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Research Article

Cyclic Incidence of Visceral Leishmaniasis in Central Sudan is it due to an Ecological Succession or Climate Change?

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Received: June 11, 2020; **Published:** December 30, 2020

Abstract

Background: Emergence of Leishmaniasis in relation to climate change has been reported in many countries. WHO reports that the public health impact of leishmaniasis worldwide has been grossly underestimated for many years.

Objectives: The aim of this study is to discuss the ecological factors that lead to re-emergence of visceral leishmaniasis in central Sudan.

Method: The focused around a small village called El Gilla, White Nile State, where cyclic outbreaks of VL has been reported. We conducted an entomological survey and reviewed the metrological data, vegetation cover over a long period of time.

Results: The results supported the notation that climate change have affected vegetation cover and therefore played a role in the epidemiology of VL. Results of the entomological survey indicate the presence of *Phlebotomus orientalis.*

Conclusion: This study concludes that altering environment due to changing climate can lead to emergence of visceral leishmaniasis, because the changed environmental pattern provides suitable habitat requirements for sand fly vector of Leishmaniasis.

Keywords: *Sand Fly; Visceral Leishmaniasis; Climate Change; Vegetation Cover; White Nile Area; Khartoum*

Introduction

Leishmaniasis are group of neglected tropical diseases which caused by a protozoan parasite, of the genus Leishmania and transmitted by bite of infected female sandfly of the genus *Phlebotomus* in the Old World and the genus *Lutzomyia* in the New World [1]. The diseases are range from self-healing cutaneous leishmaniasis (CL) to disfiguring diffuse cutaneous/post-kala-azar dermal leishmaniasis (DCL/PKDL) and the fatal visceral leishmaniasis (VL, kala-azar) [2]. The diseases are epidemiologically complex, involving multiple vector species and reservoir hosts and diverse transmission cycles [3]. Generally, Visceral leishmaniasis cases are zoonotic, transmitted to humans from animal reservoir hosts by the bite of sand fly vector [4]. However, in East Africa including Sudan, anthroponotic or zoonotic transmission of the VL is thought to occur [5]. However, no reservoir host has been incriminated [6].

Many diseases including leishmaniasis, transmitted by arthropods to and from dogs have attracted increasing interest from the general public and the scientific community [7]. In the New World and Mediterranean regions of the South Europe and North Africa, VL is a zoonotic disease, involving different canine species, especially the domestic dog that consider the main reservoir host and several fox species [8]. It is noteworthy that in all VL zoonotic foci, where the dog is considered as the primary reservoir host, the disease is caused by *L. infantum* [9] or *L. chagasi* [10]. The leishmaniasis caused by *L. infantum* in dog is known as canine leishmaniasis which threatens a large number of dogs in endemic areas and it is difficult to control [11] and the percentage of infected dogs living in an area where canine leishmaniasis is endemic has major public health implications [12]. However, in Sudan, dog is among domestic animals which have been found infected by the parasite, but its role in the epidemiology of VL still poorly understood [13].

Leishmaniasis is endemic in 98 countries worldwide from which about 90% of the estimated annual worldwide case of visceral leishmaniasis (VL) occur in Brazil, Bangladesh, India, Nepal, Sudan, Southern Sudan, Uganda and Ethiopia [14].

From the early 1900s, visceral leishmaniasis (VL) has been among the most important health problems in Sudan [15]. The annual incidence of kala-azar is estimated to be about 1000 cases among the relatively sparse populations living along the north-eastern bank of River Rahad in Eastern Sudan [16,17], but the number of cases increase to a total of 29,700 between 2002 - 2011 [18]. In all foci of East Africa including Sudan, kala-azar is caused by *L. donovani* [19] which is transmitted by *Phlebotomus* orientalis as principal vector [20].

Although VL has been reported from many countries world wild, however, it is confined to specific ecological niches. In Sudan, visceral leishmaniasis and its vector is restricted to specific localities with specific environmental variables associated with the distribution of the vector. The vector is correlated with maximum temperature; normalized difference vegetation index, presence of chromic vertisols (black cotton soils) and rainfall range for *Balanites aegyptiaca* and *Acacia seyal* trees [21].

The reported occurrence of VL cases in Sudan is wide, erratic and variable. After the first reported case of VL in 1904, up to 1912, the disease was endemic in eastern parts of Sudan as reported in distribution map by El Hassan and Zijlstra from Kassala, Gedaref, Senja and Sennar. Sporadic cases were also reported from one locality in southern Sudan [18]. Then, endemic areas started to expand considerably, following an epidemic pattern [20]. Between 1912 - 1939, the endemic area spread to south-eastern part with sporadic cases reported from new foci in Darfur and Kordofan Province. Then, between 1940 - 1969, endemic areas extend to south-west in Paloich area. Also, sporadic cases were reported from new locality in Kordofan and Kosti. After that, the disease disappear from Western parts of Sudan until 1990 - 1992, where an outbreak of VL were reported from south of Kordofan State [18] and between 2006 - 2010 then 2011 - 2016 new cases reported from Darfur [22]. Before the year 1988, VL did not exist in in White Nile area [23] where 100 cases of VL was reported in the area. Then, since 2006, a surge of new cases has been reported in White Nile State, central Sudan, close to Khartoum [24]. Following this outbreak, this area has become an endemic focus of VL, with an annual incidence of 20 - 30 cases [25]. Based on the brief history of disease incidence and emergence of VL cases in Sudan, it is clear that the epidemic of the disease show fluctuation and irregular pattern with exception of El Gedaref the only known stable hyperendemic region in Sudan, with a consistently high annual incidence of thousands of reported cases. The factors the caused this fluctuation or stability remain unclear. Some authors suggest emergence of the disease in western Sudan due to nomadic tribes moving between endemic and endemic areas [18], while others suggest that this may be due to regeneration of the *Acacia seyal* and *Balanitis aegyptiaca* forest in these area [26].

Emergence of Leishmaniasis in relation to climate change has been reported in many countries [27] or new foci within countries that endemic with the disease in some areas. Climate change might affect leishmaniasis distribution directly, by the effect of temperature on parasite development in female sandflies [28], or indirectly by the effect of environmental variation on the range and seasonal abundances of the vector species [27]. The mapping of statistical measures of climate has permitted transmission cycles to be loosely associated with some Mediterranean bioclimates [29]. However, bioclimate zones and their vegetation indicators vary regionally, and ongoing climate change may alter the patterns of land cover and land use [27]. Emergence and re-emergence of VL in Sudan in new foci have never been attributed to climate change in pervious publications.

The apparent resurgence of a VL focus in central Sudan, after 25 years of first cases had been detected in White Nile area, and the appearance of *Phlebotomus orientalis* in Khartoum North region is inquisitive. Although there are many researches carried out concerning the leishmaniasis, still little is known about factors affecting the re-emergence and dispersion of the disease. The study of these factors in the natural environment is of interest from an ecological and epidemiological point of view because they are the risk factors for the disease. Further, ecological investigations will help to determine reasons for the relationship of some species of sand flies with particular types of vegetation.

Aim of the Study

The present study was focus on the changing environmental factors that lead to reemergence of visceral leishmaniasis in some foci in White Nile State and appearance of *Phlebotomus orientalis* in Khartoum North region with emphasis to changed environment especially vegetation cover.

Materials and Methods

Study area

Two areas in Central Sudan were investigated which are Khartoum and White Nile Area.

Khartoum region is located at latitude and longitude; 15° 36’ N 32° 33’E and altitude 382m and with total area of 22.736 km^2. Khartoum region considered as semi-desert with low rainfall and high evaporation potential. The short rainy season is confined to late summer and extends from July to October with an average annual rain of 55 mm. However, maximum temperature (42°C) is reached in May and the minimum (l5°C) in January. Mean relative humidity for an average year is recorded as 21.8% and on a monthly basis it ranges from 13% in March, April to 42% in August. The population of Khartoum area estimated to be 6,203,000 inhabitants. This study was carried out in Surrugia village located at the edge of the main Nile course about 25 Km north of the capital, Khartoum, at latitude and longitude 15° 47′ 42′′ and 32° 33′ 25′′ and at altitude between 277 and 382 m west-east direction. The area is flat and the soils are characterized by high level dry dark clay. The vegetation cover is low and comprises only 20% of the total land cover. The dominant tree species at collection site is *Acacia seyal*, *Balanites aegyptiaca* and *Zyziphus spina-christi* which grows naturally and left as wind belt to protect the farms.

White Nile region considered as semi-arid with moderate rainfall. The short rainy season is confined to late summer and extends from July to October with an average annual rain of 59.7 mm. However, maximum temperature (43.7°C) is reached in May and the minimum (18°C) in January. Mean relative humidity for an average year is recorded as 35.8% and on a monthly basis it ranges from 19% in March, April to 75% in July. This study was carried out in small village called El Gillaa where first cases of VL reported.

The area under consideration lies in the White Nile Province, 140 kilometers south of Khartoum and 52 kilometers north El Dueim town, the provincial capital. It is located at latitude and longitude 14° 35′ 20.8′′ and 32° 08′ 23.9′′ and at an altitude 388m, on flat plain and characterized by light black soil and located in the semi-arid region of the open savanna belt characterized by short grass and Acacia trees.

Ecological survey

Metrological data

Climate data were obtain from tutiempo website to compare the changing climate between past and present. These data cover the time since 1950’s up to date 2010. The rainfall precipitation were obtained from previous publications between 1950’s - 2010’s [30,31]. Annual average temperature and relative humidity records were obtained from tutiempo website for the period 1950 - 2010 at 10 years interval [32] (Table 1). Then, these data were subjected to statistical analysis to elucidate any increasing/deceasing change in these factors.

The year	Khartoum Area			White Nile Area		
	Max Temp	Min Temp	Mean Temp	Max Temp	Min Temp	Mean Temp
1950	37.6°C	23°C	30.3°C	36.2°C	21.8°C	29°C
1960	38.6°C	24°C	31.3°C	37.2°C	22.8°C	30°C
1970	39.6°C	235°C	31.6°C	38.4°C	22.3°C	30.9°C
1980	40.3°C	32.9°C	32.1°C	39.6°C	22.5°C	31.1°C
1990	40.5°C	24.5°C	32.4°C	40.2°C	23.3°C	31.8°C
2000	41.5°C	23.7°C	32.6°C	41.3°C	23.1°C	32.2°C
2010	42.5°C	24°C	33.3°C	42.7°C	24°C	33.4°C

Table 1: *Estimation of areal average annual mean maximum and minimum temperature variations in the study region from 1950 - 2010.*

Vegetation cover survey

An ecological survey was carried out in 2010 to study the vegetation cover in El Gillaa (Figure 1) and Surrugia villages. The map showed the vegetation of the area in question were compare to an old map showed the vegetation cover during 1950's (Figure 2).

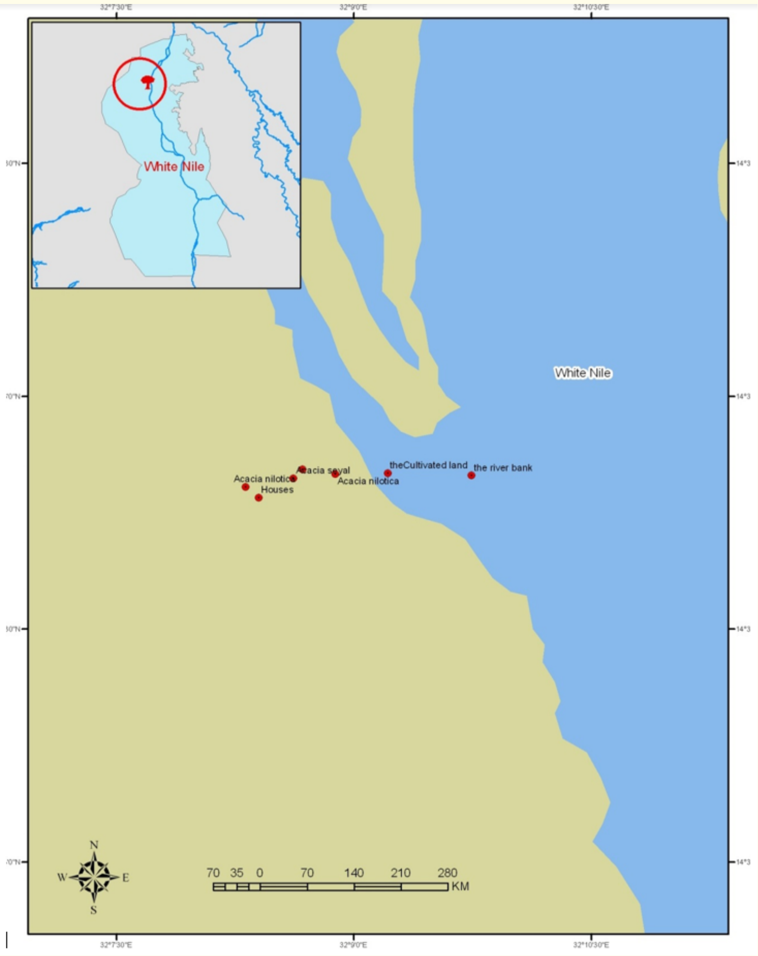

Figure 1: *The land cover profile map of El Gillaa village White Nile State-2010.*

Citation: Raiyed Mohamme Abdelhamid Adeel., *et al.* "Cyclic Incidence of Visceral Leishmaniasis in Central Sudan is it due to an Ecological Succession or Climate Change?". *EC Microbiology* 16.12 (2020): 17-29.

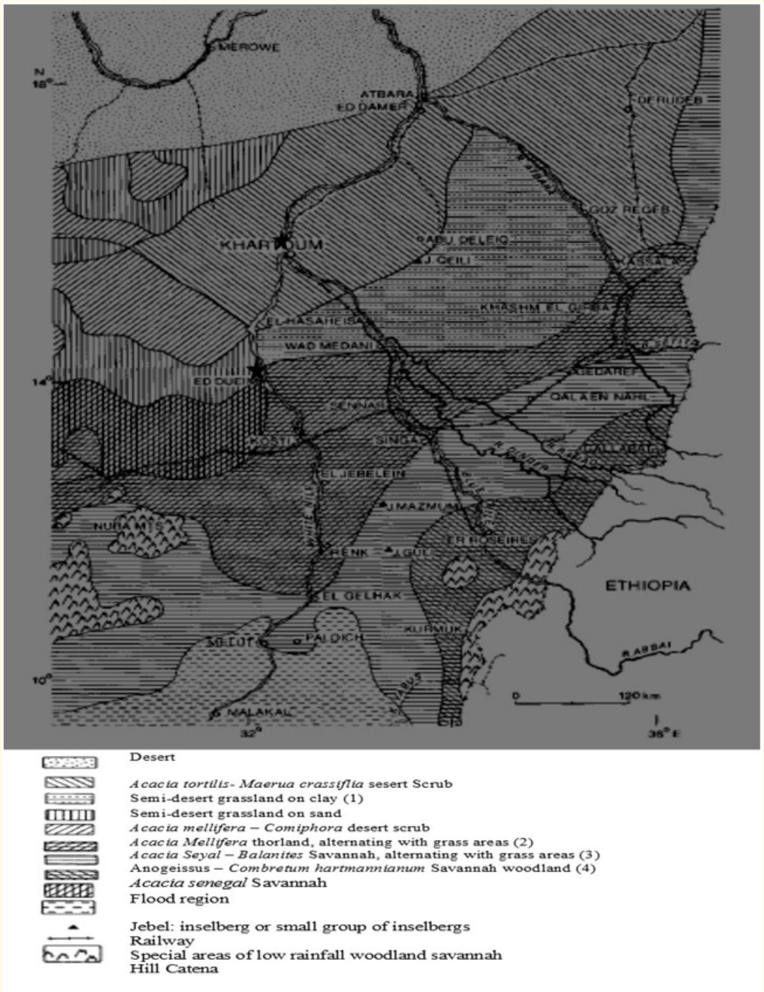

Figure 2: *Vegetation types of the Central Clay Plain and adjoining areas (after Harrison and Jackson 1958). *Indicates the study areas. Source: (BLOKHUIS, 1993 ©).*

Soil of the study area

In general, the study area in White Nile is flat and covered by an alluvium of silt clay soil, with black cracking clay soil on the river bank as described by Musa., *et al* [33]. The study area in Khartoum region. The area is flat and the soils are characterized as high-level dry dark caly and high-level sand described by Elsyaed [34].

Entomological survey

In White Nile region, Sand flies were collected during the period from 19 - 21 July 2011. Six light traps have been used for the collection of adult sand flies in which the number of the trap/night was 18. In Surrugia village, six light traps have been used for the collection of adult sand flies in which the number of the trap/night was 12 over 2 days (5th - 6th/June/2011) and 25 traps/night over five days (14th - 18th July/2011). The traps were set up at 1.5m above the ground hanged at the same tree for each collection night and at distance of 25m from each other. Then, the collected sand flies were subjected to Morphological identification based on keys of Quate [35] and Lewis [36]. The previous reported surveys to specify the history of *Phlebotomus orientalis* and other *Phlebotomus* species occurrence in study areas were reviewed (Table 2).

Location	Year of collection	Source of Data	***Phlebotomus* species record and density**		
			P. orientalis	***P. papatasi***	***P. rodhaini***
White Nile	1986	Musa., *et al*. 1991	No Record	2521	No record
White Nile	2008 - 2011	Widaa., *et al*. 2012	1521	1603	No record
White Nile	2008	Adam., *et al*. 2017	248	203	21
White Nile	2011	By this author	180	170	56
Surrugia	1984 - 1987	Elsayed., *et al*. (1991)	No record	4,715	No record
Surrugia	2007	Hassan., *et al.* 2007	42	333	8
Surrugia	2011	By this author	134	296	No record

Table 2: *History of Phlebotomine sand fly fauna vector of Leishmaniasis in White Nile and Khartoum state (Surrugia village) during the period 1984 to 2017. *The density of sand flies caught varying due to the varying number of trap/nights collection.*

Statistical analysis

Data of temperature and relative humidity in study areas were subjected to statistical analysis using Linear regression curve estimated line test to elicit a changing trends in those climate factor. Differences were considered significant at $p < 0.01$. All the analysis were carried out using Statistical Package for Social Science (SPSS) version 20.

Results

Climatic factors

Rainfall precipitation showed decreasing and increasing pattern since 1950, where the annual rainfall in White Nile areas up to 1960 was about 400 - 500 mm [30]. Then this ratio drop to 200-300 mm between 1990 - 2010 [31]. In Khartoum area, the rainfall precipitation decrease from 150 mm in 1950's - 2000 drop to 118.9 mm in 1990 - 2000 and then increase to 121.3 mm in 2000 - 2010 [31]. The result of temperature and relative humidity in this study reveals different changing characteristics of warming process of Sudan (Figure 3 and 4). The annual mean temperature is in significant increasing trend ($P = 0.000$). These observations were concern the period between 1950 to 2010 in which the mean annual temperature increase from 28.5°C up to 33.4°C in Central Sudan (Figure 3). In other hand, there is a significant decreasing trend in relative humidity ($p = 0.000$), in which the mean annual relative humidity drop from 58% down to 54.5% (Figure 4).

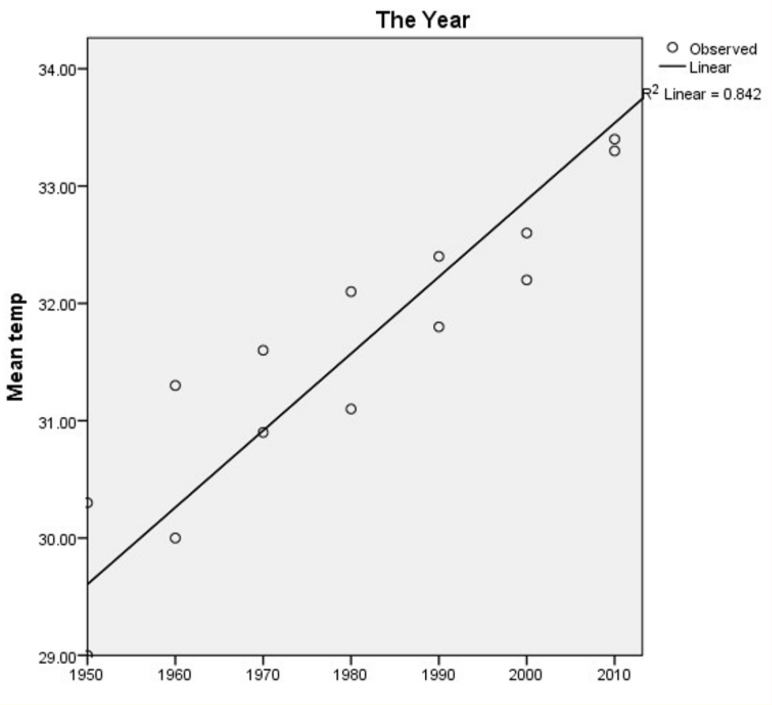

Figure 3: *Regression line of areal average estimation of mean annual temperature from 1950 - 2010 in central Sudan.*

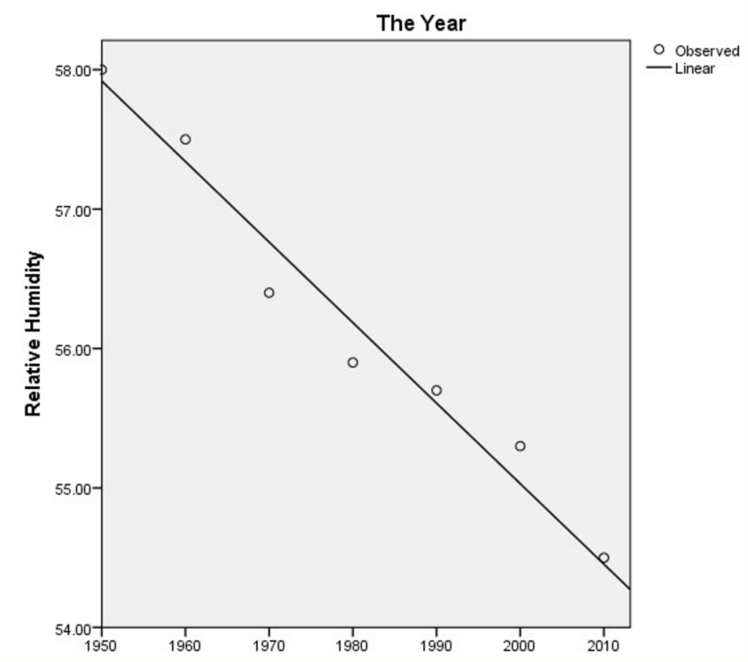

Figure 3: *Regression line of areal average estimation of mean relative humidity from 1950 - 2010 in Central Sudan.*

Vegetation cover

In the present days, the study area of White Nile is characterized by *Acacia* forest with stands of *Acacia nilotica* and *Acacia seyal* trees. The map of Harrison and Jackson and Blokhuis [37,38], reveal that, the tree species in that area was *Acacia mellifera* trees. In Khartoum, the dominant tree species at collection site (Surrugia) is *Acacia seyal*, *Balanites aegyptiaca* and *Ziziphus spina-christi* which grows naturally and left as wind belt to protect the farms. Historically, the work of Harrison and Jackson described Khartoum region vegetation as Acacia belt in which the dominant tree species were *Acacia tortilis* and *Acacia albida* [37].

Entomological survey

The sand fly fauna in White Nile and Khartoum based on previous publication to give clue about the history of occurrence of *Phlebotomus orientalis* and other *Phlebotomus* species in Study areas has been reviewed (Table 1). Besides reviewing the literature also an entomological surveys have conducted in the study areas.

Seven species have been collected in study area from which three species are belonging to the genus *Phlebotomus*, which are *Phlebotomus papatasi*, *Phlebotomus orientalis* and *Phlebotomus rhodeni* while the other four species are belonging to the genus *Sergentomyia*. The total number of *Phlebotomus orientalis* collected during 18 nights trap were 180 in which caught females were 109 (Table 3). Pilot study was carried during 1986 by Musa., *et al*. to give a base line information about sand fly fauna the study area [33]. Their results indicates absence of *Phlebotomus orientalis*. This flowed by the work of Widaa., *et al*. 2012 and Adam., *et al*. 2017 in which they record appearance of *Phlebotomus orientalis* in the area [25,38].

			No/trap/night					
Species	**No of nights trap**		**males**		**females**		**Total**	
	El Gillaa	**Surrogia**	**El Gillaa**	**Surrogia**	**El Gillaa**	**Surrogia**	**El Gillaa**	**Surrogia**
P. papatasi	18	37	4.8	3.5	4.6	5.4	9.4	8.9
P. orientalis	18	37	3.9	1.6	6.1	2.0	10.0	3.6
P. rhodeni	18	37	1.0	0	2.1	0	3.1	0
S. clydei	18	37	6.9	8.1	7.4	9.3	14.3	17.4
S. squamipleruis	18	37	2.8	3.5	2.4	2.4	5.2	5.9
S. antennata	18	37	2.6	2.0	3.9	4.5	6.5	6.5
S. schwetzi	18	37	2.1	0	2.3	0	4.4	0
S. africana	18	37	0	2.8	0	1.7	0	4.5

Table 3: *The sand fly fauna and abundance/night trap captured in El Gillaa (White Nile) and Surrogia (Khartoum) during June and July 2011.*

Six species have been caught in Surrogia, from which two species are belonging to the genus *Phlebotomus*, which are *P. papata*si and *Phlebotomus orientalis*, while the other four species are belonging to the genus Sergentomyia. The total number of *Phlebotomus orientalis* collected during 37 nights trap were 133 in which caught females were 74 (Table 3). The sand fly fauna literature of the area report first record of *Phlebotomus orientalis* in 2006 by Hassan., *et al* [39]. The previous study of El Sayed., *et al*. [34] in the area aforementioned to this study report absence of *Phlebotomus orientalis*.

Discussion

This study was carried out to investigate the factors that lead to emergence of visceral leishmaniasis in White Nile Area and enlighten the appearance of *Phlebotomus orientalis* vector of visceral leishmaniasis in Surrugia village North of Khartoum with emphasis on the changing ecology. A metrological data reviewed to elaborate climatic changes in the study areas. The results reveals different changing characteristics of climatic factors such as rain fall precipitation, temperature and relative humidity in the area under consideration. Rainfall precipitation showed decreasing trend from more than 500 mm down to 200 mm [30,31]. The annual average temperature is in significant increasing trend in which the mean temperature increase from 28.5°C which up to 33.4°C which corresponds with results of this study, Blokhuis [37] and Xu., *et al* [40]. The rate at which temperature has been increasing in this region over the period from 1950 to 2017 was found to be 2.3^{0}C per century. The relative humidity also showed a decreasing trend in in which the humidity drop from 58% down to 54.5 %. All these findings reveals a dramatic climate change in Sudan as general and in the study areas in particular in which the climate become more suitable for sand fly according to several published reports [35,40]. Furthermore, the climate history since 1950's shows either increasing or decreasing trends without a cyclic change, which can suggest an ecological succession instead of climate change. The history of vegetation cover in the study areas showed replacement of the prevailing tree species *Acacia mellifera* [36] in White Nile with *Acacia nilotica* and *Acacia seyal* trees; while in Surrugia village *Acacia tortilis* and *Acacia albida* [36] replaced with *Acacia seyal*, *Balanites aegyptiaca* and *Ziziphus spina-christi*. In Sudan, the relation of sand flies specially vectors of leishmaniasis to certain plant species was studied by Quate and Elnaiem., *et al* [17,35]. Their findings emphasized the relation of sand flies particularly *Phlebotomus orientalis* with *Acacia seyal* which corresponds with findings of this study where *A. seyal* tree species is prevailing in the study areas. Also, *Phlebotomus orientalis* has been associated with a black cotton clay soil which found in the two study areas [41] in which this soil type was confirmed to be one of the important ecological determinants for the distribution of the sand fly vector in Sudan [17]. Entomological survey of sand fly vector *Phlebotomus orientalis* report the merging of this species in White Nile areas by this study and published articles [25,38]. The possibility that *L. donovani* has been maintained in a sylvatic cycle, in or near the focus area in White Nile, since the 1980s [24], can elucidate presence of reservoir host or an unrevealed source of infection in the area.

Globally, the emergence of New World ZVL from *L. infantum*/*L. chagasi* infection was attributed to urbanization in Colombia and Venezuela, and movements from rural areas of Brazil to northeastern urban centers. Finally, AVL from *L. donovani* was noted to re-emerge in East Africa due to refugee movements in Southern Sudan and Ethiopia, while on the Indian subcontinent a variety of factors was responsible for maintaining AVL infection foci including cross-border movements, environmental degradation and human habitats in proximity to cow-sheds or river embankments [42]. Climate change has the potential to alter or extend the natural ranges of these organisms and make regions of our globe that were previously uninhabitable for parasites habitable [43]. WHO emphasises that climate change is also likely to cause changes in ecological systems that will affect the risk of infectious diseases in the European region, including the seasonal activity of local vectors and the establishment of (sub-)tropical species [44]. Evaluated research findings documenting the impact of climate change on communicable diseases for human and animal health where, numerous vector-borne and other zoonotic diseases have emerged or re-emerged in Europe such as Spain [45], Italy [46] and France [47]. Also, climate change has its impact on emergence of VL in North America [48]. More generally, the changing distribution of vectors and vector-borne diseases may not necessarily be explained by a single factor acting in isolation (for example, a change in temperature or precipitation) but rather by an interplay of factors (including changes in land use and human behaviour) that may also be influenced by climate change [49].

Based in the aforementioned and the findings of this study, climate factor such as temperature, relative humidity and rainfall precipitation have been changing dramatically since 195's. These changes have their effect on land cover vegetation and land use in the study areas. All these factors lead to reemerge of visceral leishmaniasis in foci under study. This situation is witness in Europe and American continent. Comparing the finding of this study to El Gedaref area, the stable endemic area of Sudan, elucidate that land cover remain unaltered (Forest of Acacia seyal and Balanitis aegyptiaca), emphasize the critical role of the land cover in the epidemic of VL and its vector as stated by Ready [37].

Finally, regardless of the fact that ecology of the study areas have been changed which can either be attributed to long-term climate change or to an ecological succession, but findings of this work indicate that this change has relation to emergence of VL in one of the study areas and introduction of *Phlebotomus orientalis* to the other area. These findings and literature of sand flies and leishmaniasis enlighten epidemiological aspects of the proper ecological conditions that can lead to spread of visceral leishmaniasis and its emergence in new foci.

Conclusion

In conclusion the findings of this work showed the fact that the climate of Sudan has be changed dramatically since the meds of twentieth century which lead to changing environment specially vegetation cover in Central Sudan. The possible role of these changes regarding emergence of visceral leishmaniasis in White Nile area and appearance of *Phlebotomus orientalis* the proven vector of this disease in Khartoum area is therefore more or less strongly connected.

Limitation of this Research

This research conducted in two areas in Sudan where visceral leishmaniasis and its vector *Phlebotomus orientalis* emerge. The research cover only these areas due ease accessibility. The research data for climate and land cover change cover the time from 1950's due to availability of data source covering this period of time but not before this time.

Acknowledgement

Our gratitude to Wageningen University and Research - Library for their permission to use the image of Vegetation types of the Central Clay Plain and adjoining areas (published by BLOKHUIS, 1993 ©) in our work. Also, our gratitude to Higher Ministry of education for funding this research.

Conflict of Interest

The author declares no financial interest and other conflict of interest.

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