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Does flooding undermine the management capacities of the COVID-19 pandemic? A study of Lagos State, Nigeria

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Abstract: Given the dynamics of climate events (hazards) and their linkages to human health, it is imperative to continuallly check the impacts of these events on the public health system. While efforts have been made to understand fluvial flood and COVID-19 vulnerability and impacts, substantial gaps about impacts of their simultaneous occurrence on densely-populated communities abound. This paper presents an assessement of the occurrence of fluvial flooding and its potential to undermine the management of the COVID-19 pandemic in Lagos State, Nigeria. This study applied the indicator-based risk assessment method to determine the pattern of COVID-19 risk in the study area. Flood hazard and health facilities datasets of Lagos State were also used to determine the flood extent and pattern of flood-exposed health facilities in ArcGIS 10.7.1. Results revealed that Apapa, Eti Osa, Ibeju Lekki, Mushin, and Lagos Mainland local government areas (LGAs) were at a very high risk of COVID-19. Results also highlight six LGAs that should be prioritized in managing COVID-19 due to the exposure of the majority of its health facilities to flood. Far-reaching recommendations on the need to prioritize these flood-exposed health facilities for COVID-19 risk reduction, humanitarian aid and prevention strategies is made. Also, future research in the study area should explore sustainable strategies to adapt to COVID-19 and flood events from an interdisciplinary perspective.

Key words: COVID-19 risk, fluvial flood, hazard, health infrastructures, Lagos State.

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1. INTRODUCTION

In today's world of increasing unprecedented and extreme events, humans and the world remain connected as our actions continue to generate global impacts. These impacts range from triggering natural hazards, biodiversity degradation, pandemics, heatwaves, and the like [1]. These hazards, events, and disasters are not just connected, they can also compound or undermine the management capacities of the other, thus generating cascading impacts [1,2]. In this study, fluvial flooding (a climatic event) and its implication for COVID-19 pandemic management has been explored in Lagos State, Nigeria.

A fluvial flood happens when the water level in a body of water (such as a river, lake, and the like) rises and spills onto the banks, coasts, and nearby land. The rise in water levels could be caused by excessive rain, tectonic activity, or snowmelt [3]. Flood exposure refers to people and assets in floodplains. The average monthly rainfall in Lagos State (hereinafter called "Lagos"), Nigeria, exceeds 200 mm during the rainy season, often more extensive than the soil's infiltration capacity [4] and therefore, a leading cause making flooding the most popular and frequent hazard [5,6]. Fluvial floods (hereinafter called "flood or flooding") occur every year in Lagos [7], resulting in the loss of lives, livelihoods, and

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infrastructure costing millions of dollars [8,9]. Because of its coastal location and status as the country's commercial and most populated state, it is especially exposed to flood [10,11].

Events of flooding have had a significant direct impact on residents of Lagos due to the lack of pre-flood preparedness. Many Lagos inhabitants live in flood-prone areas because they are uninformed of the risk at the time, proximity to their workplace, or its inexpensiveness [12,13]. This is making the vulnerability to floods increase with the rate of urbanization [6] and [14]. Some of the devasting recent flood events in Lagos are that of July 2011, which killed roughly 25 people and forced 5393 people to flee their homes, resulting in a total loss of NGN 30 billion (USD 200 million) value of properties. The June 2012 flood, which poured 216 mm of rain in a single storm, caused havoc on infrastructure, took seven lives, and impacted locals' livelihoods [8]. The flooding on July 16, 2021, affected the entire Lagos, with a flood height that submerged cars and houses on the coastlines. The full account of the damage of this recent flood event is still being estimated [15].

On the other hand, Coronavirus disease (COVID-19), a global pandemic, recorded its first case in Nigeria on February 27, 2020, and this was recorded in Lagos [16–18]. As of April 8, 2022, the state has recorded 99,226 lab-confirmed cases, which is 41.3% of the total lab-confirmed cases in the 36 States of Nigeria [19]. Since the discovery of the deadly virus in the State, the State's government has been utilizing a combination of public health and social measures to prevent the spread of the virus [20,21]. These include the closure of schools, businesses, offices, and other public facilities [17,20]. Irany et al [22] modelled the impacts and outcomes of these closures. This disease and its control measures have worsened institutional adversities and underlying and persistent economic challenges [23]. Thus, the continuing COVID-19 outbreak primarily affecting Lagos [24,25] has combined with the existing consequences of floods, resulting in severe impacts.

Floods and COVID-19's catastrophic combined effects are not new or unique to Lagos. Researchers have revealed that many other places are also struggling to manage these two dangers. For instance, on July 4, 2020, flooding caused the deaths of 65 people in Kumamoto, Japan; 217 homes were damaged, and 458 were partially destroyed, resulting in a spike of 188 COVID-19 cases by the end of the month [26]. In July 2020, as the COVID-19 cases were slowing down, serious flood incidents in 27 provinces across central and southern China threatened people's lives and homes [27]. Despite being confronted with the two dangers between May and September 2020, residents in New York, U.S.A. were more worried about and adhered to the COVID-19 measures, but were less prepared and worried about flooding during that time, which caused different exposures and casualties between the pandemic and floods [28]. Like in Lagos, floods are wreaking havoc on most of Africa's coastal areas. Due to the people's lower economic and technological capabilities to adapt, combined with the COVID-19 repercussions, puts the population in these places in a dangerous situation [29].

From the foregoing, and at the time of this research, no study had investigated the double hazards of flood and COVID-19 in Lagos State. Studies investigating either of the two hazards did so without considering the implications flood may have for the coping and management capacities of COVID-19. In addition, the Intergovernmental Panel on Climate Change characterization of risks [30,31] has not been considered in studies exploring COVID-19 risk in Lagos. Such understanding is relevant and required for a comprehensive understanding of the underlying problems for better informed local policies and actions. To address this knowledge gap, this study assesses flood hazards amid the COVID-19 pandemic in Lagos State, Nigeria from a geospatial perspective. The guiding research questions are: (a) What is the spatial pattern of COVID-19 risk in Lagos? (b) What is the pattern of flood hazards in Lagos? and (c) what implication(s) does flooding have for the management capacity of COVID-19 in Lagos? This paper is organized as follows. The next session detailed the conceptual framework and the methods employed. They are followed by a presentation of key results. Following the results is a discussion of result implications. The last session concludes the paper with a take-home message and recommendations.

2. METHODS AND DATA

2.1. Study area

The study area is Lagos State in Nigeria (Figure 1). It is a coastal state, the former capital of Nigeria, and is located between Latitude 6.520 N and Longitude 3.370 E. In terms of administration, the state has 20 Local Government Areas (LGAs), which are subsequently divided into 377 wards. It is Africa's most populous city with an estimated population of 20 million people [32]. It is also the most industrialized of the 36 states in Nigeria and houses 60% of industries in the country [33,34]. The climate is tropical wet and dry with peak rainfall between April and November [34], and annual flood events between July and November [10,35]. Lagos State is the hub of COVID-19 cases in Nigeria. Figure 1 shows the administrative map of Lagos State.

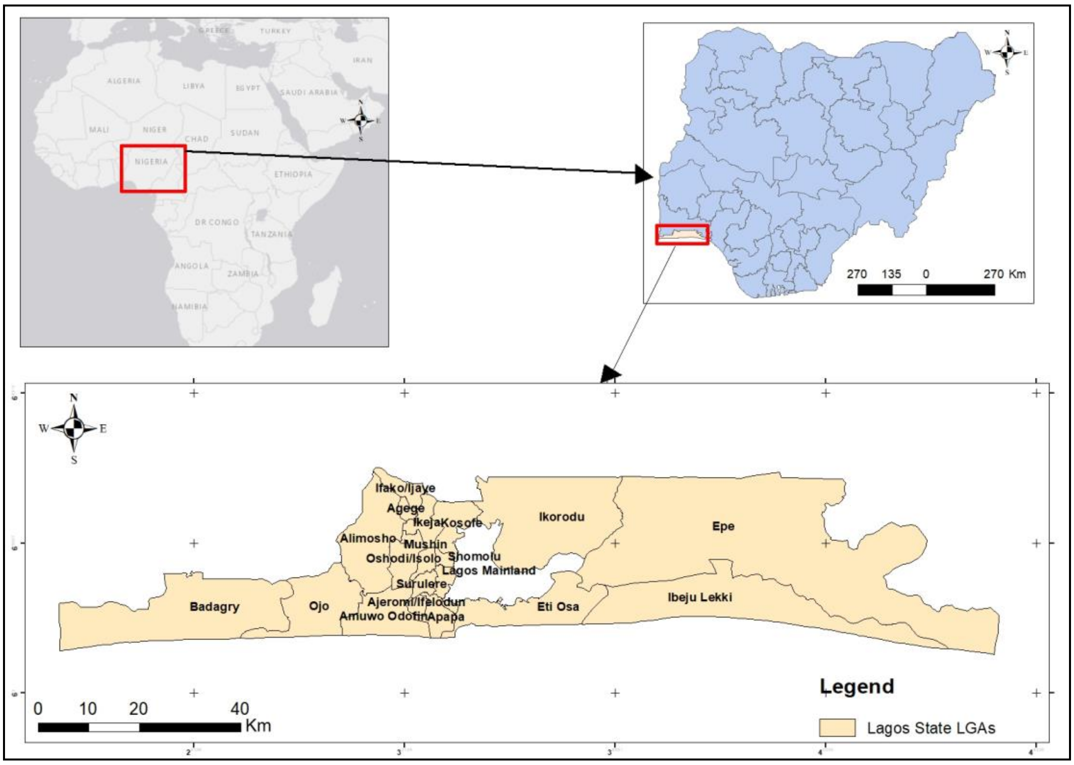

Figure 1. Showing Lagos state and its LGAs.
Source: The authors.

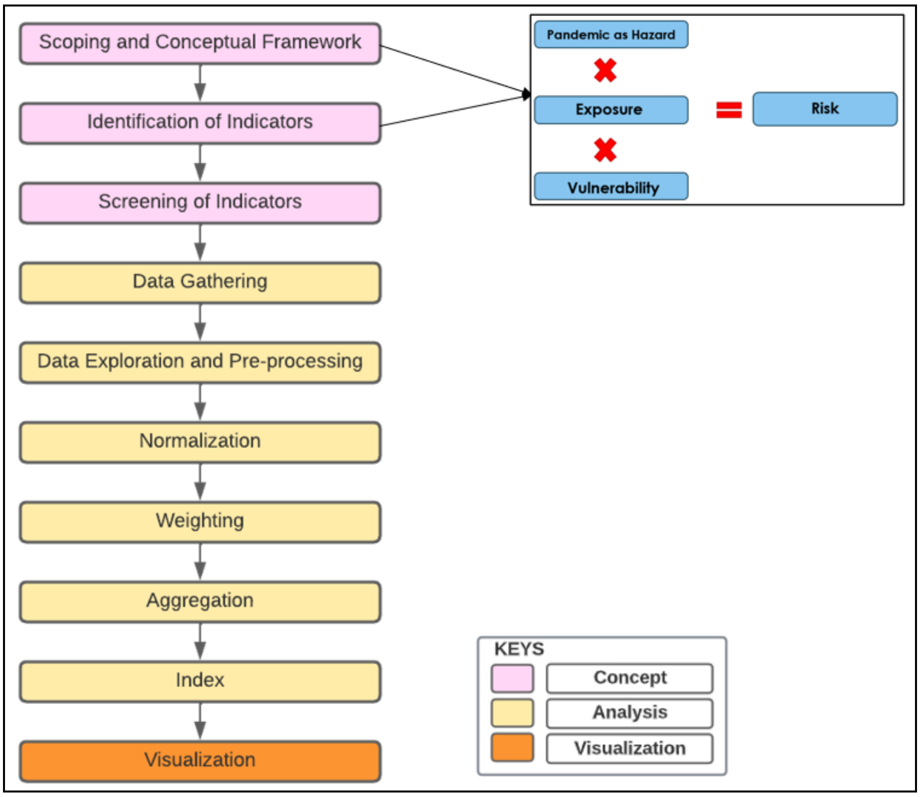

Figure 2. Workflow of methodology and conceptual framework for the COVID-19 risk index construction.
Source: Adapted from GIZ, 2017, OECD, 2008 and IPCC, 2014, 2019.

2.2.1. COVID-19 risk index construction

The first phase, which relates to the first research question (to assess the spatial pattern of COVID-19 risk), employed the indicator-based risk assessment workflow as adapted from [36] and [37] (Figure 2).

Scoping

This involves taking an exploratory lens from the literature on COVID-19 risk. A literature search on the Web of Science database yielded 25 relevant articles. The objective of this scoping was to narrow the topic of investigation to a manageable level that aligns with the existing body of knowledge. The scoping process was guided by the Intergovernmental Panel on Climate Change framing of risk, as explained in section 2.3 below [31] and the guiding questions were: (a) what are the exposed elements to COVID-19 risk? (b) what drives vulnerability and exposure to COVID-19 risk? and (c) what are the consequences of the COVID-19 risk? These guiding questions were also applied to fluvial floods; however, the focus was on COVID-19 risk. The answers to these questions as derived from the 25 reviewed articles gives first-hand information on the kinds of datasets explored in this study.

Table 1. Initial datasets for COVID-19 risk (from drivers to indicators).

S/N	Risk components	Drivers	Indicators	Definition	Format	Source
1	**Vulnerability**	Economic/ financial status	Socioeconomic vulnerability	This shows household socioeconomic status, income, and housing type	Shapefile	GRID3 Nigeria Geoportal (2021)
		Healthcare capacity/ access	Health facilities access	This shows accessibility to and usage of health facilities	Shapefile	GRID3 Nigeria Geoportal (2021)
		Pre-existing disease burden	Co-morbidities	This shows the general health condition of inhabitants	Shapefile	GRID3 Nigeria Geoportal (2021)
		Literacy	Literacy	This raster shows the number of literate people per cell grid	Raster (1 km)	WorldPop (2017)
		Awareness and negligence	Communication access	This shows the households accessibility to Television, radio and other media	Shapefile	GRID3 Nigeria Geoportal (2021)
		Aged population	Proportion of population ≥ 65	Proportion of the population ≥ 65 years per 1,000 inhabitants	Raster (1 km)	WorldPop (2020)
2	**Exposure**	Population, sanitation, housing condition	COVID-19 exposure	This shows population density, proximity to others in the household and access to water, sanitation, and hygiene	Shapefile	GRID3 Nigeria Geoportal (2021)
3	**Hazard**	COVID-19 cases as hazard	Proportion of COVID-19 cases per 1000 population	This shows the number of COVID-19 cases per 1000 population	Excel	Nigeria Center for Disease Control (2021)

Data (gathering, screening, and pre-processing)

The initial datasets for this study (COVID-19 risk) were suggested by the scoping process. That is, from drivers (emanating from literature review) to indicators (real datasets). This process yielded eight initial datasets for COVID-19 risk (Table 1). The scale of analysis of this study is the LGA level as all the datasets were available at this level for Lagos State. Tables 1 show the datasets emanating from the scoping process.

The above datasets in Table 1 were explored and pre-processed. Strikingly, none of the datasets had missing data. Also, to avoid data redundancy and show exceptional vulnerabilities, no outlier was treated. To avoid double-counting of the COVID-19 vulnerability indicators, a Pearson correlation was conducted to test for multicollinearities (Table 2). This process led to the exclusion of communication access data from the COVID-19 vulnerability datasets. This is because access to television, radio, and other communication media (as depicted by communication access data) is strongly dependent on people's financial status.

Table 2. Multicollinearity test (Pearson Correlation) for COVID-19 vulnerability datasets.

Correlations		nga_commun	HFA	SocecoV	Commorb	ABV65prop	LITERACY
nga_commun	Pearson Correlation	1	.179	.857**	-.046	.568**	-.499*
	Sig. (2-tailed)		.450	.000	.846	.009	.025
	N	20	20	20	20	20	20
HFA	Pearson Correlation	.179	1	.309	.263	.106	-.034
	Sig. (2-tailed)	.450		.185	.263	.655	.888
	N	20	20	20	20	20	20
SocecoV	Pearson Correlation	.857**	.309	1	-.020	.392	-.706**
	Sig. (2-tailed)	.000	.185		.933	.088	.001
	N	20	20	20	20	20	20
Commorb	Pearson Correlation	-.046	.263	-.020	1	-.372	-.069
	Sig. (2-tailed)	.846	.263	.933		.107	.773
	N	20	20	20	20	20	20
ABV65prop	Pearson Correlation	.568**	.106	.392	-.372	1	.198
	Sig. (2-tailed)	.009	.655	.088	.107		.402
	N	20	20	20	20	20	20
LITERACY	Pearson Correlation	-.499*	-.034	-.706**	-.069	.198	1
	Sig. (2-tailed)	.025	.888	.001	.773	.402	
	N	20	20	20	20	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Index construction

This sub-section explains the steps involved in constructing the COVID-19 risk index. This includes data normalization, weighting, and aggregation.

Normalization

This was done by applying the [37] and [38] Linear min-max methods. This method transforms the variables into a range of 0 – 1 and is useful in showing exceptional vulnerabilities among the 20 LGAs. Mathematically, it is represented as:

$$V_n = \frac{(v_i - v_{min})}{(v_{max} - v_{\min})} \quad (1)$$

where v_i is the individual data point to be transformed, v_{min} is the lowest value of that indicator, v_{max} is the highest value for that indicator and v_n is the transformed value (new value). All datasets for COVID-19 risk were normalized using this method.

Weighting

Weighting assigns coefficients to the score of the indicators, thus rebalancing their importance to the final index. There are no universal rules for assigning weight [39]. While authors like [40] applied equal weighting, others like [39] applied a weighting system that suited their needs. For this paper, weighting was employed to aggregate the five COVID-19 normalized vulnerability indicators into one COVID-19 vulnerability index. For this purpose, the average weights from literature and experts (participatory weights) were employed. The literature scores (which ranges from 1-5) was assigned by the authors and they represent the importance of the various indicators in contributing to COVID-19 vulnerability (with 1 representing the least important and 5 implying the most important) as was deduced from the reviewed literature. As seen in Table 3, socioeconomic vulnerability is considered by various authors to be most important while other indicators were more or less seen to be of equal importance. The expert scores (ranging from 1-5) emanate from the conducted expert consultation and they represent the importance of the various indicators in contributing to the COVID-19 vulnerability. Three experts, which were accessible and relevant to this study were consulted: a public health professional, an Assistant Professor of medical geography and a development professional. They ranked the indicators in this order: socioeconomic vulnerability, health facility access, comorbidities, literacy and aged population (depicting the most important to least important indicator) (Table 3). The method is justified because the reviewed literature did not consider local peculiarities and the expert list is not very comprehensive. Hence, the average weight emanating from both complement each other. Table 3 shows the weights assigned to the COVID-19 vulnerability indicators.

Table 3. Weighting process applied to aggregate the COVID-19 vulnerability datasets.

Indicators	Literature scores	Expert scores	Literature weight	Expert weight	Average weight
Socioeconomic vulnerability	5	5	0.29	0.33	0.31
Health Facility access	3	4	0.17	0.26	0.22
Comorbodities	3	3	0.17	0.20	0.19
Aged population	3	1	0.17	0.07	0.13
Literacy	3	2	0.17	0.13	0.15
Total	**17**	**15**	**1**	**1**	**1**

Aggregation

Here, the normalized risk components of COVID-19 datasets (hazard, exposure and vulnerability) were combined into one metric, using [38] weighted linear aggregation method:

$$\sum_{i=1}^{n}(w_i * x_i) \quad (2)$$

where w_i is the weight of the index (i) and x_i is the value of the index (i). For the COVID-19 risk index construction, equal weights were assigned to the three risk components. This was done to reflect the IPCC [30,31] risk framework.

Index visualization

The COVID-19 vulnerability, exposure, hazard (representing COVID-19 cases) and risk of Lagos was visualized on maps designed in ArcGIS 10.7.1 environment.

2.2.2. Pattern of Flood Hazard and Flood-Exposed Health Facilities

The phase (second phase) relates to the second and third research questions: to assess the pattern of flood hazards and the implication for flood hazards on the management capacity of COVID-19. Here, flood hazard extent data, obtained from the UNEP Global Risk Data Platform, was entered and mapped in ArcGIS 10.7.1 environment. The description of the flood hazard data is presented in Table 4.

Also, the exposure of healthcare facilities to floods was examined from a geospatial perspective (by overlaying health facilities' shapefile on the flood hazard extent in ArcGIS 10.7.1 environment).

Thereafter, the proportion of flood-exposed health facilities in each LGA was compared with their COVID-19 risk levels, and their implications were discussed. Table 4 shows the description of the flood hazard and health facilities datasets.

Table 4. Datasets for flood hazards and health facilities.

S/N	Datasets	Indicators	Definition	Format	Source
1	Health facilities	Health infrastructures in the study area	This shows the locations of health facilities	Shapefile	GRID3 Nigeria Geoportal (2021)
2	Flood hazard	Flood hazard extent (100 years return period)	This shows the extent and depth of flood	Raster (1 km)	UNEP Global Risk Data Platform (2015)

2.3. Conceptual framework

This paper employed the Intergovernmental Panel on Climate Change – IPCC [30,31] risk framework, which conceptualized risk as a composite of hazard, vulnerability and exposure. The IPCC framework gave equal importance to the three risk components (hazards, vulnerability and exposure) and this is lacking in previous studies [41,42]. In the same vein, the IPCC allows for a more nuanced approach to risk by employing a multiple-lens perspective and deconstructing the natural disaster notion by giving equal importance to the risk components [31,43].

Risk, according to the [30,31] framework (Figure 2), is the potential of harmful consequences resulting from the combined interaction of hazards, exposure, and vulnerability. The hazard here is seen as the possibility of a natural or human-induced event to occur, that may cause loss of life, injury, health impacts, as well as other socioeconomic and environmental losses and damages [30]. Vulnerability is conceptualized as the attributes of a person or group of persons and their situation that influence their capacity to anticipate, cope with, resist and recover from the impacts of a hazard of natural, socio-natural, or anthropogenic origin (adapted from [44]). Exposure, a spatial concept, as adapted from [31], is the presence of people, ecosystem services and functions, livelihoods, and social, environmental, economic, and cultural assets and infrastructures in places that could be adversely affected by hazards of natural, socio-natural or anthropogenic origins.

This framework has been appraised by several authors. For example, [45] appraised this framework for its better contextualization of risk assessments. [46] argued that applying the framework reduces the predisposition of adverse impacts by reducing a system's sensitivity while building its capacity (vulnerability) to adjust from exposure to external stressors (hazards). However, [45] argued that the framework does not individually account for sensitivity and adaptive capacity and this might be a limiting factor for studies emphasizing differential vulnerability.

This framework (Figure 2) guided the scoping and theoretical framing.

3. RESULTS

This section presents the results of this paper.

3.1. COVID-19 risk pattern in Lagos State

This section presents the COVID-19 vulnerability, exposure, hazard, and overall risk in Lagos. This was visualized in four classes (representing low, moderate, high and very high conditions of what they depict) using the quantile classification method in ArcGIS 10.7.1.

Figure 4(b) shows that Badagry, Ibeju Lekki, Epe, Mushin, and Ajeromi LGAs are the most vulnerable (very high) to COVID-19. Ikorodu, Agege, Oshodi, Ojo, and Surulere LGAs are highly vulnerable (high); Amuwo Odofin, Apapa, Lagos Mainland, Shomolu, and Ifako are moderately vulnerable (moderate); while Alimosho, Ikeja, Kosofe, Eti Osa and Lagos Island are the least vulnerable (low) to COVID-19 in Lagos. As visualized in Figure 4(c), Apapa, Lagos Island, Eti Osa, Ibeju Lekki, and Ikorodu LGAs show very high exposure to COVID-19; Badagry, Ojo, Amuwo Odofin, Ajeromi, and Lagos Mainland LGAs shows high exposure; Oshodi, Ikeja, Shomolu, Kosofe, Mushin and Surulere LGAs shows moderate exposure; while Epe, Agege, Ifako, and Alimosho LGAs shows low exposure to COVID-19. As presented in Figure 4(d), Apapa, Eti Osa, Ibeju Lekki, Lagos Mainland, and Mushin have very high COVID-19 cases (or hazard); Ikeja, Kosofe, Shomolu, Amuwo Odofin, and Lagos Island have high COVID-19 cases; Epe, Ikorodu, Alimosho, Oshodi, and Surulere have moderate cases; while Ojo, Badagry, Ifako, Agege, and Ajeromi have low COVID-19 cases.

Applying the IPCC framework [22,24], the result shows very high COVID-19 risk in Apapa, Eti Osa, Ibeju Lekki, Mushin, and Lagos Mainland LGAs; high COVID-19 risk in Ikorodu, Ikeja, Shomolu, Amuwo Odofin and Lagos Island LGAs; moderate COVID-19 risk in Oshodi, Surulere, Ajeromi, Kosofe and Badagry LGAs; and low COVID-19 risk in Ojo, Alimosho, Ifako, Agege and Epe LGAs. This is visualized in Figure 4 (a). Figures 4a-d show the pattern of COVID-19 risk, vulnerability, exposure, and hazard respectively in Lagos.

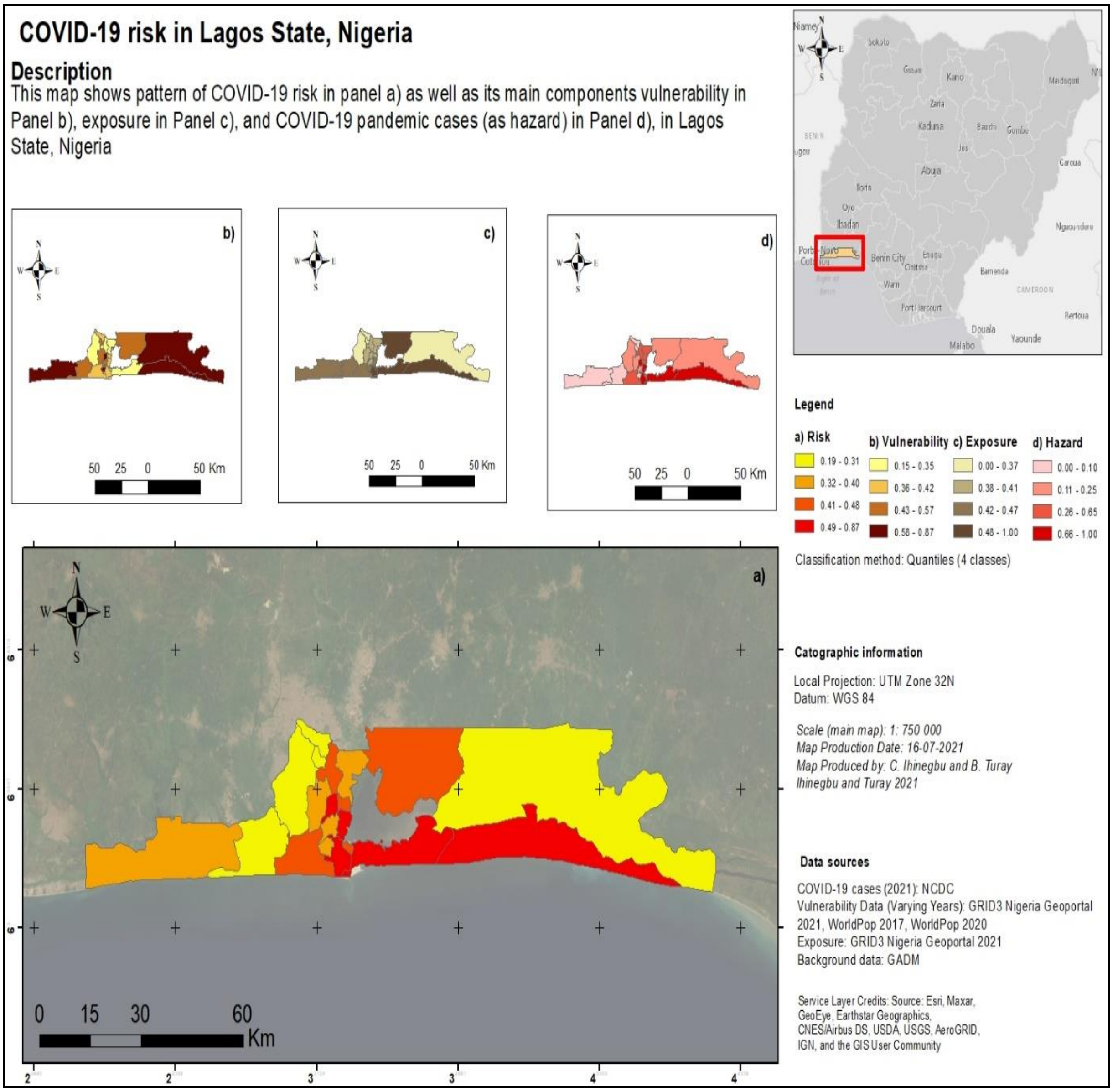

Figure 3. COVID-19 risk, vulnerability, exposure and hazard (cases) pattern in Lagos.
Source: Own processing.

3.2. Flood hazard, flood-exposed health facilities and COVID-19 risk in Lagos State

This section presents the pattern of flood hazards (Figure 5) and the exposure of health facilities to floods in Lagos. It also compares this pattern of flood exposure (of health facilities) with the COVID-19 risk in the state to identify LGAs whose healthcare systems may be overwhelmed or need emergency intervention during the flood peaks in Lagos. Figures 6(a) and 6(b) shows the distribution of health facilities and health facilities exposed to flood in Lagos respectively.

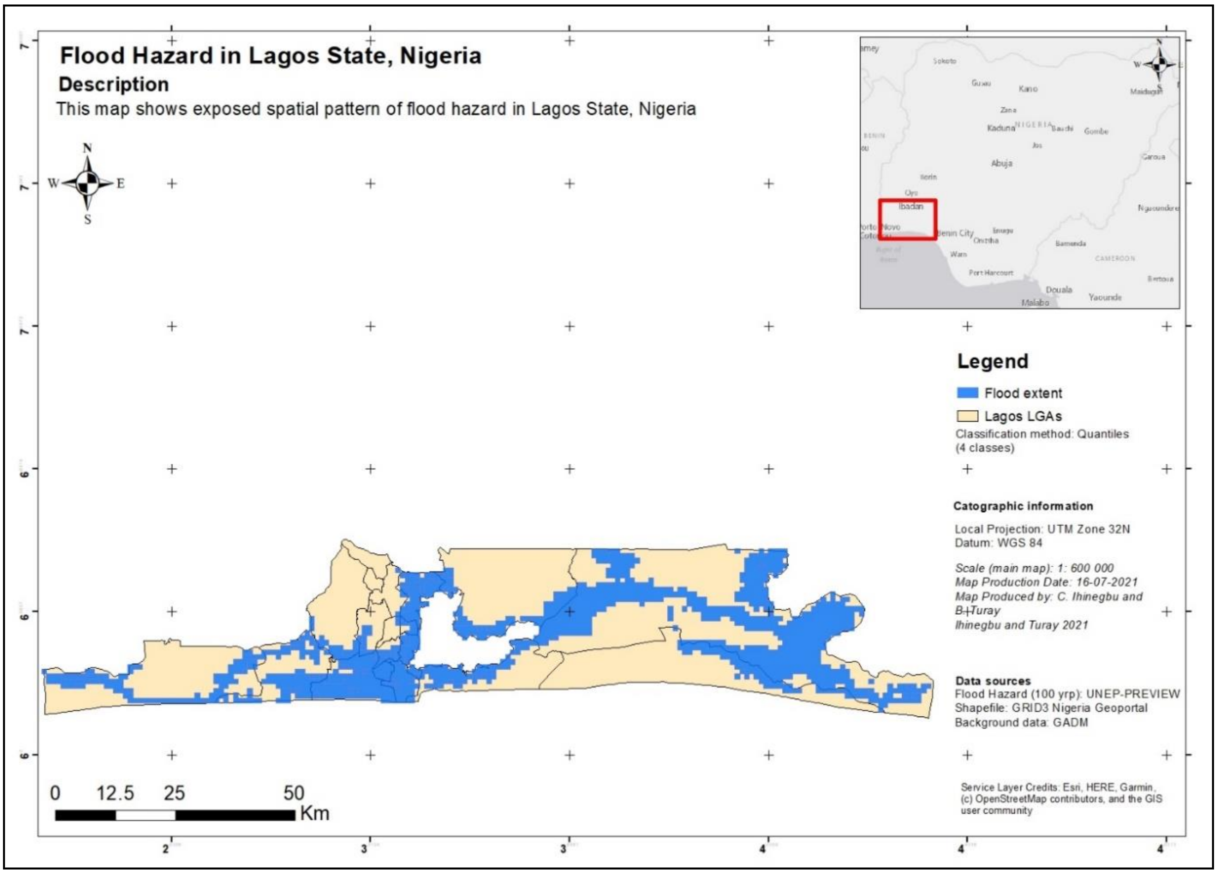

Figure 4. Pattern of Flood Hazard in Lagos State.
Source: Own processing.

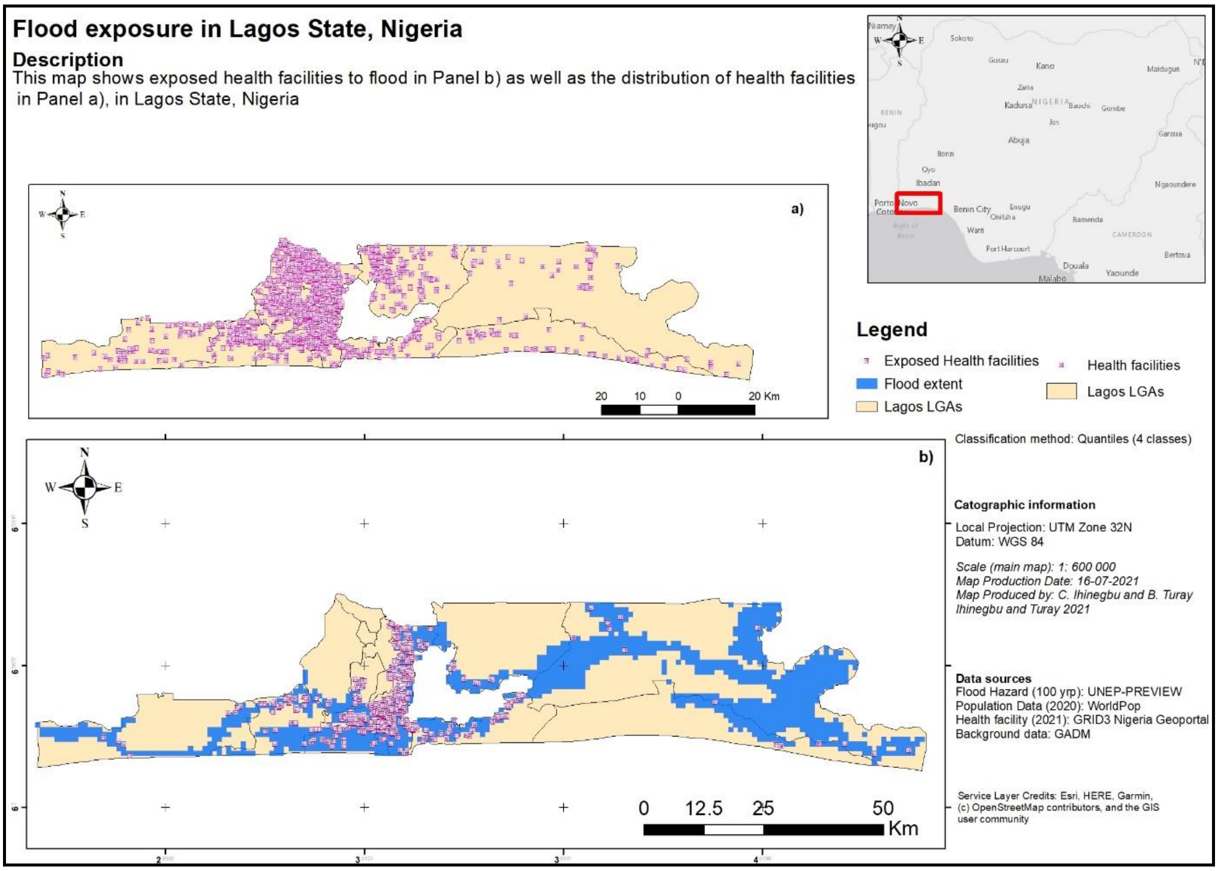

Figure 5. Pattern of health facilities and flood exposed health facilities in Lagos State.
Source: Own processing.

Table 5 compares COVID-19 risk and the pattern of flood-exposed health facilities (HF) in the LGAs and shows the LGAs whose health system may be overwhelmed due to flood exposure. This is important in managing COVID-19 risk in the state as it accounts for coping capacity (in this case, HF is a coping mechanism to fight COVID-19). Also, among the five LGAs with the highest COVID-19 risk index (Table 5), two (Apapa and Lagos mainland) LGAs are relatively at a higher risk because a high percentage of their health facilities are exposed to flood. The implication of this is that these LGAs should be prioritized in COVID-19 management decisions. Six LGAs that should be prioritized (among the 20 LGAs in Lagos) in managing COVID-19 include Apapa, Lagos Mainland, Amuwo Odofin, Lagos Island, Ajeromi and Kosofe. On the other hand, table 5 also revealed that some LGAs with very high COVID-19 risk levels (for example, Eti Osa, Ibeju Lekki and Mushin), may not be overwhelmed. This is because only a few proportions of their HF are exposed to flood.

Table 2. COVID-19 risk and flood-exposed health facilities in Lagos State.

S/N	LGAs	COVID-19 risk level	Total Health Facilities (HF)	Flood exposed HF	Percentage of flood exposed HF
1	Apapa	Very high	58	58	100
2	Eti Osa	Very high	92	53	58
3	Ibeju Lekki	Very high	51	4	8
4	Lagos Mainland	Very high	95	88	93
5	Mushin	Very high	121	15	12
6	Amuwo Odofin	High	102	90	88
7	Ikeja	High	163	6	4
8	Ikorodu	High	188	11	6
9	Lagos Island	High	61	58	95
10	Shomolu	High	79	61	77
11	Ajeromi	Moderate	80	80	100
12	Badagry	Moderate	85	8	9
13	Kosofe	Moderate	163	147	90
14	Oshodi	Moderate	189	23	12
15	Surulere	Moderate	176	92	52
16	Alimosho	Low	215	4	2
17	Agege	Low	80	-	-
18	Epe	Low	47	10	21
19	Ifako	Low	122	-	-
20	Ojo	Low	153	42	27

Key	
	LGAs with high exposure of HF to flood and should be prioritized in managing COVID-19

4. DISCUSSION

This study assessed fluvial flooding amid the COVID-19 pandemic in Lagos and revealed the hotspots of COVID-19 risk using the IPCC [30,31] lens. Our findings agree with scholars [44,47] that called for the shift from the hazard-focused narrative to a holistic one that accounts for vulnerability, exposure and hazard. The study went further to reveal LGAs whose health facilities may be overwhelmed due to their exposure to floods amid a pandemic. We argue that disaster risk reduction or assessment efforts should go beyond the hazard-exposure-vulnerability spectrum to include coping capacity (in our case study, health facilities) as people have differential shock-absorbing capacities [48,49].

Having a higher number of lab-confirmed COVID-19 cases is not immediately interpreted as being at risk unless this higher number of cases coincides with a socio-economic, medically vulnerable, and exposed population [31,50]. In this sense, the relatively higher population densities in Apapa, Osa, Ibeju Lekki, Mushin, and Lagos Mainland explain the higher possibility of person-to-person contact. Such a condition determines the exposure of individuals to the virus. When combined with the relatively higher number of over-60-year-old people, higher comorbidity, lower household income, poorer housing conditions, and other socioeconomic features, they put the population of the named LGAs at a very high risk of COVID-19, compared to the population of the other LGAs in the state [51,52]. These results are in agreement with our findings, as shown in Figures 3a-d.

The Lagos State Emergency Management Agency in 2021 identified Agege, Ifako Ijaye, Ikeja, Mushin, Oshodi, Ikorodu, and Epe LGAs to be at a relatively lower risk and exposure to flooding [53] and this aligns with the findings of this study. The flood circumstances in Apapa, Lagos Mainland, Amuwo Odofin, Lagos Island, Ajeromi, and Kosofe, mainly due to their low-lying topographies and unplanned spaces, are exposing and endangering the inadequate healthcare equipment and buildings to harm, subjecting health personnel working in such facilities to increasing difficulties in managing the rising spread of the virus [53–57]. Similar to our findings, studies on flooding and health implications have previously shown the increased complications of dealing with healthcare emergencies amid flooding in the LGAs of Ajeromi-Ifelodun and Lagos Island [58,59].

As a limitation, it is acknowledged that the experts' list used in weighting the COVID-19 vulnerability indicators was not comprehensive and may be subjective. However, the literature opinion/scores were used to adjust for this limitation. This paper is relevant to urban sustainability research in Lagos as it assessed flood hazard (a climatic hazard) and its impact on a pandemic (in this case, undermining the potential of managing COVID-19), and by so doing, agrees that indeed, risk and hazards are sometimes interconnected [1,2].

Future research on this subject should look at whether households in the areas are preparing to adapt to future flood and COVID-19 conditions, or any other combined hazards of a similar nature, make recommendations and take practical actions following such investigations. Efforts should also be made to develop an LGA-specific flood evacuation and humanitarian response plan from a multi-disciplinary perspective.

5. CONCLUSSIONS

This study, which assesses flood hazard amid a COVID-19 pandemic, has revealed how floods may potentially undermine the management capacities of COVID-19, taking into account the exposure and vulnerability to COVID-19. Such knowledge is critical in understanding how flood hazards may impede COVID-19 management, particularly at this time when the State is struggling with both catastrophes. With the revelation of the hotspots of flood-exposed health facilities and the COVID-19 cases, this paper becomes critical and timely for disaster managers and humanitarian responders.

Following the results of this analysis, it is recommended that hotspots (for both flood-exposed health facilities and COVID-19) should be the major focus of humanitarian aid and Disaster Risk Reduction (DRR) strategies. Also, government policies should be geared toward addressing socio-economic vulnerabilities. Extreme efforts should be made to address flood hazards in the State. Healthcare infrastructure should be removed from highly flood-exposed areas where possible. If relocation to a less exposed terrain is not an option, they should be renovated or rebuilt to modern standards that are designed to minimize flood damage. Universal health and property insurance which is lacking in the state should be initiated and made affordable by the government to reduce the impacts of floods and disease outbreaks in the flood and COVID-19 hotspots (Table 5). These measures would contribute to achieving sustainable health and flood resilience in Lagos.

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