ISSN 1996-3343

Asian Journal of Applied Sciences

http://knowledgiascientific.com

Knowledgia SCIENTIFIC
A Place to Publish Outstanding Research

OPEN ACCESS Asian Journal of Applied Sciences

ISSN 1996-3343
DOI: 10.3923/ajaps.2018.172.182

Research Article
Modeling the Vulnerability to Zoonotic Cutaneous Leishmaniasis at the Local Scale

Ahmed Karmaoui and Siham Zerouali

Department of Biology, Southern Center for Culture and Sciences (SCCS), Zagora, Morocco, Lycée Imam Ali, Zagora, Morocco

Abstract

Background and Objective: Several variables involved in favoring the Zoonotic Cutaneous Leishmaniasis (ZCL) occurrence at local scale were categorized and integrated in a new Cutaneous Leishmaniasis Vulnerability Index. The main objective was to test its applicability and explore which sector(s), site(s) or factor(s) presenting the high vulnerability regarding this disease. **Materials and Methods:** This proposed index was a numerical tool conglomerating and categorizing five components of variables that may accelerating the vulnerability to this disease, socio-economical, climatic, hydraulic, vegetation and health. The calculations were applied in four case studies from the Moroccan arid region. **Results:** This Index gave a lot of information in a single profile of the local vulnerability. All the selected sites had high vulnerability scores to this disease. Agdez presened the very high score of vulnerability than the rest, Tamezmoute, Zagora and Tagonite following an upstream-downstream evolution. **Conclusion:** The findings gave a scientific basis, which is helpful for the decision making regarding the control and surveillance in an arid region at a local scale.

Key words: Public health, numerical index, moroccan arid region, socio-economical impact, vector-borne-disease, high vulnerability scores, composite indicator

Citation: Ahmed Karmaoui and Siham Zerouali, 2018. Modeling the vulnerability to zoonotic cutaneous leishmaniasis at the local scale. Asian J. Applied Sci., 11: 172-182.

Corresponding Author: Ahmed Karmaoui, Department of Biology, Southern Center for Culture and Sciences (SCCS), Zagora, Morocco, Lycée Imam Ali, Zagora, Morocco Tel: +212662832783

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The origin of the history of leishmaniasis was recorded in the 7th century before the Common Era by the description of cutaneous lesions similar to cutaneous leishmaniasis[1]. Currently, several regions around the world, especially in the developing countries, are vulnerable to this disease. The leishmaniasis is the second vector-borne disease that affects the people after malaria[2]. In fact, there are about 350 million people threatened by this disease[3,4]. This broad distribution requires rapid intervention to stop and eradicate this disease. Any intervention should be based on a diagnosis of the causes and factors that promote the spread of this disease.

Several studies reported the importance of bio-physical and socio-economical factors in the occurrence of the vector-borne diseases[5-7]. Many of them investigate and analyze the health vulnerability[5,8-10] to climate and socio-economical changes.

Composite indicators have been found valuable approaches to evaluate the impact of many risk factors on the occurrence of the disease.

Various tools may help competent authorities, decision makers and researchers to study, analyze and decide who and when an intervention and a control of the disease are needed. Among the most used tools in the environment and extreme events management are the composite indicators. The use of the composite indicator for cutaneous leishmaniasis is an alternative to support countries in their decision making[11]. In previous report[11], the Pan American Health Organization used a composite indicator for cutaneous leishmaniasis based on three variables, the number of cases, the incidence rate and the case density at countries scale. Another initiative is the construction of a cutaneous leishmaniasis vulnerability index at a regional scale, in the pre-saharan provinces of Morocco[5]. In this study, the conceived composite indicator uses 20 indicators classified as anthropogenic, geographical, socio-economical, services, health, climatic category and hygiene components. The proposed index is based on this later study, but, the contribution of present work is the introduction of new factors and the downscaling of the existing composite indicator. This model helps to evaluate the cutaneous leishmaniasis at communal scale. The new variables and components concern the hydraulic category (dam outflow and groundwater pumped), the climatic (temperature, relative humidity and wind speed), the vegetation variables (cropping area) and the health category (age and sex ratio of patients). Previously, these factors were studied separately by several researchers. Present model has been the first of its kind in the Middle East and North Africa countries (MENA countries), as far as it is know, no studies have yet undertaken similar composite indicators in this field.

The developed index is an important step in the estimation of cutaneous leishmaniasis vulnerability at communal scale (in oasis desert region). The benefits obtained from these oases ecosystems consist of provisioning, regulating, cultural and supporting services. Changes in the ability to offer these benefits can affect the well-being of human as impacts on health. In 2009, Zagora province (including the studies sites) recorded 1882 zoonotic cutaneous leishmaniasis (ZCL) cases and notified of epidemic outbreaks[12]. In response to this epidemic, the Moroccan Health Ministry has intervened to control the disease transmission and take the appropriate measures.

In order to study the cutaneous leishmaniasis vulnerability, a multivariable index was proposed. Among the aims of this work is to test the applicability of this index and compare the vulnerability according to different dimensions (biophysics and climatic) of the four selected case studies.

MATERIALS AND METHODS

Study area: This study was conducted in Zagora province, the southeast of Morocco during September 2017 to July, 2018. The studied area consists of four sites (Fig. 1) including 15 municipalities. This area was crossed by Draa Wadi, a temporary river. This watercourse is fed by the Mansour Eddahbi Dam installed in the upstream zone. The average annual temperature is 22.5°C, with 25.25% of relative humidity and 64.1 mm in total annual precipitation (data of 1970-2009 cited in Karmaoui[13]. This area is among the most threatened by drought and desertification[14,15] and by floods[16].

It is an oasis region whose climate is arid and the vegetation is very sparse and concentrated mainly in the six palm groves, from upstream to downstream, Mezguita, Tinzouline, Ternata, Fezouata, Ktaoua and M'Hamid[17-20].

Approach: Tibúrcio and Corrêa[9] and Confalonieri[10] explored the associations of the socio-economic, epidemiological and climatologic of the cutaneous leishmaniasis; however, Almeida and Werneck[21] investigated the socio-territorial organization of the municipality that affecting the visceral leishmaniasis and De Toledo *et al*.[8] examined its transmission process

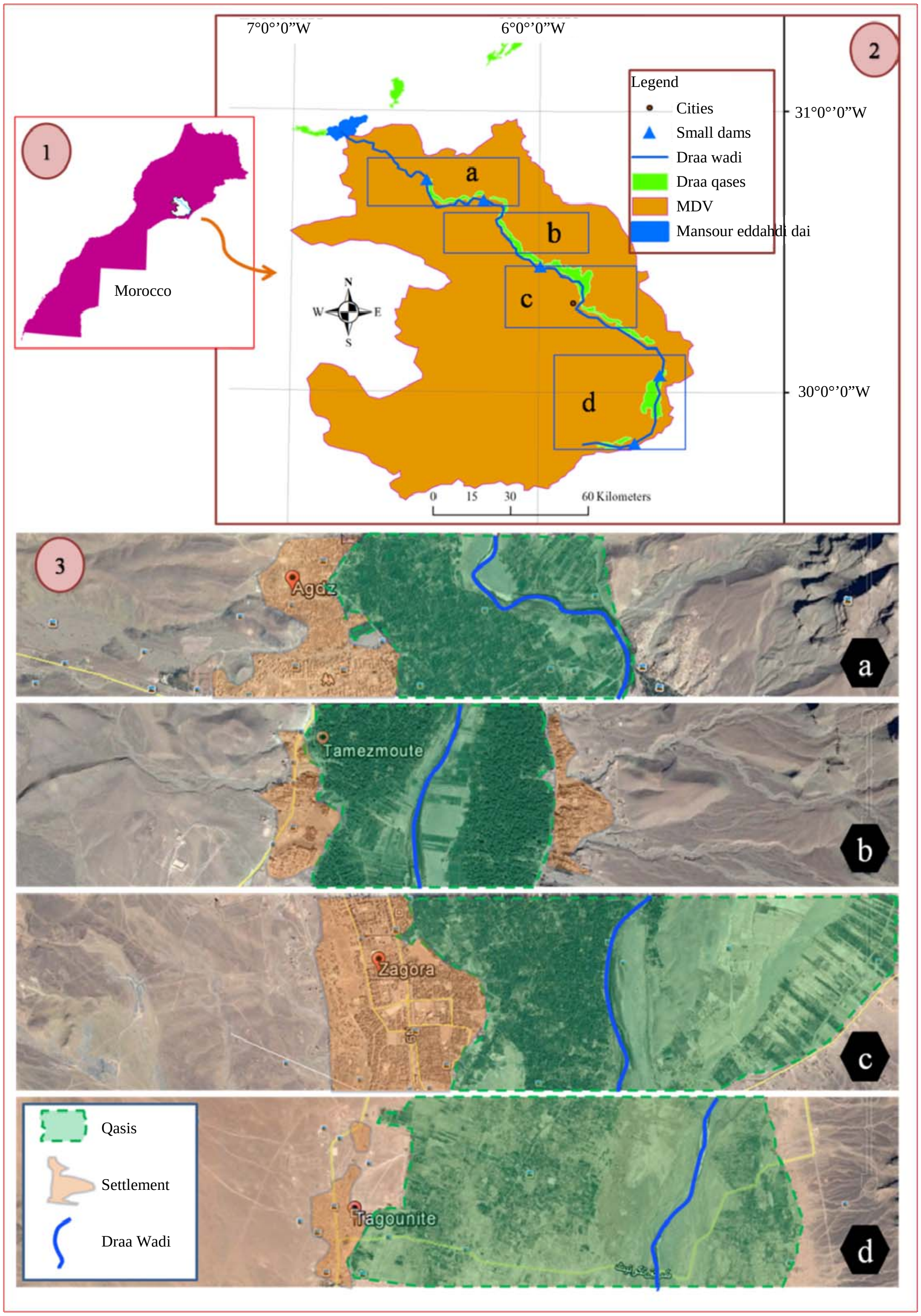

Fig. 1: 1: Localization of the middle Draa Valley in Morocco, 2: Middle Draa Valley including the four sites with leishmaniasis data, 3: Landscape of the four studied sites: (a), Agdez, Tamezmoute, Zagora and Tagounite (a, b, c and d) modified from Google earth)

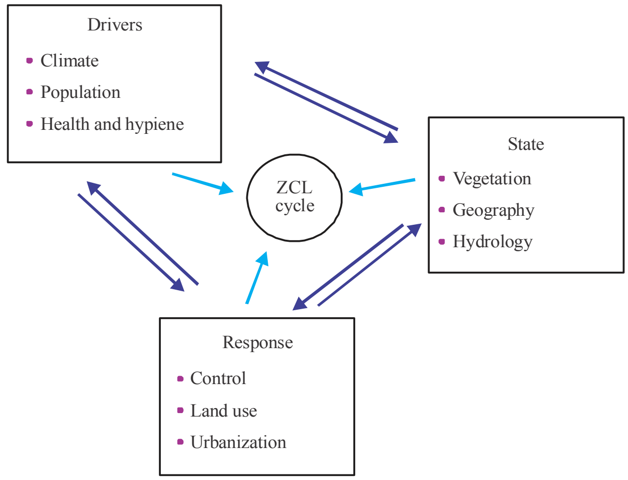

Fig. 2: Interactions between ZCL parameters

under the socio-demographic and urban infrastructure situation of the municipality. Ready[22] explored the relationship between socio-economical changes and the leishmaniasis cycle. At pre-Saharan region (including the studied sites), Karmaoui[5] studied the importance of anthropogenic, geographic, socio-economical, services, health, climate and hygiene indicators in the regional population vulnerability to ZCL.

The proposed index benefits and brought together these aspects and proposed others. It conglomerated and analyses the possible interactions between the disease and several bio-physical parameters at a local scale, such as socio-economical, climatic, hydraulic, vegetation and health.

This index was based on 20 indicators for estimating the vulnerability to cutaneous leishmaniasis of a site to future hazards. Six categories of indicators were defined basing on data availability and the possible association with the zoonotic cutaneous leishmaniasis, the social category the geographic category, the hydraulic category, the climatic, the vegetation and health category.

The variables involved in favoring the ZCL occurrence were categorized in three levels (Fig. 2), the drivers of change, the variables of state and the response variables. The interactions between these three levels influence the zoonotic cutaneous leishmaniasis cycle and then the occurrence of the disease.

The term of vulnerability was used in this paper to reflect the local fragility to leishmaniasis disease. The equation used was adapted from the work of Balica and Wright[23] as follows:

$$\text{Vulnerability} = \text{Exposure} + \text{Susceptibility} - \text{Reselience} \quad (1)$$

According to Karmaoui[5], where, the exposure refers to the predisposition to be impacted by ZCL, the susceptibility is the characteristic allowing the local population facing the disease and resilience refers to the adaptation and resistance to the disease.

The generated equations allowing the calculating of the vulnerability to the zoonotic cutaneous leishmaniasis are hereafter.

- **Social component:**

$$\text{LCLVI s} = [P+Pg+D+Ur+Un+H+S] \quad (2)$$

- **Geographic component:**

$$\text{LCLVI g} = [L+Al] \quad (3)$$

- **Hydraulic component:**

$$\text{LCLVI hy} = [Do+Rof+Gp] \quad (4)$$

- **Climatic component:**

$$\text{LCLVI c} = [T+Rh+R+W] \quad (5)$$

- **Vegetation component:**

$$\text{LCLVI v} = [Ca] \quad (6)$$

- **Health component:**

$$\text{LCLVI h} = [Lc+Ag+Sx] \quad (7)$$

where, P is Population, Pg is Population growth rate, D is Density, Ur is Urbanization (Rural), Uu is Urbanization (Urban), H is Houses, S is Size of family, L is Land area, Al is Altitude, Do is Dam outflow, Rof is Runoff, Gp is Groundwater pumped, T is Temperature, Rh is Relative humidity, R is Rainfall, W is Wind speed, Ca is Cropping area, Lc is Leishmania cases, Ag is Age, Sx is Sex ratio.

The total local Cutaneous Leishmaniasis Vulnerability Index Eq. 8 was estimated summing the six selected components:

$$\text{LCLVI total} = \Sigma\ \text{LCLVIs}+\text{LCLVIg}+\text{LCLVIhy}+\text{LCLVIc}+\text{LCLVIv}+\text{LCLVIh} \quad (8)$$

The normalization formula has been applied to four case studies (Eq. 9). however, the negative associations were transformed using Eq. 10. A level of local vulnerability to Cutaneous Leishmaniasis ranging from 0 to 1, where 0 indicated a very low vulnerability and 1 indicated a very high vulnerability (Table 1).

$$\text{LCLVI normalized} = \frac{[\text{LCLVI site}]}{[\text{LCLVI max}]} \quad (9)$$

$$\text{LCLVI normalized} = 1 - \frac{[\text{LCLVI site}]}{[\text{LCLVI max}]} \quad (10)$$

To determine the correlation of some climatic, hydrologic and biologic variables with the incidence of ZCL in the study area from urban to the rural area, from male to female, age variable, upstream-downstream change, parametric (Pearson correlation coefficient Eq. 11, significant at the 0.05) and nonparametric statistics (Spearman Eq. 12 were carried out for the four selected sites:

$$r = \frac{1}{n-1}\sum \frac{(x_i - \overline{X})(y_i - \overline{Y})}{s_x s_y} \quad (11)$$

$$r_s = 1 - \frac{6\sum D_i^2}{n(n^2-1)} \quad (12)$$

Where:

- X and Y = Correlated variables
- $\bar{X}$ and $\bar{Y}$ = The averages
- S_x and S_y = The standard deviations
- Σdi = The difference in the rank on the two variables
- n = Number cases of each variable

Table 1: Cutaneous Leishmaniasis vulnerability designations

Index value	Designations
<0.2	Very low vulnerability to cutaneous leishmaniasis
0.2-0.4	Low vulnerability to cutaneous leishmaniasis
0.4-0.6	Medium vulnerability to cutaneous leishmaniasis
0.6-0.8	High vulnerability to cutaneous leishmaniasis
0.8-1.0	Very high vulnerability to cutaneous leishmaniasis

Source: Karmaoui[5]

RESULTS

Overview on the ZCL at national and local scale: Leishmaniasis is a parasitosis caused in Morocco by three species of Leishmania (*Leishmania major, Leishmania tropica* and *Leishmania infantum*) all transmitted by sand flies. A large number of ZCL cases in Morocco in 2005 was found between 15 and 49 and lower than 9 years at the national scale and the age less affected was higher than 50 years (Fig. 3a). Concerning the seasonality of ZCL infection, a large number of cases was recorded for Cutaneous Leishmaniasis (*L. tropica*) in winter and spring and for Visceral Leishmaniasis (*L. infantum*) was identified in spring and summer (Fig. 3b). Historically (Fig. 3c) 2008-2011 was the period with the high incidence of cutaneous leishmaniasis in general at Moroccan scale and for ZCL at the studied area scale.

For the ZCL, since 1997-2015, 33101 (Table 2) people had been affected in nationwide. The majority lived in oases, where the parasite (*L. major*), the vector (*Phlebotomus papatasi*) and the reservoir (*Meriones shawi*) co exist. The disease caused a skin infection on its basis the extent of the disease was assessed.

The most important rate of ZCL cases was found in three provinces (Errachidia, Ouarzazate and Zagora). In Errachidia and Ouarzazate, the total population and the urban population were the most important compared with the rest of ZCL endemic provinces. However, Zagora recorded the high score of poverty severity index in urban area as showed in Table 2.

Construction of local cutaneous leishmaniasis vulnerability index: With quantifiable indicators, LCLVI defines the vulnerability following these components under the three dimensions of vulnerability, exposure, susceptibility and resilience.

The information of each site were gathered and normalized (Table 3) for a reason of comparison between the different units.

ZCL disease and the possible associate parameters: As mentioned above, six components including 20 variables were used, Social, Geographic, Hydraulic, Climatic, Vegetal and

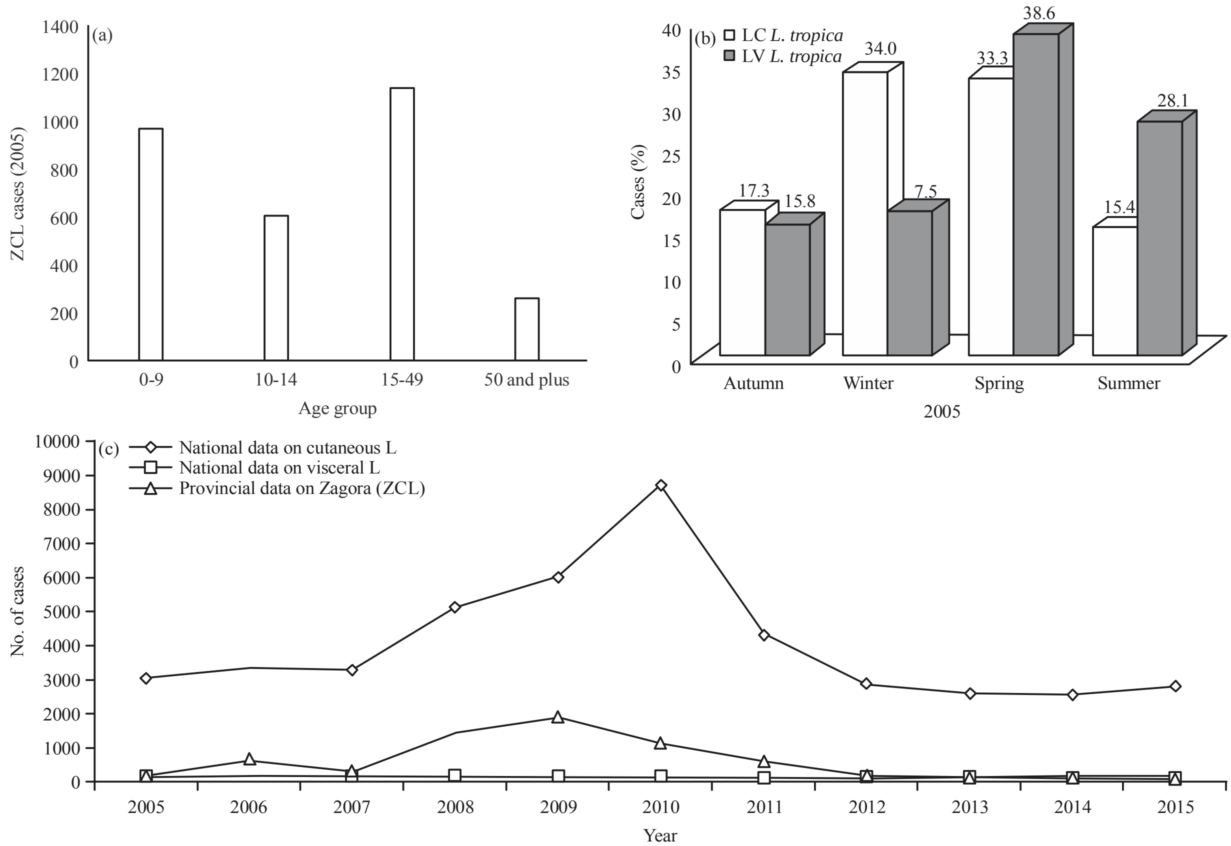

Fig. 3(a-c): (a) National data on ZCL classified by age, (b) Cases at national scale by season and (c) Leishmaniasis cases from 2005 to 2015 both at national and local scale (Zagora province including the four studied sites)
Moroccan Ministry of Health[12]

Table 2: Cases number of zoonotic cutaneous leishmaniasis at national scale and some socio-economic parameters

Years	Ouarzazate	Zagora	Tata	Errachidia	Figuig	Boulemane	Jrada	Tinghir
1997	11	574	0	337	247	0	0	n.d
1998	98	244	0	92	96	17	3	n.d
1999	135	154	2	46	60	18	0	n.d
2000	62	161	1	40	65	3	2	n.d
2001	210	60	0	56	29	1	3	n.d
2002	251	22	0	4	26	1	6	n.d
2003	2064	52	0	3	3	0	21	n.d
2004	865	103	2	4	63	31	273	n.d
2005	679	160	76	379	344	108	429	n.d
2006	388	645	31	304	629	54	113	n.d
2007	259	307	1	337	353	44	54	n.d
2008	381	1421	0	1333	244	50	14	n.d
2009	518	1882	29	1624	204	124	38	n.d
2010	1037	1135	14	4153	225	106	75	n.d
2011	295	588	16	557	146	78	45	733
2012	130	186	12	52	74	101	11	330
2013	90	131	6	13	39	97	3	495
2014	255	95	13	13	34	68	0	334
2015	421	48	15	231	41	59	96	228
Total	8149	7968	218	9578	2922	960	1186	2120
Cases (%)	24.6	24.1	0.7	28.9	8.8	2.9	3.6	6.4
Total population	295622	305510	114758	415963	135603	197 475	108011	321184
Urban population	112 092	50 668	37 917	138730	66461	65587	65918	75007
Urban poverty severity index	0.10	0.68	0.42	0,32	0.62	0.21	0.4	0.34

n.d: No data for Tinghir from 1997 to 2010 (a new delimited province: before 2009, Tinghir was a commune of Ouarzazate province), Data source: The data source of population, urban population and urban poverty severity index[24]. The data source of cutaneous leishmaniasis from 1997 to 2015: Moroccan Ministry of Health[12]

Table 3: General information of each site normalized and compiled according to the selected indicators

N	Indicators	Symbol	Agdez	Tamezmoute	Zagora	Tagonite
1	Population	P	0.43	0.28	1.00	0.44
2	Population growth rate	Pg	0.98	1.00	0.83	0.00
3	Density	D	0.52	0.75	1.00	0.19
4	Urbanization (Rural)	Ur	1.00	0.23	0.41	0.06
5	Urbanization (Urban)	Uu	1.00	0.00	0.91	0.00
6	Houses	H	0.45	0.29	1.00	0.45
7	Size of family	S	0.95	0.99	1.00	0.97
8	Land area	L	0.35	0.16	0.42	1.00
9	Altitude	Al	1.00	0.91	0.78	0.65
10	Dam outflow	Do	1.00	0.78	0.68	0.89
11	Runoff	Rof	1.00	0.78	0.36	0.26
12	Groundwater pumped	Gp	1.00	0.76	0.44	0.87
13	Temperature	T	0.77	1.00	0.91	0.96
14	Relative humidity	Rh	1.00	0.78	0.96	0.84
15	Rainfall	R	1.00	0.89	0.73	0.66
16	Wind speed	W	0.77	1.00	0.19	0.71
17	Cropping area	Ca	0.68	0.51	0.49	1.00
18	Leishmania cases	Lc	1.00	0.20	0.47	0.06
19	Age	Ag	0.55	0.55	1.00	0.18
20	Sex ratio	Sx	0.30	1.00	0.35	0.07

Table 4: Parameters compiled according to categories and their associations with cutaneous leishmaniasis occurrence

Sub-index	N	Indicators	Unit	Sym	Pearson correlation**	Spearman correlation***
Social	1	Population	nb	P	0.125*	1.0
	2	Population growth rate	%	Pg	0.603	1.0
	3	Density	%	D	0.206*	1.0
	4	Urbanization (Rural)	%	Ur	0.996	1.0
	5	Urbanization (Urban)	%	Uu	0.874	1.0
	6	Houses	nb	H	0.151*	1.0
	7	Size of family	nb	S	-0.594	0.9
Geographic	8	Land area	km^2	L	-0.438	0.9
	9	Altitude	m	Al	0.754	1.0
Hydrology	10	Dam outflow	m^3	Do	0.484	0.9
	11	Runoff	m^3	Rof	0.697	1.0
	12	Groundwater pumped	m^3	Gp	0.279*	1.0
Climatic	13	Temperature	°C	T	-0.831	
	14	Relative humidity	%	Rh	0.735	0.9
	15	Rainfall	mm	R	0.742	1.0
	16	Wind speed	-	W	-0.527	0.9
Vegetal	17	Cropping area (2005)	nb	Ca	0.534	-
Health	18	Leishmania cases (2005)	nb	Lc	-	1.0
	19	Age (2005)	nb	Ag	0.365*	0.9
	20	Sex ratio (2005)	F/M	Sx	-0.152*	1.0

*Indicators that are not statistically associated with the disease, **Pearson correlation between row data and the ZCL occurrence, ***Spearman correlation was used between normalized data of all used indicators and ZCL occurrence

Health. These variables were considered basing on the Pearson and Spearman correlations (Table 4). Table 4 showed the 20 variables normalized and categorized in components or sub-Index and their correlations with the ZCL cases. From these 20 indicators, only 6 were not statistically associated with the disease (Population, density, Houses, Groundwater pumped, age and sex). These no-correlated variables were considered basing on associations found in the literature

Estimating the vulnerability in the studied sites based on vulnerability equations: Until now, only a conglomerate of 20 variables characterizing the given area in terms of climate, land use, environment, hydraulic, demography and social parameters has been given. Using the vulnerability equations, a detailed comparison of the vulnerability of the selected sites and the used variables was carried out (Fig. 4).

After Fig. 4 and Table 3, for the social component, Zagora and Agdez score the very high vulnerability. Additionally, these sites had the high rate of urbanization. In terms of geographical aspect, the all sites recorded a high vulnerability. Regarding climatic component, the four sites were vulnerable to ZCL. Concerning the hydrologic indicators, Agdez and Tamezmoute were the most vulnerable. However, the healthy component indicated a very high vulnerability of the studied

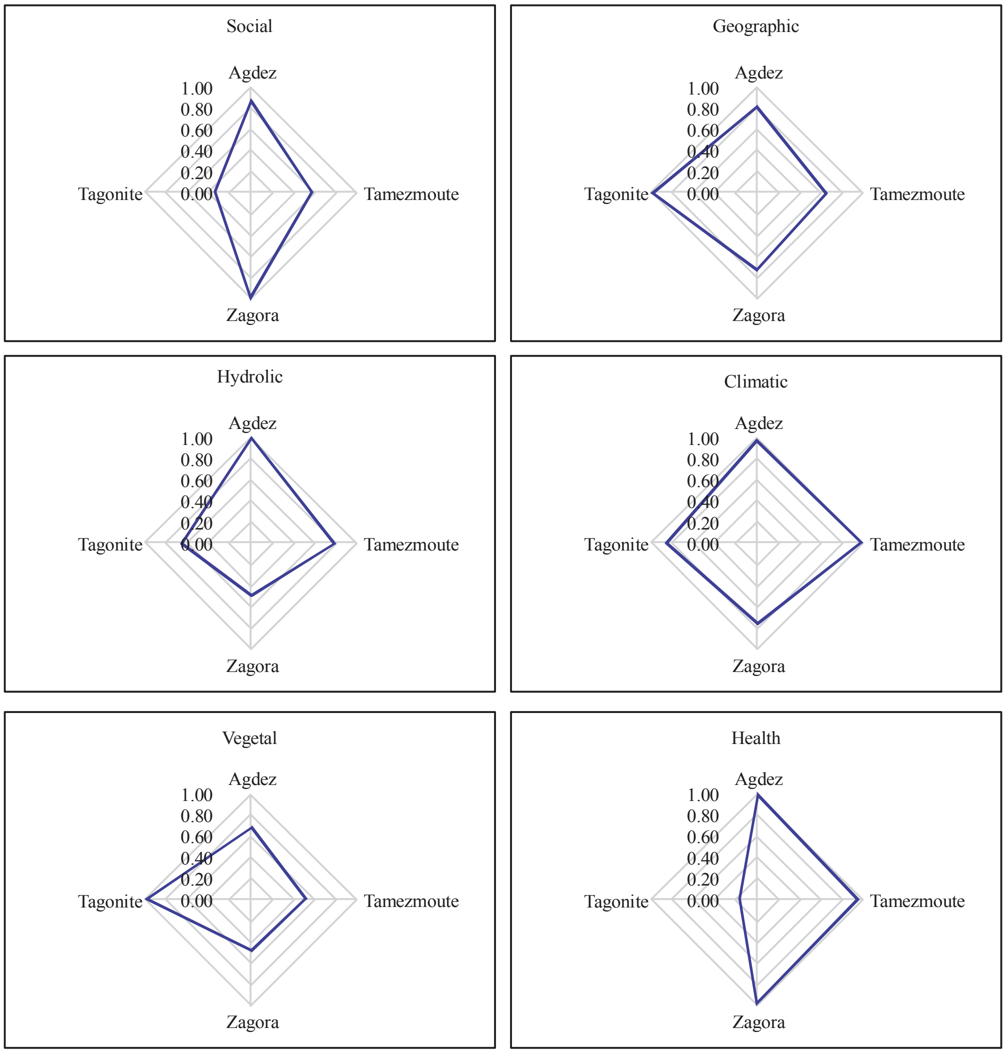

Fig. 4: Comparison of vulnerability between the selected sites according to the main used categories (average of each category variables)

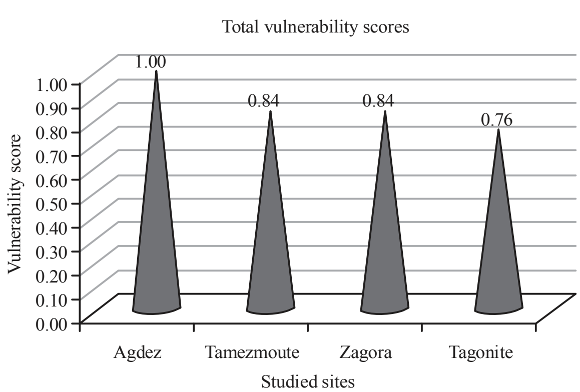

Fig. 5: Total cutaneous leishmaniasis vulnerability at local scale from upstream (Agdez) to downstream (Tagonite), following an increasing aridity.

sites to leishmaniasis except Tagonite, which had a relatively low vulnerability. Tagonite followed by Agdez had the high score of vulnerability regarding the vegetation component.

Concerning the total cutaneous leishmaniasis vulnerability at a local scale, the all sites had high vulnerability scores (Fig. 5). Agdez presented the very high score of vulnerability than the rest, Tamezmoute, Zagora and Tagonite, following an upstream-downstream evolution.

DISCUSSION

The proposed downscaled model (LCLVI) can reflect the local priorities regarding the ZCL control. The use of the notions of vulnerability and resilience are important contributions in the reflection of the study. These notions are basic tools for the comparative analysis of vulnerability to the multi disciplinary challenges of climate change.

At national scale since 1997, ZCL cases were found in the pre-saharan provinces. It seems that this neglected disease is concentrated mainly in the oasis zone. In this arid region, the socio-economical and ecological systems are vulnerable[25-27]. According to the data of the Moroccan Ministry of Health[12], at national scale since 1997, ZCL disease was recorded in the pre-saharan provinces. The largest rate of this disease was recorded in three main provinces, Errachidia, Ouarzazate and Zagora. Currently, these provinces know the most important occurrence. This trend can be explained by the high urbanization and poverty rates. According to the World Health Organization (WHO)[28], the leishmaniasis spread can be due to urbanization. In fact, Errachidia recorded 28.9% and Ouarzazate 24.6%, according to the general census of the population and housing[24] . In these provinces, the total and the urban population were the most important compared with the rest of ZCL endemic provinces. However, Zagora recorded the high score of poverty severity index in urban area.

For the social component, the very high vulnerability of Zagora and Agdez was due to the high population growth rate and the high population density of these two sites. The high vulnerability of all sites regarding the geographical indicators is explained by the fact that these sites are located in an elevation, where, the cutaneous leishmaniasis vector is abundant. According to Boussaa *et al.*[29] it ranges between 400 and 800 masl. Climatically, the high score of the four sites can be justified by the presence of these sites in an arid area, where the disease is endemic and both the reservoir and the vector coexist. However, the hydrologic indicators of Agdez and Tamezmoute scored a high vulnerability, which is justified by their location in the upstream part of the Middle Draa Valley where the water and vegetation are relatively available. Talking about the healthy component the studied sites indicate a very high vulnerability to leishmaniasis except the commune of Tagonite, which has a relatively low vulnerability. The results depict that the focus on socio-economical and biophysical can contribute to the disease surveillance and control. The control planning must take into account the climate change that increases or decrease the water availability and vegetation density. The findings can give necessary knowledge and the understanding of interactions between the suspected risk factors of ZCL. Consequently, this can support awareness in term of surveillance and parasite control measures.

Tiburcio and Correa developing an index based on socioeconomic, epidemiological and climate indicators exploring that socioeconomic and climate parameters are the main contributor to epidemiologic vulnerability index. In Karmaoui[5] at regional scale, a strong correlation was recorded between socio-economic and health indicators (r = 0.677).

The results showed also that there are several factors in the oasis system all varying together to cause the ZCL. There are three entities; each one has several dimensions, drivers and the biophysical and human response at local scales. The leishmaniasis transmission is explored in light of the upstream-downstream and the aridity change. Climatic and hydrological changes at a regional scale affect the human activity at local scale.

This article explores the vulnerability of four selected communes (desert oasis region) to zoonotic cutaneous leishmaniasis based on an integrated method. The proposed model differs from the existing indices by its simplicity, ease of use and specific for particularly local arid regions. It gathers also both the socio-economic and geo-physic components at three levels of vulnerability (exposure, susceptibility and resilience) under climatic context. The indicators were selected according to the relationships between indicators mentioned in Table 2. Basing on the literature, the proposed index added new parameters never used in the existing composite indicators. Thereby, cropping area, wind speed, groundwater pumped, dam outflow, runoff, age, sex ratio are used and are missing from common cutaneous leishmaniasis vulnerability indexes, but crucial to be added to a local cutaneous leishmaniasis vulnerability index. The paper was carried out in an endemic arid region. Six comparative graphs were produced for various leishmaniasis vulnerability sub-indexes and may be used in disease control and preparedness. The proposed model does not explore the human reaction in response to the epidemic transmission of this disease. The proposal can benefit from the Drivers-state-pressure framework family. DPSIR is among the most used models in environment sciences exploring the well-being and health[30,31]. The major disadvantage of the proposed tool is the qualitative aspect of the evaluation.

CONCLUSION

The findings depict that all selected sites have high vulnerability scores. Agdez present the very high score of vulnerability than the rest, Tamezmoute, Zagora and Tagonite, following an upstream-downstream evolution. The indicators used in the Local Zoonotic Cutaneous Leishmaniasis Vulnerability Index are essential to understand the tendency, estimate the vulnerability and compare it between several sites.

SIGNIFICANCE STATEMENT

In this paper, a new index on zoonotic cutaneous leishmaniasis (ZCL) vulnerability and an analysis of its applicability were introduced. The results help the researchers, stakeholders and the decision makers to explore the degree of vulnerability and the factors impacting the ZCL infection at local scale. The findings give also a scientific basis for the decision making regarding the control and surveillance of the disease.

REFERENCES

1. Mandal, F.B., 2015. Human Parasitology. 3rd Edn., PHI Learning Pvt. Ltd., India.
2. Chaves, L.F. and M. Pascual, 2006. Climate cycles and forecasts of cutaneous leishmaniasis, a nonstationary vector-borne disease. Plos Med., Vol. 3. 10.1371/journal. pmed.0030295
3. Cardenas, R., C.M. Sandoval, A.J. Rodriguez-Morales and C. Franco-Paredes, 2006. Impact of climate variability in the occurrence of leishmaniasis in Northeastern Colombia. Am. J. Trop. Med. Hygiene, 75: 273-277.
4. Schriefer, A., L.H. Guimaraes, P.R. Machado, M. Lessa and H.A. Lessa *et al*., 2009. Geographic clustering of leishmaniasis in Northeastern Brazil. Emerg. Infect. Dis., 15: 871-876.
5. Karmaoui, A., 2018. The cutaneous leishmaniasis vulnerability index (CLVI). Acta Ecol. Sin., 38: 288-295.
6. Ghatee, M.A., A.A. Haghdoost, F. Kooreshnia, Z. Kanannejad, Z. Parisaie, M. Karamian and A. Moshfe, 2018. Role of environmental, climatic risk factors and livestock animals on the occurrence of cutaneous leishmaniasis in newly emerging focus in Iran. J. Infect. Public Health, 11: 425-433.
7. Palaniyandi, M., P. Anand and R. Maniyosai, 2014. Spatial cognition: A geospatial analysis of vector borne disease transmission and the environment, using remote sensing and GIS. Infor. Syst., 1: 39-54.
8. De Toledo, C.R.S., A.S. de Almeida, S.A. de Miranda Chaves, P.C. Sabroza, L.M. Toledo and J.P. Caldas, 2017. Vulnerability to the transmission of human visceral leishmaniasis in a Brazilian urban area. Rev. Saude Publica, Vol. 51.
9. Tiburcio, L.H. and M.D.P. Correa, 2012. Analise da vulnerabilidade da microrregiao de Itajuba por meio do IVG com vistas a mitigacao dos impactos causados pelas mudanças climaticas. Ambiente Soc., 15: 123-139.
10. Confalonieri, U.E.C., D.P. Marinho and R.E. Rodriguez, 2009. Public health vulnerability to climate change in Brazil. Clim. Res., 40: 175-186.
11. PAHO/WHO., 2016. Leishmaniases: Epidemiological report in the Americas. Pan American Health Organization, World Health Organization, Washington.
12. Moroccan Ministry of Health, 2016. Sante en chiffre. (Direction de la Planification et des ressources financiere, division de la Planification et des Etudes, Service des Etudes et de l'information Sanitaire). Moroccan Ministry of Health, Rabat.
13. Karmaoui, A., 2015. Evaluation des services ecosystemiques et impact du changement climatique dans la Vallee du Draa Moyen, Sud-Est du Maroc. Ph.D. Thesis, Cadi Ayyad University.
14. Chelleri, L., G. Minucci, A. Ruiz and A. Karmaoui, 2014. Responses to drought and desertification in the moroccan drâa valley region. resilience at the expense of sustainability. Int. J. Clim. Change Imp. Resp., 5: 1835-7156.
15. Minucci, G. and A. Karmaoui, 2017. Exploring the Water-Food-Energy and Climate Nexus: Insights from the Moroccan Draa Valley. In: Peri-Urban Areas and Food-Energy-Water Nexus. Sustainablity and Resilience Strategies in the Age of Climate Change, Colucci, A., M. Magoni and S. Menoni (Eds.)., Springer International Publishing, Germany, pp: 89-97.
16. Karmaoui, A., S.F. Balica and M. Messouli, 2016. Analysis of applicability of flood vulnerability index in Pre-Saharan region, a pilot study to assess flood in Southern Morocco. Nat. Hazard Earth Syst. Sci. Discuss., 10.5194/nhess-2016-96, 2016.
17. Karmaoui, A., M. Messouli, Y.M. Khebiza and I. Ifaadassan, 2014. Environmental vulnerability to climate change and anthropogenic impacts in dryland (Pilot study: Middle Draa valley, South Morocco). J. Earth Sci. Climatic Change, Vol. S11.
18. Karmaoui, A., M. Messouli, M.Y. Khebiza and I. Ifaadassan, 2014. Environmental vulnerability to climate change and anthropogenic impacts in dryland, (Pilot Study: Middle Draa Valley, South Morocco). J. Earth. Sci. Clim. Change.,
19. Karmaoui, A., I. Ifaadassan, M. Messouli and M.Y. Khebiza, 2015. Monetarization of ecosystem services of oasean biome (Case study: Provisioning services of middle draa valley oases). Br. J. Applied Sci. Technol., 11: 1-18.
20. Karmaoui, A., I. Ifaadassan, A. Babqiqi, M. Messouli and M.Y. Khebiza, 2015. Analysis of the water supply-demand relationship in the middle draa valley, morocco, under climate change and socio-economic scenarios. J. Sci. Res. Rep., 9: 1-10.
21. Almeida, A.S. and G.L. Werneck, 2014. Prediction of high-risk areas for visceral leishmaniasis using socioeconomic indicators and remote sensing data. Int. J. Health Geogr., Vol. 13. 10.1186/1476-072X-13-13
22. Ready, P.D., 2010. Leishmaniasis emergence in Europe. Eurosurveillance, Vol. 15.
23. Balica, S. and N.G. Wright, 2010. Reducing the complexity of the flood vulnerability index. Environ. Hazards, 9: 321-339.
24. Anonymous, 2014. General census of the population and housing, 2014. https://rgph2014.hcp.ma/.

25. Karmaoui, A. and A. Moumane, 2016. Changes in the environmental vulnerability of oasean system (Desert oasis), pilot study in middle draa Valley, Morocco. Exp. Opin Environ. Biol., Vol. 5. 10.4172/2325-9655.1000135
26. Karmaoui, A., I. Ifaadassan, M. Messouli and M.Y. Khebiza, 2015. Characterization of common environmental indicators of the moroccan oasean biome, pilot study in the reserve biosphere of oases in Southern Morocco. Adv. Res., 5: 1-15.
27. Karmaoui, A., M. Messouli, I. Ifaadassan and M.Y. Khebiza, 2014. A multidisciplinary approach to assess the environmental vulnerability at local scale in context of climate change (Pilot Study in Upper Draa Valley, South Morocco). Global J. Technol. Optim, Vol. 6. 10.4172/2229-8711.1000167
28. WHO, 2002. Urbanization: An increasing risk factor for leishmaniasis. Weekly Epidemiol. Rec., 77: 365-370.
29. Boussaa, S., M. Neffa, B. Pesson and A. Boumezzough, 2010. Phlebotomine sandflies (Diptera: Psychodidae) of southern Morocco: Results of entomological surveys along the Marrakech-Ouarzazat and Marrakech-Azilal roads. Ann. Trop. Med. Parasitol., 104: 163-170.
30. Bradley, P. and S. Yee, 2015. Using the DPSIR framework to develop a conceptual model: Technical support document. Office of Research and Development, USEPA., Atlantic Ecology Division, Narragansett, RI, EPA/600/R-15/15.
31. Sekovski, I., A. Newton and W.C. Dennison, 2012. Megacities in the coastal zone: Using a driver-pressure-state-impact-response framework to address complex environmental problems. Estuarine Coastal Shelf Sci., 96: 48-59.