RISK ASSESSMENT OF CHOLERA EPIDEMIC IN CAMEROON

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Abstract

Risk assessment and forecasting are vital for the development of preparedness and response to epidemics. Despite the age-long burden of cholera around the world, cholera epidemics are still a recurrent health challenge in Cameroon. This research contributes to the risk assessment of cholera in Cameroon by examining the influence of climatic, environmental, and socio-economic factors on a cholera outbreak. The assessment involved identifying, evaluating, and aggregating the cholera risk factors to construct a spatial risk index using the INFORM conceptual equal weighting framework. Our findings reveal that not all indicators identified in the literature are relevant to cholera incidences in the context of Cameroon. Cholera is endemic in Cameroon but is more prominent in the southern regions of Cameroon. We show that the risk index developed in this study is statistically valid for the cholera incidence over the period considered. Although this assessment provides an overview of the risk levels of the regions in Cameroon, it may not be useful for estimating epidemic risk at a higher resolution. Further studies should be conducted to assess localized trends of cholera in relation to identified risk factors.

Keywords: Risk, Factors, Indicators, Index, Cholera, Epidemic.

1 Introduction

Risk assessment and forecasting are vital for the development of preparedness and response to epidemics. Understanding the process of the emergence and spread of a disease is crucial to responding and preparing for an outbreak (Hierink et al., 2022). The assessment of risk factors of an epidemic is an essential part of epidemiological studies, and risk factors can be used as predictors in forecasting models (Richterman et al., 2018). These models can estimate the severity and the possible spread of the disease across a geographical area.

Cholera is a public health challenge with a significant presence worldwide. It is an acute diarrhoeal infection transmitted through the intake of food and water exposed to the causative agent - *vibrio cholerae* (WHO, n.d.). Cholera has been a recurrent epidemic in Cameroon since its first incidence was reported in 1971 (Ngwa et al., 2016). The burden of cholera in Cameroon increased during the rainy seasons between 2000 and 2012 (Ngwa et al., 2016). A cholera outbreak began in October 2021 and became the most devastating outbreak in decades (Nalova, 2022). The epidemic outbreak has resulted in 6,652 suspected cases and 132 deaths as of April 2022 (WHO, 2022).

The incidence of cholera is strongly related to the physical and social environment. The natural habitation of the *vibrio cholerae* is an aquatic environment (Colwell, 1996). The factors contributing to cholera risk are water, sanitation, and hygiene (WASH) factors (Idoga et al., 2019). Environmental factors such as proximity to regional rivers, heavy rainfalls, and floodings encourage the interaction between the causative agent and the host (Jutla et al., 2013). In this research, an assessment of the risk of cholera is made to

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examine the influence of climatic, environmental and socio-economic factors on a cholera outbreak in Cameroon.

2 Study Area

Cameroon lies at the confluence of western and central Africa. It has a population of 27 million people and a land mass of 475,442 square kilometres. Outside the central government, Cameroon's administration is divided into 10 regions (Appendix, Figure A1) and 58 departments. One-third of the households in Cameroon have unimproved sanitation facilities, and health staff are not sufficient to address the medical needs of the population (National Institute of Statistics (Cameroon) & ICF, 2020; Tandi et al., 2015).

3 Methodology

This research culminates into a risk index based on the influence of different risk factors in relation to the 2021 outbreak of cholera in Cameroon. Risk factors were aggregated using INFORM model; this model improves the objective allocation of resources for humanitarian emergency management (Hierink et al., 2022; Marin Ferrer et al., 2017). The dimensions of the INFORM model are hazard and exposure, vulnerability, and lack of coping capacity (Marin-Ferrer & Vernaccini, 2017). Risk factors were identified from the literature, and datasets were gathered from different sources to satisfy their information needs. The datasets were normalized to ensure consistency in resolution. Pairwise correlation was used to determine the risk factors included in the INFORM risk index. Finally, the risk index was validated by regressing it against the cholera incidence.

3.1 Identification of risk factors

The first stage was to mine information from studies in Cameroon and beyond about the risk factors of cholera through a systematic literature review. The keywords and their categories used for the search query are defined in Appendix, Table A1. 35 peer-reviewed papers from the SCOPUS database were dissected. A threshold was created to filter out global factors with less than 2 references in order to exclude factors with very little supporting evidence. Given the information needs of each factor, a data search was completed to identify and download suitable data. The datasets obtained were available at different spatial resolutions. While a higher resolution would have been preferred, some datasets were only available at a regional level. Therefore, all the datasets were reclassified to indicate a value per region. These values were eventually linearly rescaled to [0,10] for the sake of uniformity.

3.2 Selection of risk factors

Correlation analyses were done to determine if the identified risk factors (independent variables) are related to cholera incidences (dependent variable) in Cameroon. A pairwise correlation among the factors was also completed to understand their interrelationship. Pearson's Correlation Coefficient was used to achieve this objective, the coefficients (r) range from -1 to 1. Indicators that show negligible correlation ($r < 0.10$) with cholera incidence are withdrawn from further analysis, while negatively correlated indicators are inverted. Additionally, indicators that are strongly correlated ($r > 0.70$) with other independent variables within the same dimension are reduced. It is better to have a low correlation among indicators in the same dimensions by retaining the dominant variables (Marin Ferrer et al., 2017).

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3.3 Risk indexing

The computation of a spatial risk index is completed by overlaying associated risk factors in combination with the weight of each indicator. Based on the aggregation method in INFORM (Equation 1), an equal weighting approach was used to obtain the final risk score (European Commission, n.d.). The risk scores are classified into five classes according to INFORM Classification namely: very high, high, medium, and low, very low (Appendix, Figure A2). Using an equal weighting approach for the calculation is based on the premise that all risk dimensions contribute to the overall level of risk (Marin Ferrer et al., 2017).

$$Risk = Hazard\&Exposure^{1/3} * Vulnerability^{1/3} * Lack\ of\ coping\ capacity^{1/3} \ldots\ldots\ldots\ldots\ldots (1)$$

3.4 Risk validation

The risk index is validated by computing the simple linear regression between the index and cholera incidence in Cameroon. An Analysis of Variance (one-way ANOVA) was completed to understand if there is a linear association between the two datasets.

4 Results

4.1 Identification of risk factors

Given the evidence from the literature and data suitability checks, the relevant risk factors considered in this research are provided in Table 1. The datasets used are provided in Appendix, Table A2

Table 1. The risk factors identified in this study.

INFORM Risk dimensions	Risk factors
Hazard and Exposure	Precipitation, Land Surface Temperature, Climate-related disasters, Population Density, Surface water amount
Vulnerability	Poverty, conflicts
(Lack of) Coping Capacity	Population per healthcare facility, Water and Sanitation Hygiene (WASH)

4.2 Selection of risk factors

The correlation revealed that almost all indicators have a significant correlation ($r > 0.10$) with cholera incidence. The only risk factor that did not satisfy this condition is “conflicts”. As a result, conflict was exempted from further analyses. While most other factors were positively correlated to cholera incidence, risk factors such as poverty, availability of WASH facilities, and population-to-HCF ratio indicate a negative correlation (Appendix, Figure A3). Given the pairwise comparison of each risk factor for each dimension of risk, precipitation and climatic hazards/disasters are removed from further analyses because of their high correlation ($r > 0.70$) to surface water amount and temperature respectively (Appendix, Figure A4).

4.3 Risk indexing

Using the risk factors that show a significant correlation to cholera, a spatial risk index was created using the INFORM model (Figure 1, Appendix, Table A3). It can be observed that the northern regions are also

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exposed to vibrio cholera, however, they are less vulnerable as compared to the southern parts. The respective maps of the risk dimensions are in Appendix, Figure A5. Southwest and littoral regions are the potential high-risk areas while the region with the lowest risk of cholera in Cameroon is the Extreme–Nord region.

4.4 Risk validation

Finally, the risk index was subjected to regression analyses to validate them against the actual cholera incidence. The ANOVA analysis shows that the probability of obtaining an F-value that is at least as high as our study's value (19) is less than 0.05 (Table 2). Therefore, at a 95% confidence level, there is strong evidence to reject the null hypothesis. Furthermore, 71% of the variability of the cholera incidence can be explained by the risk index ($R^2 = 0.71$).

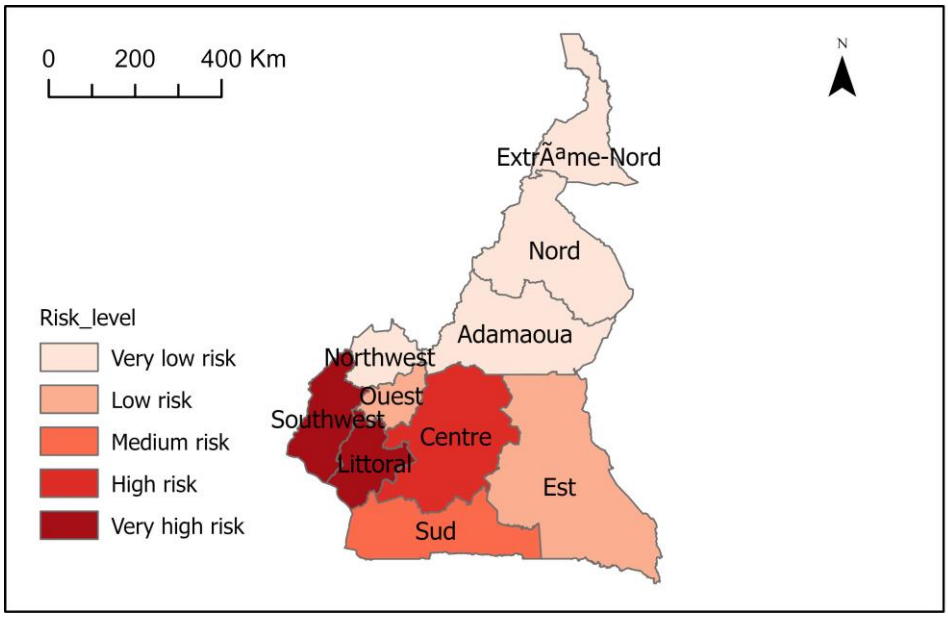

Figure 1. Subnational risk map of cholera in Cameroon.

Table 2. ANOVA analysis for the risk index. ($R^2 = 0.71$)

	Degree of freedom (df)	Sum of squares (SS)	Mean of square (MS)	F-value
Regression	1	38925390	38925390	19*
Error	8	159747206	1996840	
Total	9	54900110		

*($p<0.05$)

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5 Discussion

While cholera is a global epidemic, Cameroon's risk factors remain underexplored.In addition, some risk indicators that were excluded owing to unsuitable or unavailable data sources may have improved the quality of this assessment. The development of effective strategies to mitigate cholera demands an assessment of transmission patterns at local levels (Ngwa, Liang, Kracalik, et al., 2016). Unlike climatic datasets, socioeconomic datasets are mostly available at a regional level making it difficult to identify localized trends. The developed index is useful to compare the risk of the regions on the three fundamental dimensions of INFORM to aid the development of mitigation strategies. The risk maps show which regions to be prioritized in anticipatory planning and response. Although this assessment provides an overview of the risk levels of the regions in Cameroon, it may not be useful for estimating epidemic risk at a higher resolution. The risk index has been validated for a single incidence year but should ideally be compared with incidence data for other years as well.

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Appendix

Figure A1: Study area showing the ten regions.

Table A1. Literature search strategy

Category	**1**	**2**	**3**	**4**
Keywords	("risk" OR "hazard" OR "susceptibility" OR "exposure" OR "vulnerability" OR "coping capacity" OR "Outbreak" OR "incidence")	("factor" OR "indicator" OR "cause" OR "influence" OR "affect" OR "predict" OR "explain")	("cholera" OR "vibrio cholerae")	("Cameroon")
Search strategy 1	Included	Included	Included	
Search strategy 2 & 3*	Included	Included	Included	Included

*Grey literature

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Table A2. Summary of data and sources

Data	Description	Spatial Resolution	Year	Source
Cameroon shapefiles	Boundaries of the regions of Cameroon	Polygon data	2023	OSM
Cholera data	Situation reports for cholera in Cameroon	Administrative level 1*	2021 - 2022	CCSOUSP
*Regional level				
	Hazard and Exposure			
Precipitation	Average Rainfall depth	1km	2023	WorldCLIM
Land Surface Temperature	Average surface temperature	1km	2023	WorldCLIM
Climate-related disasters	The aggregated score for frequency of hazards such as floods, droughts and landslides	Administrative level 1	2021	INFORM Subnational Model
Population Density	Unconstrained population-weighted density based on the geometric mean	1km	2020	WorldPOP
Surface water amount	Raster of water bodies in the region	250m	2015	NASA LP DAAC
	Vulnerability			
Poverty level	The global Multidimensional Poverty Index (MPI) 2022 disaggregation results	Administrative level 1	2022	OPHI
Conflicts	Aggregated score from GCRI Conflict score, Conflict Intensity and ACLED events	Administrative level 1	2021	INFORM Subnational Model
	(Lack of) Coping Capacity			
Population per Health care Facilities (HCFs)	Shapefiles of HCFs in Cameroon	Point data	2023	Healthsites
	Population per region	Administrative level 1	2022	UNFPA
Water and Sanitation Hygiene (WASH) factors	Unimproved WASH facilities per region	Administrative level 1	2018	The National Institute of Statistics (INS), Cameroon

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CLASSES THRESHOLDS IN INFORM			
Dimension	CLASS	MAX	MIN
RISK	very high	10	6.5
	high	6.4	5.0
	medium	4.9	3.5
	low	3.4	2.0
	very low	1.9	0.0
HAZARD & EXPOSURE	very high	10.0	6.1
	high	6.0	4.1
	medium	4.0	2.7
	low	2.6	1.5
	very low	1.4	0.0
VULNERABILITY	very high	10.0	6.4
	high	6.3	4.8
	medium	4.7	3.3
	low	3.2	2.0
	very low	1.9	0.0
LACK OF COPING CAPACITY	very high	10.0	7.4
	high	7.3	6.0
	medium	5.9	4.7
	low	4.6	3.2
	very low	3.1	0.0

Figure A2. Classes thresholds in INFORM (Marin Ferrer M et al., 2017)

	Cholera Incidence	Precipitation	Temperature	Climatic Hazards	Population Density	Surface water amount	Poverty	Conflicts	WASH facilities	Population per HCFs
Cholera Incidence	1.00	0.80	0.26	0.19	0.34	0.96	-0.63	0.08	-0.80	-0.25

Figure A3. Correlation between risk factors and cholera incidence data (for the year 2021)

		Precipitation	Temperature	Climatic Hazards	Population Density	Surface water amount	Poverty	Conflicts	WASH facilities	Population per HCFs
Hazard & Exposure	Precipitation	1.00	-0.33	-0.33	0.28	0.77				
	Temperature	-0.33	1.00	0.90	0.16	0.31				
	Climatic Hazards	-0.33	0.90	1.00	-0.04	0.28				
	Population Desnsity	0.28	0.16	-0.04	1.00	0.22				
	Surface water amount	0.77	0.31	0.28	0.22	1.00				
Vulnerability	Poverty						1.00	0.16		
	Conflicts						0.16	1.00		
Lack of coping capacity	WASH facilities								1.00	0.16
	Population per HCFs								0.16	1.00

Figure A4. Pairwise correlation of risk factors

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Table A3. Risk Index of cholera in Cameroon

Name of regions	Hazards	Vulnerability	(Lack of) Coping Capacity	Risk level
Adamaoua	0.54	1.24	5.79	**1.57**
Centre	4.66	5.94	6.09	**5.52**
Est	0.90	3.32	4.40	**2.36**
ExtrÃªme-Nord	4.02	0.00	1.43	**0.00**
Littoral	7.87	8.51	8.50	**8.29**
Nord	2.65	0.30	5.18	**1.60**
Northwest	0.25	5.20	5.81	**1.95**
Ouest	0.47	8.39	7.60	**3.12**
Southwest	5.04	10.00	9.88	**7.93**
Sud	2.31	7.45	7.03	**4.94**

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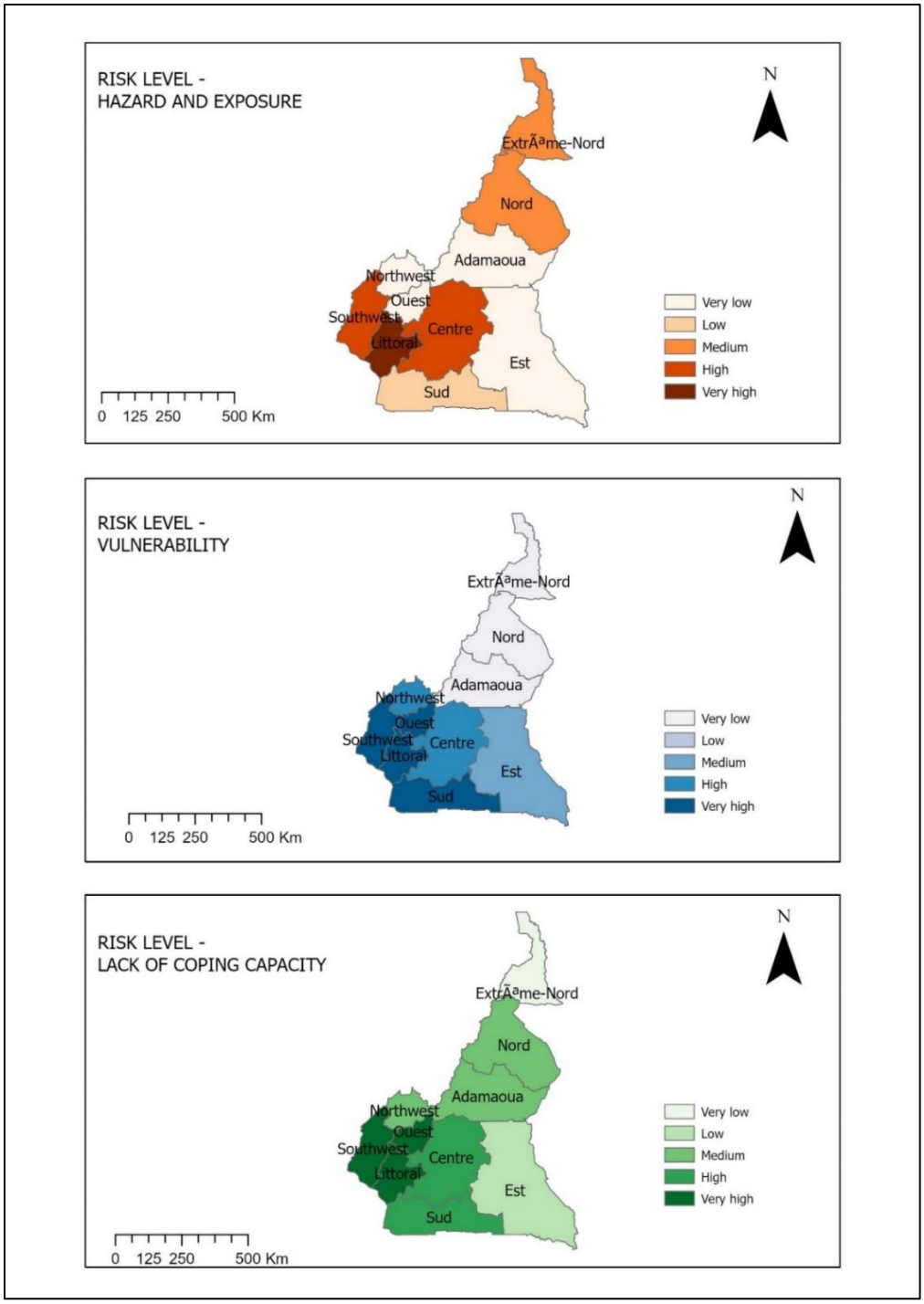

Figure A5. Risk maps of cholera in Cameroon in the dimensions of INFORM.

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