage deviation (MPD) and is a popular measure for forecast accuracy. The positive value of MPE is an indicator for overestimation, while negative one gives underestimation.

3. Results and Discussion

3.1. RVF Outbreaks in Sheep and Goat at Governorates

RVF outbreaks for sheep and goat at different governorates are shown in figurers 2 and 3 respectively. One may notice that, number of outbreaks for both animals is decreasing gradually from January to December for all governorates. Also, the maximum occurrence of this disease is happening mainly in January and February. It is clear that, the highest RVF outbreaks were reported at El-Sharkia governorate comparable to other ones. In addition, the number of cases had increased and concentrated during the first half of the year compared to the second one. In the same time, outbreaks were increased in sheep than goat at different governorates. Most of governorates did not record any outbreak during the second half of the year; especially for goat.

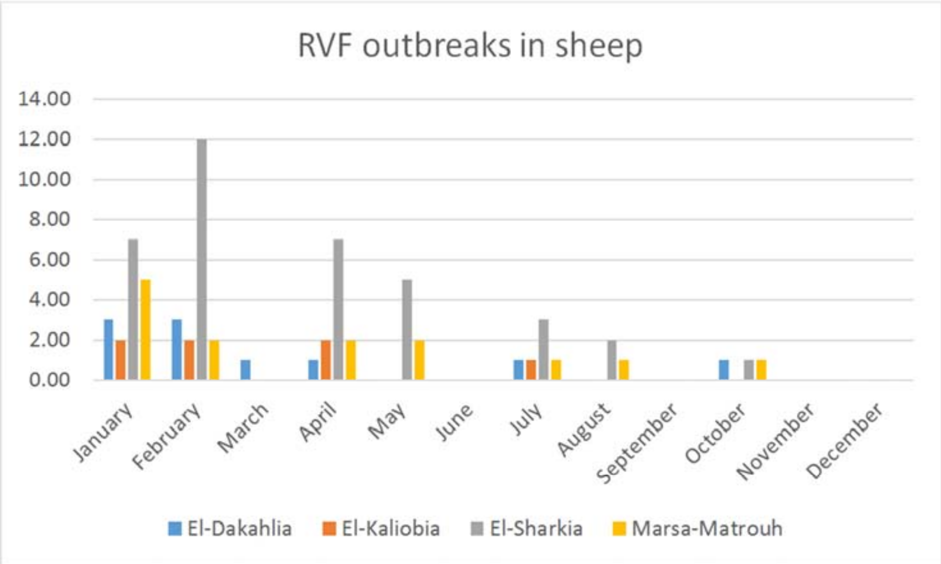

Figure 2. *RVF outbreaks for sheep at different governorates.*

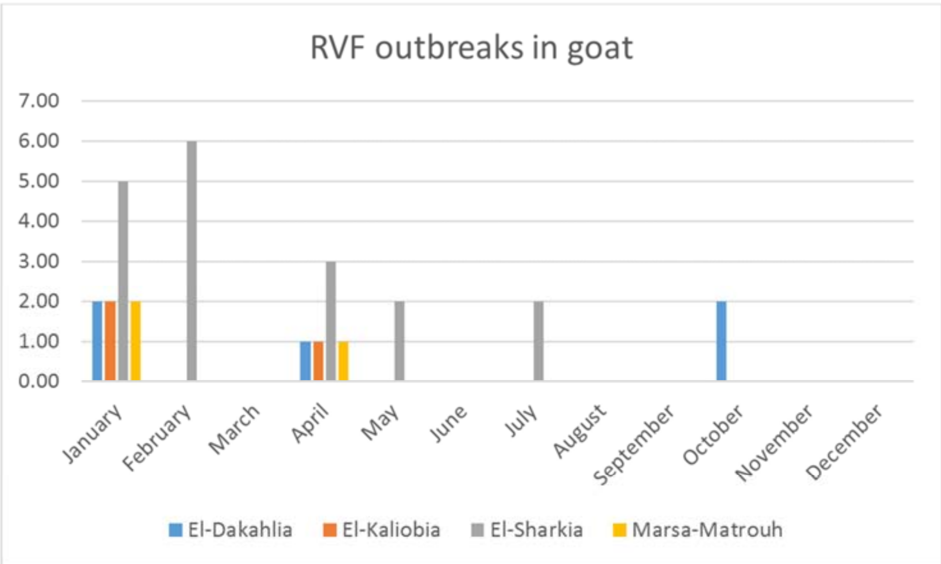

Figure 3. *RVF outbreaks for goat at different governorates.*

3.2. RVF Outbreaks Analysis in Marsa-Matrouh

Table 3 gives an overview for the correlation between number of RVF outbreaks for both sheep and goat and weather parameters in Marsa-Matrouh governorate. One may notice that, these outbreaks were negatively correlated with solar radiation, maximum, minimum, mean and dew point temperature, but positively correlated with rainfall, wind speed and relative humidity. Therefore, positive correlation means that if these meteorological variables (W, R and RH) get higher, the number of RVF outbreaks tends to get higher accordingly. While, any increment in the other meteorological variables (S, T_x, T_n, T_d and T_2) will lead to minimize the RVF outbreaks at Marsa-Matrouh.

It is obvious that, the RVF outbreaks are sensitive to any positive or negative change in the weather and climate conditions of a specific region.

Table 3. *Correlation coefficients between RVF outbreaks and meteorological variables at Marsa-Matrouh governorate.*

Meteorological variable	RVF (Sheep)	RVF (Goat)
S	-0.20	-0.29
T_x	-0.40	-0.47
T_n	-0.45	-0.48
R	0.34	0.35
W	0.32	0.47
T_d	-0.38	-0.41
T_2	-0.43	-0.48
RH	0.38	0.53

Whereas, the regression equations between number of RVF outbreaks and weather parameters can be written as:

$$Y_S = a_0 - 0.18S + 1.56T_x - 2.35T_n - 0.32R - 0.44W + 2.14T_d - 1.36T_2 + 0.15RH \quad (3)$$

$$Y_G = a_0 + 0.04S + 1.52T_x + 1.16T_n - 0.44R - 0.27W + 0.60T_d - 3.51T_2 + 0.13RH \quad (4)$$

Where, Y_S and Y_G represent number of RVF outbreaks for sheep and goat respectively.

On the other hand, the coefficient of determination (R^2) of the regression equation were 0.86, 0.93 for sheep and goat respectively. Hence, 86% and 0.93% of RVF outbreaks for sheep and goat are highly predictable from meteorological variables at Marsa-Matrouh.

3.3. RVF Outbreaks Analysis in El-Dakahlia Governorate

The number of RVF outbreaks were negatively correlated with solar radiation, maximum, minimum, mean and dew point temperature and positively correlated with rainfall, wind speed and relative humidity in El-Dakahlia governorate as shown in table 4. Therefore, these meteorological variables (W, R and RH) are directly proportional to the number of RVF outbreaks. While, any increment in the other meteorological variables (S, T_x, T_n, T_d and T_2) will lead to decrease the RVF outbreaks at El-Dakahlia.

The regression equations between number of RVF outbreaks and weather parameters can be written as follow:

$$Y_S = a_0 - 0.10S + 1.58T_x - 0.56T_n - 0.09R + 0.94W + 1.55T_d - 2.45T_2 - 0.03RH \quad (5)$$

$$Y_G = a_0 - 0.29S - 0.19T_x - 1.51T_n + 0.21R + 1.68W + 0.94T_d + 1.13T_2 - 0.13RH \quad (6)$$

Where, Y_S and Y_G are representing number of RVF outbreaks for sheep and goat.

Table 4. *Correlation coefficients between number of RVF outbreaks and meteorological elements in El-Dakahlia governorate.*

Meteorological variable	RVF (Sheep)	RVF (Goat)
S	-0.40	-0.41
T_x	-0.62	-0.35
T_n	-0.65	-0.30
R	0.62	0.41
W	0.34	0.48
T_d	-0.57	-0.26
T_2	-0.64	-0.33
RH	0.60	0.40

Based on the statistical analysis, the coefficient of determination (R^2) for both sheep and goat were 0.92. These values are considered as very good indicators to predict the number of RVF outbreaks depending on the meteorological variables with accuracy 92% in El-Dakahlia governorate.

3.4. RVF Outbreaks Analysis in El-Kaliobia Governorate

It is noticed from table 5 that, the RVF outbreaks in El-Kaliobia governorate were correlated with the weather elements similar to Marsa-Matrouh and El-Dakahlia governorates. On the other hand, the regression equations between number of RVF outbreaks and weather parameters can be written as:

$$Y_S = a_0 + 0.10S - 0.19Tx - 1.73T_n + 0.02R - 0.61W + 0.49\, T_d + 1.23\, T_2 + 0.02RH \quad (7)$$

$$Y_G = a_0 - 0.11S - 0.93Tx - 2.03T_n + 0.19R + 0.17W + 0.38\, T_d + 2.58\, T_2 + 0.00RH \quad (8)$$

Where, Y_S and Y_G are numbers RVF outbreaks for sheep and goat respectively.

Table 5. *Correlation coefficients between Number of RVF outbreaks and meteorological elements in El-Kaliobia governorate.*

Meteorological variable	RVF (Sheep)	RVF (Goat)
S	-0.19	-0.30
T_x	-0.45	-0.46
T_n	-0.53	-0.50
R	0.55	0.73
W	0.05	0.19
T_d	-0.49	-0.40
T_2	-0.48	-0.47
RH	0.22	0.38

The coefficient of determination (R^2) of the regression equation were 0.83 and 0.94 for both sheep and goat respectively. Hence, 83% and 0.94% of changes in RVF outbreaks for sheep and goat are closely correlated to meteorological elements in El-Kaliobia governorate. These results are good evidences to predict RVF outbreaks based on weather conditions.

3.5. RVF Outbreaks Analysis in EL-Sharkia Governorate

Correlations between number of RVF outbreaks and weather parameters in EL-Sharkia governorate were similar to Marsa-Matrouh, El-Dakahlia and El-Kaliobia except wind speed as displayed in table (6).

The regression equations between number of RVF outbreaks and weather parameters as following:

$$Y_S = a_0 + 0.0.7S + 3.23T_x - 3.15T_n + 1.19R - 5.20W + 1.03T_d -1.64T_2 - 0.07RH \quad (9)$$

$$Y_G = a_0 + 0.22S + 1.50T_x - 0.99T_n + 0.84R - 1.84W + 0.63\,T_d -1.43\,T_2 - 0.03RH \quad (10)$$

Where, Y_S and Y_G are RVF outbreaks for Sheep and Goat respectively.

Table 6. *Correlation coefficients between Number of RVF outbreaks and meteorological elements in EL-Sharkia governorate.*

Meteorological variable	RVF (Sheep)	RVF (Goat)
S	-0.12	-0.21
T_x	-0.35	-0.46
T_n	-0.45	-0.54
R	0.53	0.68
W	-0.11	-0.08
T_d	-0.49	-0.54
T_2	-0.39	-0.48
RH	0.05	0.19

With respect to the coefficient of determination (R^2) which is 0.79 and 0.81 for sheep and goat, respectively. Hence, RVF outbreaks could be predicted in relation to weather parameters with accuracy 79% and 0.81% for sheep and goat in EL-Sharkia governorate.

4. Evaluation of Regression Equations

Using monthly RVF outbreaks and meteorological data, the regression equations were developed for each animal during 2013 in the selected governorates. These equations were evaluated by calculating the Mean Percentage Error (MPE) between the sums of observed monthly number of RVF outbreaks and the predicted ones. As shown in table 7, MPE% values were within the acceptable percent of bias. Therefore, the regression equations can be used with high accuracy to predict number of RVF outbreaks for sheep and goat in all selected governorates. Most of MPE percentages were underestimated for most governorates except Marsa-Matrouh was overestimated also El-Kaliobia for goat. These were very little over or underestimation of MPE percentages. Therefore one may conclude that, the regression equations that used to predict the number of RVF outbreaks for the selected animals and locations achieved best goodness and high accuracy.

Table 7. *Mean Percentage Error between observed and predicted RVF outbreaks at governorates.*

Governorate	Animal	Observed	Predicted	MPE%
Marsa-Matrouh	Sheep	14	14.0031	0.022
	Goat	3	3.0035	0.115
El-Dakahlia	Sheep	10	9.9995	-0.005
	Goat	5	4.9982	-0.036
El-Kaliobia	Sheep	7	6.9907	-0.133
	Goat	3	3.0001	0.002
El-Sharkia	Sheep	37	36.9451	-0.148
	Goat	18	17.9774	-0.126

5. Conclusion

The current study had approved the relationship between the number of RVF outbreaks in sheep and goat in relation to weather conditions over different governorates in Egypt.

One may conclude that, number of outbreaks for both animals is decreasing gradually from January to December for all governorates. In addition, the maximum occurrence of this disease is happening mainly in January and February. It is clear that, the highest RVF outbreaks were reported at El-Sharkia governorate comparable to other ones. In addition, the number of cases had increased and concentrated during the first half of the year compared to the second one. In the same time, outbreaks were increased in sheep than goat at different governorates. Most of governorates did not record any outbreak during the second half of the year; especially for goat. One may notice that, these outbreaks were negatively correlated with solar radiation, maximum, minimum, mean and dew point temperature, but positively correlated with rainfall, wind speed and relative humidity.

Using monthly RVF outbreaks and meteorological data, the regression equations were developed for each animal during 2013 in the selected governorates. Through statistical calculations, these equations proved that, it could be used with high confidence and accuracy to predict the number of RVF outbreaks in relation to meteorological and weather condition over different governorates in Egypt.

6. Future Directions and Recommendations

The RVF has an economic impact on animals and can be transmitted to human. The distribution of the disease as a result of the sustainable relationship between humans, animals and the environment. Therefore, it is important to study the epidemiology, demographic data and environmental factors which affect the occurrence of the disease. The obtained data predict that the disease is mostly occurred during January and February and Veterinary authority should apply some measure to limit the distribution of the disease such as:

a. Application of insecticide in endemic governorate, to control the multiplication of the vector before the expected time of outbreak.
b. Regular vaccination of susceptible animals with killed vaccine, to decrease the prevalence of the disease.
c. Raise the knowledge of Veterinarian on diagnosis and detection of the diseases besides raising farmers' awareness.

References

[1] Arthur R, Cope S, Botros B, Hibbs R, Imam I, El-Sharkawy M, Oun S, Morrill J, Shope R, and Darwish M (1993): Recurrence of Rift Valley fever in Egypt. The Lancet 342: 1149-1150.

[2] Das R, Sailo L, Verma N, Bharti P, Saikia J, and Imtiwati Kumar R (2016): Impact of heat stress on health and performance of dairy animals: a review. Vet. World 9: 260–268, http://dx.doi.org/10.14202/vetworld.2016.260-268.

[3] Ezatkhah M, Alimolaei M, Khalili M, and Sharifi H (2015): Seroepidemiological study of Q fever in small ruminants from Southeast Iran. Journal of infection and public health 8: 170-176.

[4] Fagbo S, Coetzer JA, and Venter EH (2014): Seroprevalence of Rift Valley fever and lumpy skin disease in African buffalo (Syncerus caffer) in the Kruger National Park and Hluhluwe-iMfolozi Park, South Africa. Journal of the South African Veterinary Association 85: 01-07.

[5] Gerdes G (2004): Rift valley fever. Revue scientifique et technique-Office International des Epizooties 23: 613-624.

[6] Hartman A (2017): Rift Valley Fever. Clinics in Laboratory Medicine.

[7] Kanouté YB, Gragnon BG, Schindler C, Bonfoh B, and Schelling E (2017): Epidemiology of brucellosis, Q fever and Rift Valley fever at the human and livestock interface in northern Côte d'Ivoire. Acta tropica 165: 66-75.

[8] Linthicum K, Davies F, Bailey C, and Kairo A (1984): Mosquito species encountered in a flooded grassland dambo in Kenya. MOSQ NEWS 44: 228-232.

[9] Martin V, Chevalier V, Ceccato PN, Anyamba A, De Simone L, Lubroth J, de La Rocque Sp, and Domenech J (2008): The impact of climate change on the epidemiology and control of Rift Valley fever. Revue Scientifique et Technique, Office International des Epizooties 27: 413-426.

[10] McMichael AJ, Woodruff RE, and Hales S (2006): Climate change and human health: present and future risks. The Lancet 367: 859-869.

[11] Meegan JM (1979): The Rift Valley fever epizootic in Egypt 1977–1978 1. Description of the epizootic and virological studies. Transactions of the Royal Society of Tropical Medicine and Hygiene 73: 618-623.

[12] Moutailler S, Krida G, Schaffner F, Vazeille M, and Failloux A-B (2008): Potential vectors of Rift Valley fever virus in the Mediterranean region. Vector-Borne and Zoonotic Diseases 8: 749-754.

[13] Mpeshe SC, Luboobi LS, and Nkansah-Gyekye Y (2014): Modeling the impact of climate change on the dynamics of rift valley Fever. Computational and mathematical methods in medicine.

[14] Nanyingi MO, Munyua P, Kiama SG, Muchemi GM, Thumbi SM, Bitek AO, Bett B, Muriithi RM, and Njenga MK (2015): A systematic review of Rift Valley Fever epidemiology 1931–2014. Infection ecology & epidemiology 5.

[15] National Research Council (NRC) (1981): Effect of environment on nutrient requirement of domestic animals. In: Subcommittee on Environmental Stress, National Research Council (NRC). National Academic Press, Washington, DC.

[16] Routray A, Rath AP, Panigrahi S, Lambe UP, Sahoo S, and Ganguly S (2017): RIFT Valley Fever: An Update. International Journal of Contemporary Pathology 3: 20-23.

[17] Sang R, Arum S, Chepkorir E, Mosomtai G, Tigoi C, Sigei F, Lwande OW, Landmann T, Affognon H, and Ahlm C (2017): Distribution and abundance of key vectors of Rift Valley fever and other arboviruses in two ecologically distinct counties in Kenya. PLOS Neglected Tropical Diseases 11: e0005341.

[18] Sindato C, Karimuribo E, and Mboera LE (2012): The epidemiology and socio-economic impact of Rift Valley fever in Tanzania: a review. Tanzania Journal of Health Research 13.

[19] World Bank. 2009. The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates. The World Bank, Washington, DC.