Research Paper

Household levels of deprivation to WaSH and residential conditions in slum settlements of Lagos, Nigeria

Isaiah Sewanu Akoteyon, Ibrahim Rotimi Aliu and Olayemi Soladoye IWA

ABSTRACT

Household levels of deprivation to water, sanitation, and hygiene (WaSH) and residential conditions in slum settlements of Lagos, Nigeria were assessed and mapped using slum deprivation index (SDI). A structured questionnaire was administered to 1,398 households in 16 settlements using a random sampling method. Descriptive statistics and SDI were employed to analyze the data while ArcMap was used to map the patterns of SDI. The results show that households live in poor dwelling conditions with limited access to WaSH facilities. The SDI indicates that 18.7% of the slums are highly deprived. Based on WaSH and dwelling and physical environment (DPE) components, 18.75 and 31.25% of the slums are highly deprived. Water, sanitation, and hygiene indicators show that 37.5, 12.5, and 56.25% of the slums are highly deprived respectively. About 50, 37.5, 43.75, and 31.25% of the slum are highly deprived based on dwelling, waste disposal, waste pile, and stagnant water respectively. The study concluded that six settlements live in deplorable WaSH and DPE conditions. The study recommends urgent intervention for planning and resources allocation, and sustained urban renewal programs at Oko-Baba, Ilaje, Oko-Agbon, Abule-Nla, and Badia for improved WaSH and living conditions for sustainable service delivery and healthy slum settlements.

Key words | environmental conditions, residential conditions, slum, slum deprivation index, sustainable development WaSH

Isaiah Sewanu Akoteyon (corresponding author)
Ibrahim Rotimi Aliu
Olayemi Soladoye IWA
Department of Geography and Planning,
Lagos State University,
Ojo, Lagos,
Nigeria
E-mail: isaiah.akoteyon@lasu.edu.ng

HIGHLIGHTS

- Deprivation index helps in exposing social and environmental deficiencies in society.
- Slum exhibits poor dwelling with poor access to WaSH and residential conditions.
- Spatial patterns of social and environmental conditions enhance easy information dissemination.
- Overall SDI indicates a quarter of the slums are in highly deprived conditions.
- Adequate social amenities and efficient planning enhance healthy slum settlements.

INTRODUCTION

The rate of population growth in developing countries has witnessed a rapid increase over the years. The annual population growth rate in developing countries is estimated at 2% compared to 0.5% in developed countries (Mahabir et al. 2016). Mahabir et al. (2016) argued that the growth of slums could be influenced by several factors such as choice of location, rural-urban migration, poor urban governance, and ill-designed policies. Available statistics show

that approximately one billion people live in slums, with the majority residing in developing countries. This figure represents about 30% of their urban population (UN 2015). The rise in slum settlements poses a significant challenge to planners and policymakers in developing regions due to the series of problems such overcrowding, poor housing conditions, extreme poverty, and lack of land or property tenure, lack of health care services and infrastructure, insecurity, insufficient living area, inadequate access to improved water and sanitation services, among others (Mahabir et al. 2016). Globally, about 2.2 billion people around the world lack safe drinking water, while approximately 4.2 billion and three billion people around the world lack safe sanitation basic handwashing facilities, respectively (WHO/UNICEF 2019).

The majority of these people, especially women and children, are highly exposed to sanitary related infections and diseases (Corburn & Hildebrand 2015). The poor condition of access to water, sanitation, and hygiene in slum settlements constitute what is known as the 'silent humanitarian crisis' (Bartram et al. 2005).

The concept of the slum deprivation index (SDI)

The term 'deprivation' indicates a state of observable and demonstrable disadvantage relative to the local community or the larger society to which an individual belongs (Salmond & Crampton 2012). Deprivation can also be defined as a composite term used to depict degrees of lack of access to social and environmental amenities in a given neighborhood (Butler et al. 2013). Deprivation can exist in various forms like material deprivation such as goods, services, resources, amenities, physical environment, among others. We applied the SDI in our study because it serves as a valuable tool that has the capability of combining many indicators in exposing the slum residents' deprivation than individual indicators (Jeyakumar & Ghugre 2017). Therefore, SDI is a superior measure of deprivation at the community level that offers much specificity with more details and enhanced quantification for a larger range of dimensions. The SDI was adopted due to its simplicity, suitability, and relevance in this study that will assist policymakers in identifying areas to which access to social and environmental amenities could be allocated for improved service delivery and policy

decisions on how and where to target renewal programs within the general slum settlement.

Several deprivation indices have been developed to assist with resource allocation in the water, health, housing, and other social services sectors. For example, the area-based deprivation indices developed by Townsend (1987) for measuring social disadvantages of urban areas, similarly, the index of multiple deprivations (IMD) (Townsend et al. 1988; Carstairs & Morris 1991). These deprivation indices have been employed in different parts of the world. For instance, in New Zealand (Salmond et al. 1998), Spain (Benach et al. 2003), Belgium (Lorant 2000), Canada (Pampalon et al. 2009), Italy (Cesaroni et al. 2006), the United States (Messer et al. 2006), Japan (Fukuda et al. 2007), Accra (Weeks et al. 2007), Nairobi and Dakar (Gulyani et al. 2014) and India (Patel et al. 2014).

Similar methodologies include the slum condition index (SCI) (UNDP 1992), slum severity index (SSI) (Sajjad 2014; Okoye et al. 2017) and basic services deprivation score (BSDS) which is comprised of variables that affect health, e.g. access to piped water, latrines, solid waste disposal, schools, and health (Nolan et al. 2017). Others include the index of adequacy (IA) that incorporates four indicators of slum conditions (Tramontina 2017), socio-economic opportunity index (SEOI) which is comprised of four variables namely; health, education, income, and housing (Ahmed & Mustafa 2016) and relative approach index (RAI) (Singh & Hiremath 2010) among others. These methodologies were developed for a better understanding of inequalities and social deprivation in material and environmental amenities in the wider society or nation to which an individual, family, or group belongs (Eibner & Sturm 2006; Shaban & Sharma 2007; Ayeni & Soneye 2011).

While most of these studies have employed the combination of descriptive statistics and multivariate statistical analysis alongside SDI, there exists scanty literature on mapping the pattern of SDI across geographic locations in slum settlements for easy information dissemination to the public and the relevant stakeholders. This study, therefore, seeks to assess and map household levels of deprivation to WaSH and residential conditions in slum settlements in parts of Lagos, Nigeria, using SDI with a view to assisting policymakers in identifying areas to which access to social and environmental amenities could be allocated for improved service delivery

and policy decisions on how and where to target renewal programs that will guarantee a healthy slum neighborhood.

Study area

The study area comprised of five Local Government Areas (LGAs) namely Ajeromi/Ifelodun, Apapa, Lagos Mainland, Mushin, and Shomolu LGAs in Lagos State. The area is located between longitude 3°21′0E and 3°25′45′N and latitudes 6°25′30′N and 6°30′15N. The site is bound on the east/south by Lagos Lagoon, in the north by Ikeja and Kosofe LGAs while Amuwo-Odofin and Oshodi/Isolo LGAs forms its western boundary (Figure 1).

The area is characterized by a tropical climate. The average daily temperature is 30 °C, while the annual mean rainfall is 1,532 mm (Odumosu *et al.* 1999). The two main seasons are the dry season which spans between November and March and the wet season between April and October (Adetoyinbo & Babatunde 2010). The dominant vegetation is tropical swamp forests (freshwater/mangrove swamp forests and dry lowland rain forests). The river network system is dominated by lagoons which account for about 22% of the state's total landmass. The catchment area is drained by the rivers Ogun, Osun, and Yewa. The population is about 2,272,428 people (NPC 2006). Before the urban renewal programs in Lagos state, there were approximately 42 slums or blighted settlements across the metropolitan area of the state that required urgent attention for the provision of basic WaSH facilities.

Previous slum renewal activities in the area have suffered many setbacks due to lack of measure of deprivation and poor policy implementation. Hence, the slum renewal program has not been able to address the problems of poor access to water, sanitation, and hygiene facilities. This study will assist

Figure 1 │ The study area.

policymakers in identifying areas to which access to social and environmental amenities could be allocated for improved service delivery and policy decisions on how and where to target renewal programs within the general slum settlement.

METHODOLOGY

Study design and sample size determination

The present study assessed and mapped household levels of deprivation to WaSH and residential conditions using SDI in slum settlements of Lagos, Nigeria. In order to achieve this, a stratified systematic sampling technique was designed across five LGAs to administer structured survey questionnaires to household heads in 16 slum settlements. The survey was aimed at eliciting information on household access to water supply sources, sanitation and hygiene facilities, and the level of deprivation in social and environmental amenities. A total sample size of 1,500 was designed to yield a representative sample for the population of the study area. However, 1,398 (93.2%) questionnaires were recovered for the final analysis, as presented in Table 1. Yamane (1973) formula was adopted in determining the sample size using Equation (1):

$$n = N/1 + N(e)2 \tag{1}$$

where n = the sample size, N = the finite population, e = level of significance (or limit of tolerable error) (0.05) and 1 = unity (a constant).

Validity and reliability of the instrument

The validity of the questionnaire was ascertained to determine its consistency and accuracy with the stated objectives of the study (see Appendix 1). A pre-field test of the instrument was conducted among 50 households in July 2016. Data from the pilot survey were analyzed using Cronbach alpha to determine the reliability of the instrument.

Sampling technique and data collection

A purposive sampling method was adopted to select 16 settlements based on their unique attributes which depict

Table 1 | Distribution of questionnaires across the settlements

S/N	LGAs	Settlements	No. of questionnaire	Overall population/zone
1	Ajeromi-Ifelodun	Ago-Hausa	84	331
2		Mosafejo	83	
3		Amukoko	83	
4		Olodan	81	
5	Apapa	Badia	83	167
6		Ijora	84	
7	Lagos Mainland	Otto	83	502
8		Oko-Baba	83	
9		Makoko	85	
10		Oko-Agbon	82	
11		Pedro	82	
12		Abule-Nla	87	
13	Mushin	Idi-Araba	167	167
14	Shomolu	Bariga	64	231
15		Abule-Ijesa	82	
16		Ilaje	85	
Total			1,398	1,398

Source: Author's fieldwork (2016).

slum conditions. A total of 167 questionnaires were administered at Idia-Araba because of the areal size and nature of the population density compared to other slum settlements which are relatively smaller in size (Fadare & Olawuni 2008). The social survey was conducted between August and September 2016 to elicit information on household access to water, sanitation, and hygiene in the study area.

Data analysis and mapping techniques

Data generated from the social survey were coded and input into the IBM Statistical Package for Social Sciences (SPSS) version 22 software. Frequency and percentages were employed to describe access to WaSH and DPE attributes while SDI was applied to determine the level of deprivation of household to WaSH and DPE amenities. An ArcGIS software version 10.3 was used to map the patterns of SDI using a proportional statistical technique. A two-point scale measure was used to code WaSH variables (0 = no access and 1 = access). The DPE variables were measured on a scale of four points as 1 = single room, 2 = room and

parlor, $3 =$ flat and $4 =$ duplex for dwelling type. The total number of residents per dwelling was measured as a continuous scale. The physical environment (presence of stagnant water and waste pile) and place for handwashing was measured as no $= 0$, yes $= 1$. In contrast, waste disposal method was measured on a scale of eight point as No response $= 0$, burning $= 1$, burying $= 2$, dumping in the river/drain $= 3$, dumping along the road side $= 4$, through accredited garbage truck vendor $= 5$, dumping in Lagos State Waste Management Agency (LAWMA) depot $= 6$ and through Private Sector Partnership (PSP) $= 7$.

Sources of water supply were measured on a scale of 10 points as borehole $= 1$, public standpipe $= 2$, piped public tap $= 3$, protected dug well $= 4$, open dug well $= 5$, rainwater $= 6$, water vendor $= 7$, bottled water $= 8$, sachet water $= 9$ and stream $= 10$. Sources of sanitation facility were measured on a scale of 11 points as connection to a public sewer $= 1$, connection to septic system $= 2$, pour-flush latrine $= 3$, simple pit latrine $= 4$, ventilated improved pit latrine $= 5$, public or shared latrine $= 6$, open-pit latrine $= 7$, bucket latrine $= 8$, pour-flush latrine without connection $= 9$, surface water $= 10$, and open space $= 11$. The material(s) for handwashing was measured on a scale of four points as water only $= 1$, soap with water $= 2$, sanitizer $= 3$, and disinfectant $= 4$.

Waste disposal methods, sources of water/sanitation facilities, and material for handwashing were all transformed into binary measures as no access $= 0$, access $= 1$. For example, options, 0–4 were regarded as no access while options 5–7 represents access for waste disposal method. For water and sanitation, all unimproved sources of water and sanitation facilities were considered as no access while the improved source indicates access to those amenities. Regarding materials for handwashing, option 1 represents no access while options 2–4 indicate access based on the WHO & UNICEF (2014) benchmark for the definitions of access to improved water, sanitation, and hygiene. All the DPE and WaSH variables were used to compute the SDI in the study area.

Computation of SDI

The SDI was adopted to examine the level of deprivation in WaSH and DPE conditions of slum dwellers, see Tables A1–A3 in the supplementary data. The SDI comprised of two major components, as indicated in Table 2.

Table 2 | Variables for assessing SDI in the study area

S/N	SDI component	Variables	Options
1	WaSH	Water	Unimproved source (open dug well, water vendor bottled water, sachet water, and stream) Improved sources (piped public tap, public standpipe, borehole, protected dug well and rainwater)
		Sanitation	Unimproved sanitation facilities (public or shared latrine, open-pit latrine, bucket latrine, pour-flush latrine without connection, surface water, and open space) Improved sanitation facilities (connection to a public sewer, connection to a septic system, pour-flush latrine, simple pit latrine, and ventilated improved pit latrine)
		Hygiene	A place for handwashing Material for washing hand
2	DPE	Dwelling type	Housing unit types Total number of residents per dwelling
		Physical Environment	Presence of stagnant or sewage water near dwelling Presence of solid waste piles near dwelling Availability of waste bin in household Type of waste bin Method of waste disposal

Source: Author's fieldwork (2016).

Six steps were involved in the computation of the SDI. The first step begins with the estimation of the absolute variation in performance (AVP) which indicates the difference between the highest and the lowest proportion of residents that lack a service variable on each of the DPE and WaSH components across a settlement, as indicated in Equation (2):

$$AVP = max \ X_{ijk} - X_{ijk} \qquad (2)$$

where $AVP =$ absolute variation in performance; $X_{ijk} =$ score on a variable (1, 2, 3 …) in different locations; $Max \ X_{ijk} =$ maximum variable score in a location.

To compare the performances across the settlements, we juxtapose a variable score in a settlement with the settlement that has the highest performance, which represents the total variation in performance among the settlement on each component. The total variation in performance (TVP) is therefore represented by Equation (3):

$$TVP = max\ X_{ijk} - min\ X_{ijk} \tag{3}$$

where TVP = total variation in performance; $Min\ X_{ijk}$ = minimum score on a particular variable. Based on Equations (1) and (2), the SDI was obtained as presented in Equation (4):

$$\text{Component SDI} = \frac{\sum Max\ X_{ijk} - X_{ijk}}{Max\ \sum X_{ijk} - min\ X_{ijk}} \tag{4}$$

The SDI equation's numerator measures the difference between variable performance in a slum settlement and the least performing settlement. In contrast, the denominator measures the total variation in the value of the worst-performing slum settlement and the least performing settlement.

The SDI stated in Equation (4) is a version by Sajjad (2014) (when negative indicators are employed) while an alternative method is given by Equation (5) when positive indicators are employed:

$$\text{Component SDI} = \frac{\sum X_{ijk} - min\ X_{ijk}}{Max\ \sum X_{ijk} - min\ X_{ijk}} \tag{5}$$

In this study, both Equations (4) and (5) were employed. The aggregate SDI was estimated by simply summing up the component SDIs and dividing the sum by the number of components, as indicated in Equation (6):

$$\text{Aggregate SDI} = \frac{\sum SDI_{ijk}}{\sum \pi} \tag{6}$$

where SDI_{ijk} = sum of SDI for each variable, component, and location; π = the number of components.

The SDI value ranges from 0.0 to 1.0. The most deprived slum settlement has a value of 1 while the least deprived has a value of 0. Hence, the lower the SDI value, the less the level of deprivation, and the higher the SDI value, the more the level of deprivation. Based on the SDI values, the 16 settlements were grouped into three categories, according to Sajjad (2014) classification scheme. However, we modified the classification scheme into three groups to accommodate the median group in order to prevent over or under classification. The classification schemes are: less deprived slum (0–0.49), fairly deprived slum (0.50–0.74) and highly deprived slum (0.75–1.0).

Ethical consideration

Standard protocols were followed with approval from the ethics committee of the University. The consent of the respondents was sought and was assured of their anonymity and confidentiality for participating in the survey.

RESULTS

Access to DPE and WaSH in the study area

Dwelling and physical environment

The results of the dwelling type shows that nearly 80.0% of the residents lived in a one-room apartment, while 16.5% lived in a room-parlour apartment and 3.9% lived in flat dwelling units. As expected, less than 1% of the residents lived in duplex dwelling units, see Appendix 2 of the supplementary data. The descriptive statistics of the environmental conditions indicate that approximately 55.0% of the households had stagnant water around their dwellings. In comparison, the remaining 45.0% were devoid of stagnant water around their dwellings, see Appendix 2 of the supplementary data. Household method of waste disposal shows that 57.5% employed proper waste disposal methods through the PSP operators while the remaining 42.5% improperly disposed of their waste. Approximately 47.5% of the households had solid waste piles around their dwellings, see Appendix 2 of the supplementary data.

Water, sanitation and hygiene conditions

The dominant source of water in the study area is borehole representing 39.8%, while the least is protected dug well

accounting for 0.5%, see Appendix 2 of the supplementary data. Regarding sanitation facilities, the results indicate that 26.5% depend on surface water defecation. In comparison, the least sanitation facility used by the household is a ventilated improved pit latrine, representing 0.6% in the study area. Concerning hygiene practice, only 8% engaged in handwashing, while the majority (92%) do not practice handwashing in the study area, see Appendix 2 of the supplementary data.

Slum deprivation index

Overall computed SDI

The overall computed SDI of the study area varies from 0.23 to 0.84 with about 18.7, 43.8 and 37.5% of the settlements classified as highly, fairly, and less deprived slums, respectively. The worst SDI was recorded at Oko-Baba while Idi-Araba has the

least SDI in the study area (see Table A1 in the supplementary data for detailed computation).

WaSH indicators

The computed WaSH component of the SDI shows that it varies from 0.35 to 0.86. About 18.75, 37.5 and 43.75% of the settlements were highly, fairly, and less deprived respectively. Oko-Baba recorded the worst SDI for WaSH while the least was obtained at Ago-Hausa. (see Table A2 in the supplementary data). Regarding the water indicator of the SDI, the results range from 0.0 to 1.0 with about 37.5, 18.75, and 43.75% of the settlements categorized as a high, fair, and less deprived slum, respectively. Abule-Nla recorded the worst water indicator while the least was obtained at Olodan (Figure 2), see Table A2 in the supplementary file for detailed computation. The sanitation
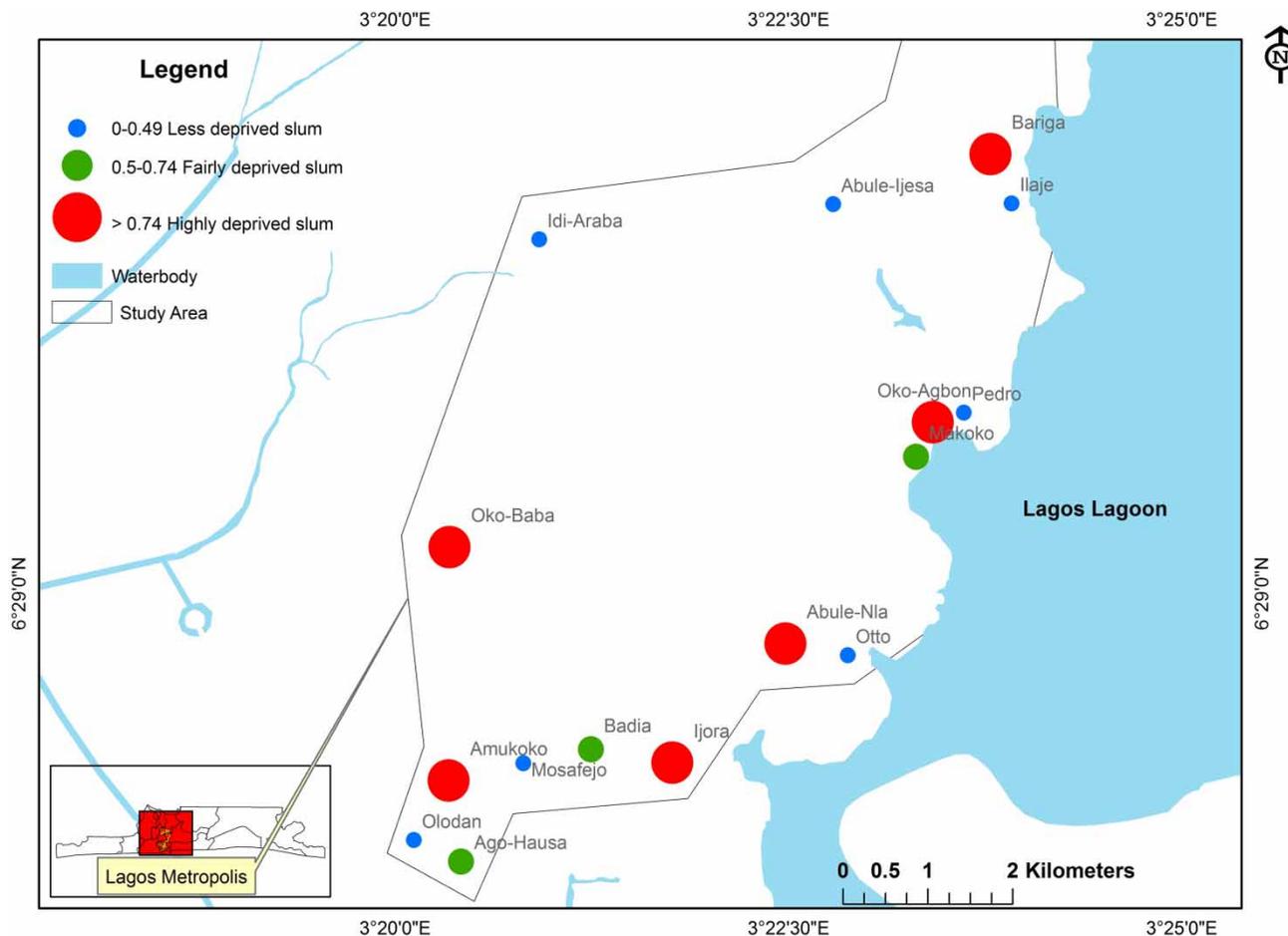

Figure 2 | Water indicator of the slum deprivation index.

indicator of the SDI varies from 0.0 to 1.0 with approximately 12.5, 18.75, and 68.75% of the slum settlements representing highly, fairly, and less deprived slum respectively (Figure 3). The worst sanitation indicator of the SDI was obtained at Oko-Baba while the least was obtained at Ijora, see Table A3 in the supplementary data for detailed computation. Regarding the hygiene indicator of the SDI, it ranges from 0.0 to 1.0 with about 56.25, 37.5, and 6.25% indicating highly, fairly, and less deprived slum respectively (Figure 4), see Table A3 in the supplementary data for detailed computation. The worst hygiene indicator was recorded at Oko-Agbon, while Ago-Hausa has the least.

DPE indicators

The results of the computed DPE component of the SDI shows that it varies from 0.07 to 0.83 with approximately

31.25% each of the settlements indicating highly and fairly deprived slum respectively. About 37.5% were categorized as a less deprived slum in the study area, see Table A4 in the supplementary data for detailed computation. The results of the dwelling indicator of the SDI varies from 0.0 to 1.0 with about 50, 6.25, and 43.75% of the settlements classified as highly, fairly, and less deprived slum respectively in the study area (Figure 5). Badia and Idi-Araba have the worst and least SDI, respectively, in the study area.

The waste disposal indicators of the SDI range between 0.0 and 1.0 with about 37.5% of the settlements each representing highly and less deprived slum while 25% are grouped as fairly deprived slum (Figure 6). Ilaje and Abule-Ijesa recorded the worst and least SDI, respectively, in the study area. Concerning the waste pile indicator of the SDI, it varies between 0.0 and 1.0 with about 43.75, 31.25, and 25% of the settlements classified as highly,
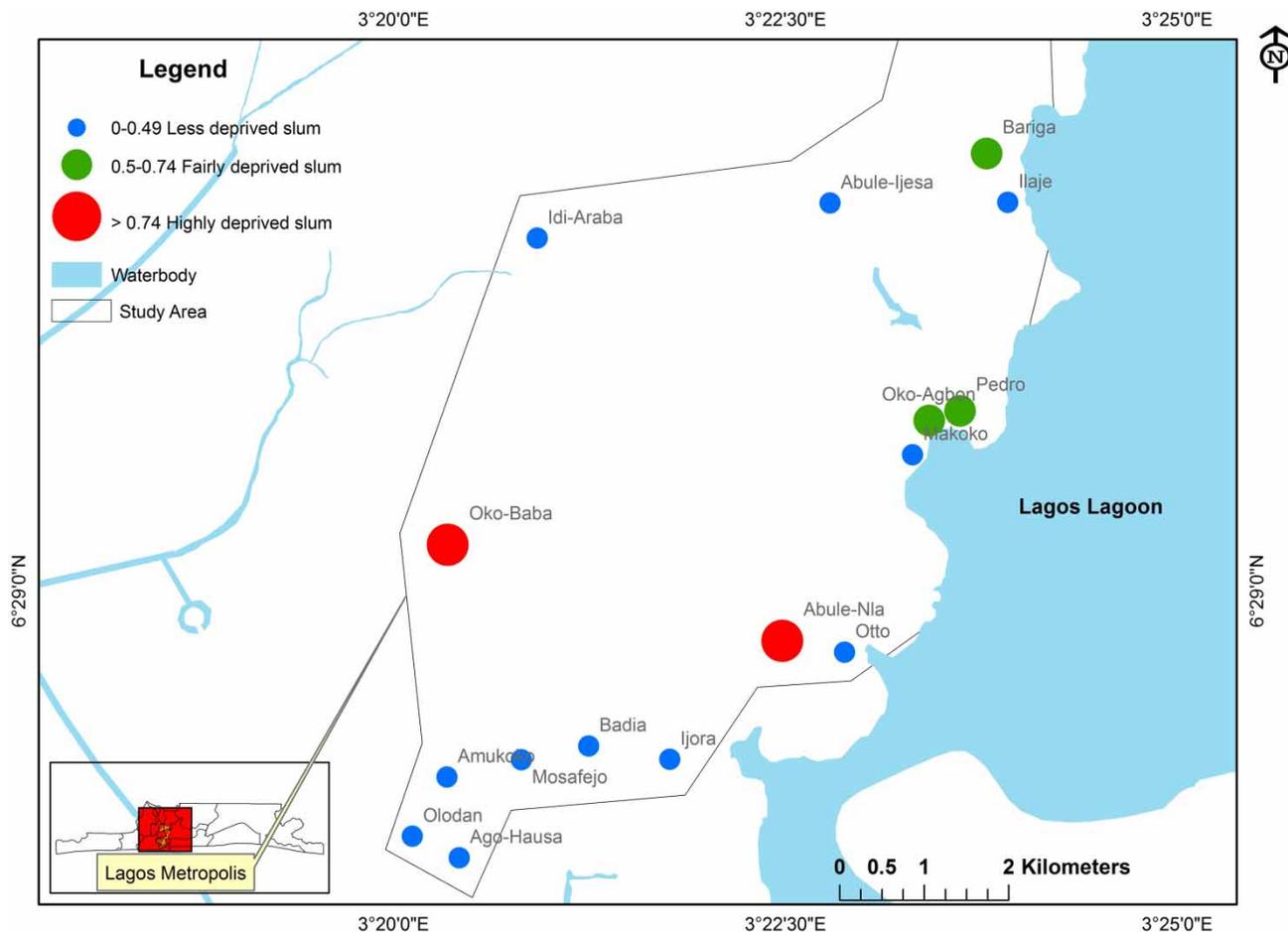

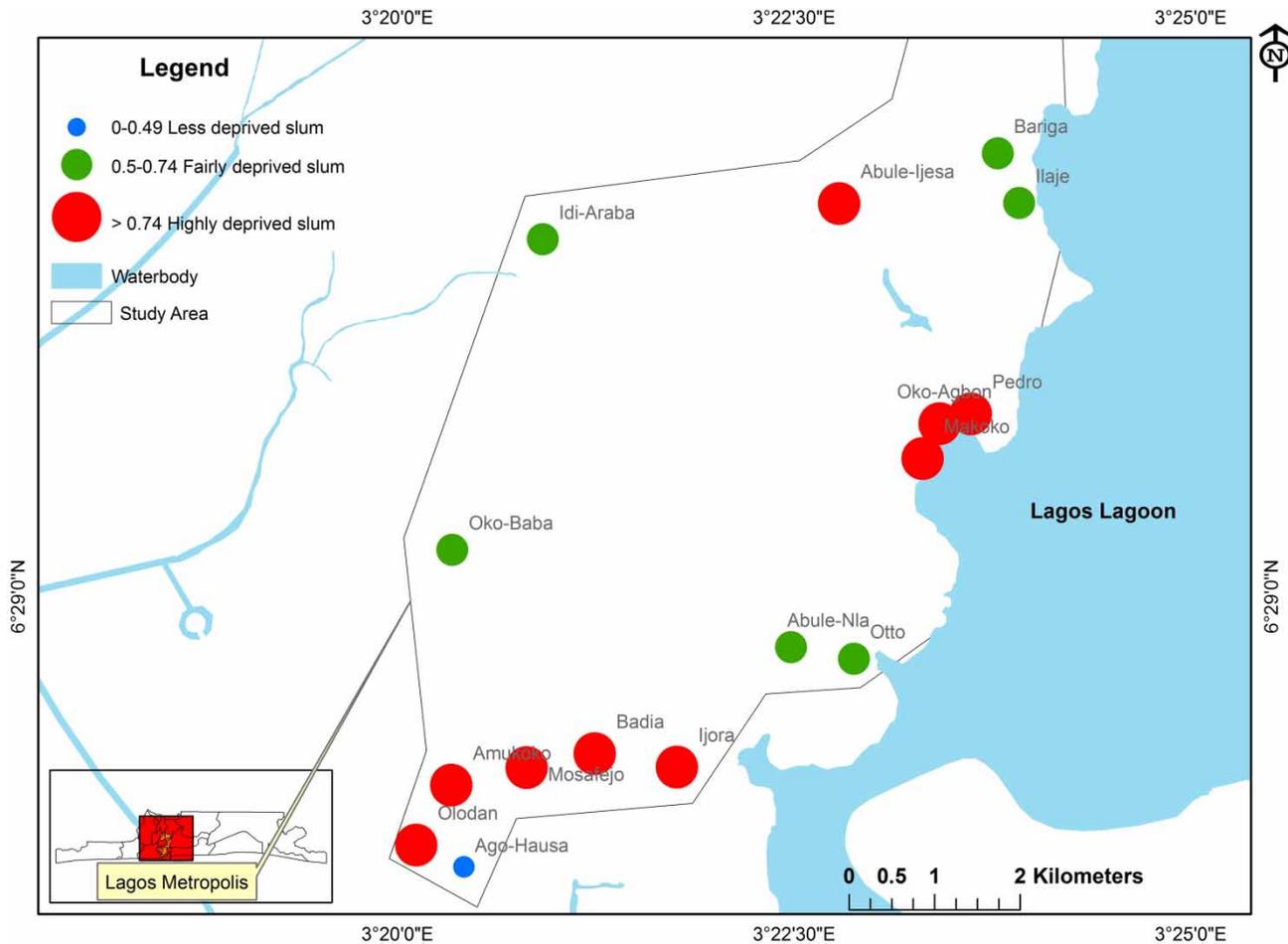**Figure 3** │ Sanitation indicator of the slum deprivation index.

Figure 4 | Hygiene indicator of the slum deprivation index.

fairly, and less deprived slum respectively in the study area (Figure 7). The worst SDI was recorded at Ilaje, while Abule-Ijesa has the least. Regarding the stagnant water indicator of the SDI, it ranged between 0.0 and 1.0 indicating 31.25, 18.75 and 50% of the settlements are highly, fairly, and less deprived slum respectively. The worst SDI was recorded at Ilaje while Abule-Ijesa has the least (Figure 8).

Policy implications of the study

The study has potential policy implications for identifying and prioritizing slum settlements that require additional social and environmental amenities, especially in the highly deprived slums. It also has the potential to facilitate the prioritization of existing slum renewal programs, such

as water, toilet, and other basic facilities. The study offers substantial opportunities for the acquisition of baseline information about social and environmental services that need proper planning for informed policy decisions. It will also assist in the profiling of deprived slum settlements at the local level to support local interventions in critical social and environmental sectors.

DISCUSSION

The observed higher proportion of the residents living in a room apartment reflects the socio-economic conditions of the settlement indicative of extremely low income group earners. This shows that the residents in these slum
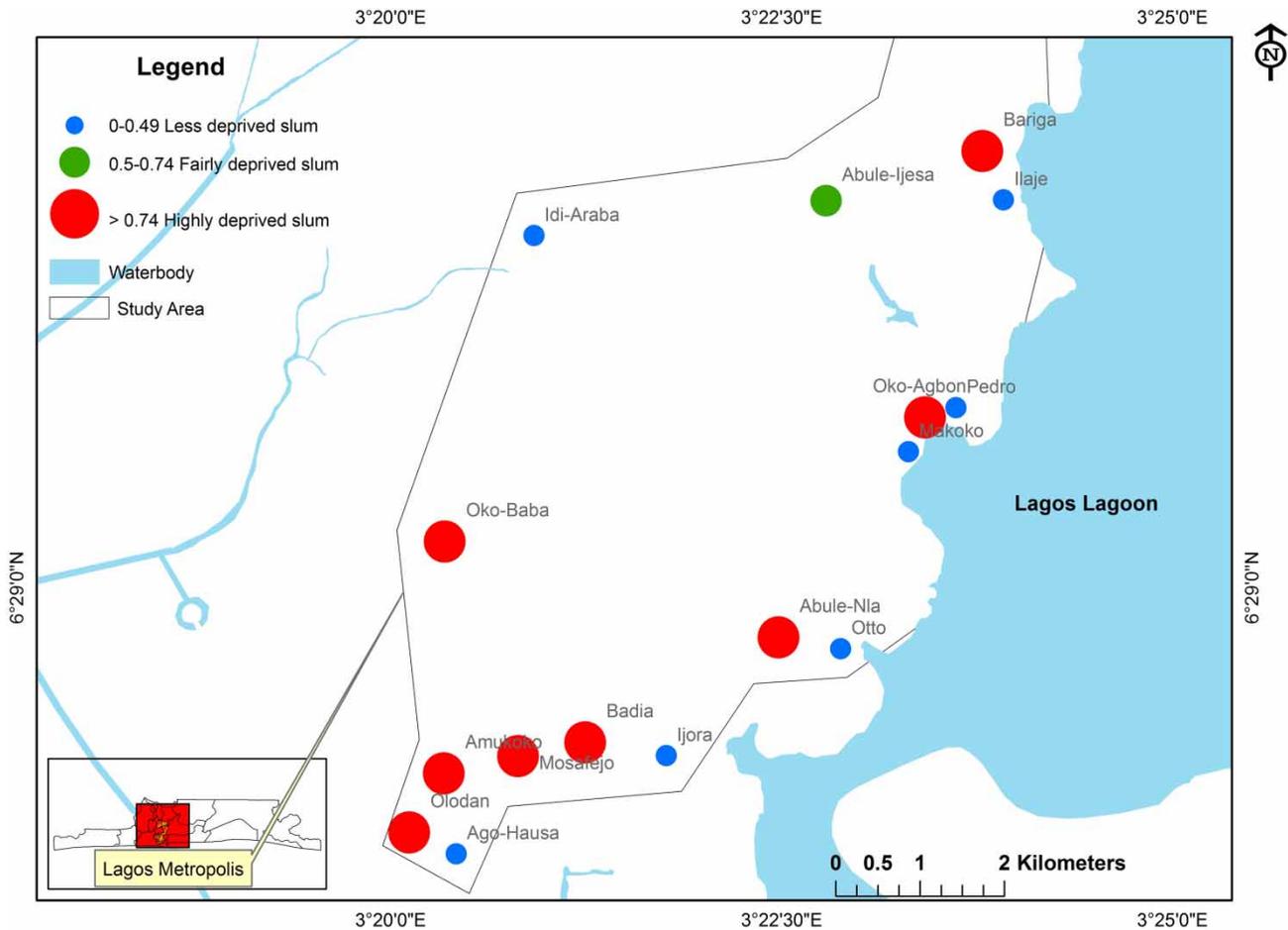
Figure 5 | Dwelling indicator of the slum deprivation index.

settlements lived majorly in deprived residential conditions with limited spaces and perhaps poor services. This result supports the findings of Adebayo & Iweka (2014) and Badaru *et al.* (2014). A similar study by Akinwale *et al.* (2014) on slums showed unhealthy living conditions that are characterized by deprivation of basic services.

Previous reports suggested that slum settlements suffer serious environmental conditions as a result of indiscriminate waste disposal, huge accumulation of waste pile around the dwelling and poor sanitary conditions with a significant impact on the socio-economic activities of slum residents (Owusu 2010; UN-Habitat 2011; Badaru *et al.* 2014; Corburn & Hildebrand 2015). A similar study has established that poor access to improved water and sanitation facilities poses a major economic burden that can increase

health care/medical services (Kimani-Murage & Ngindu 2007; Alam *et al.* 2013).

It has been documented in previous work that improvements in various aspects of water supply, sanitation, and hygiene practices will enhance public health, living conditions and socio-economic activities of the population (Hunter *et al.* 2010; Hutton & Chase 2016). The observed household deprivation in basic services such as water, sanitation, and hygiene practices exposes people to constant health hazards from a variety of diseases like malaria, typhoid, dysentery, skin problems, diarrhea, pneumonia, jaundice, etc. Previous studies have also shown that areas that are deprived based on the drainage system and waste disposal facilities could suffer greater health and environmental challenges due to their vulnerability to
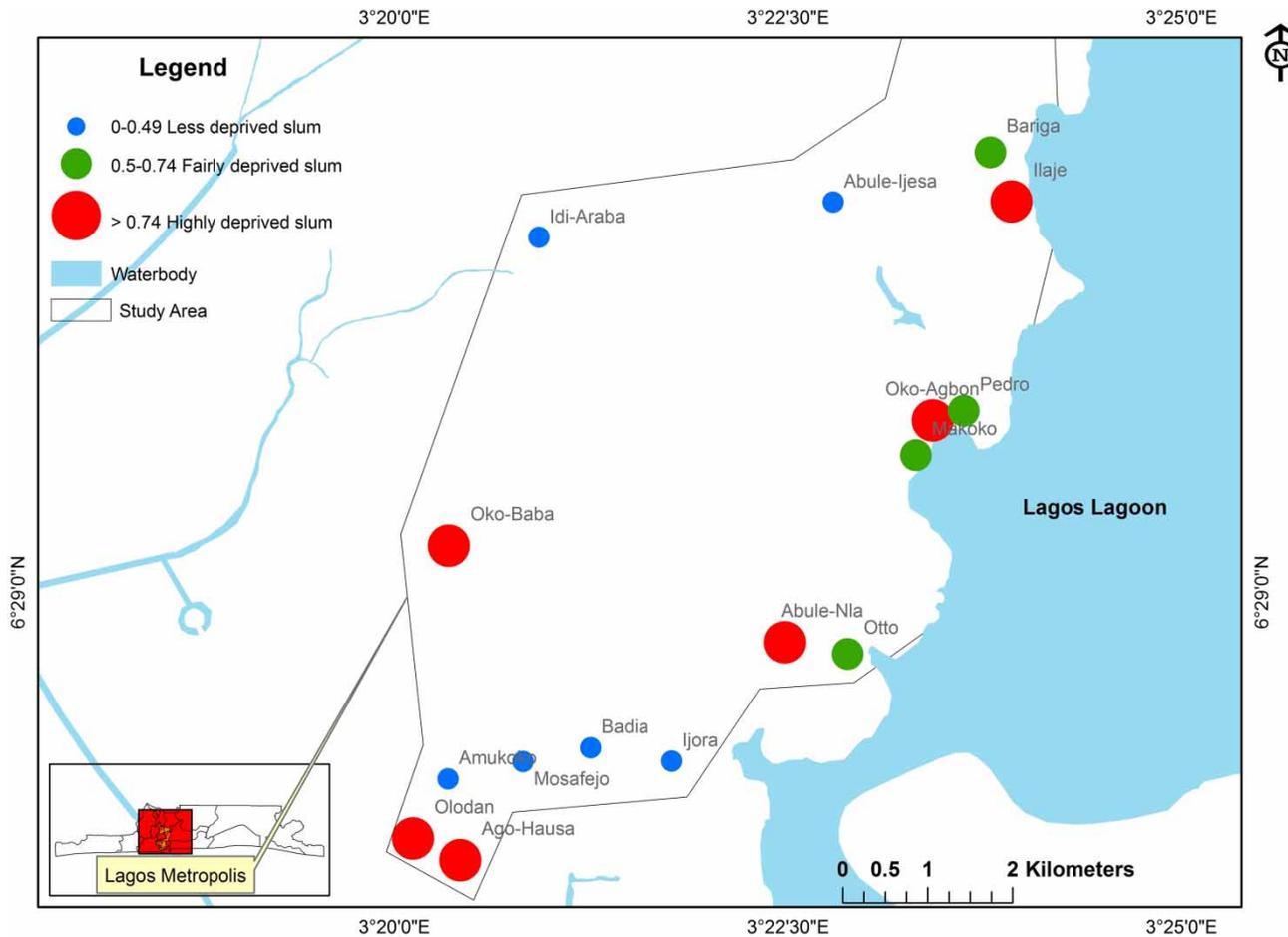
Figure 6 | Waste disposal indicator of the slum deprivation index.

environmentally-induced diseases such as mosquitoes, among others. The result agrees with the findings of Sajjad (2014).

The present study revealed that a greater proportion of the households live in deplorable dwelling and environmental conditions with inadequate spaces and poor access to WaSH facilities. The study noted that Oko-Baba recorded the worst overall SDI while a high level of deprivations of DPE indicators, e.g. the dwelling, waste disposal, waste pile, and stagnant water, predominate around Oko-Baba, Ilaje, Oko-Agbon, Abule-Nla, and Badia. Similarly, Abule-Nla, Oko-Baba, and Oko-Agbon, recorded the worst WaSH indicators, e.g. water, sanitation, and hygiene. The observed social and environmental deprivations of these basic amenities in the slum settlements will expose the

residents to various sanitary related diseases with serious implications on their well-being and general health.

CONCLUSIONS

Household levels of deprivation to WaSH and residential conditions in slum settlements of Lagos, Nigeria, were assessed and mapped using SDI. The study revealed that the majority of households live in deplorable dwelling and environmental conditions with limited space and poor access to sanitation and hygiene practices. It was observed that a significant percentage of the slum settlements are highly deprived based on the overall result of the SDI
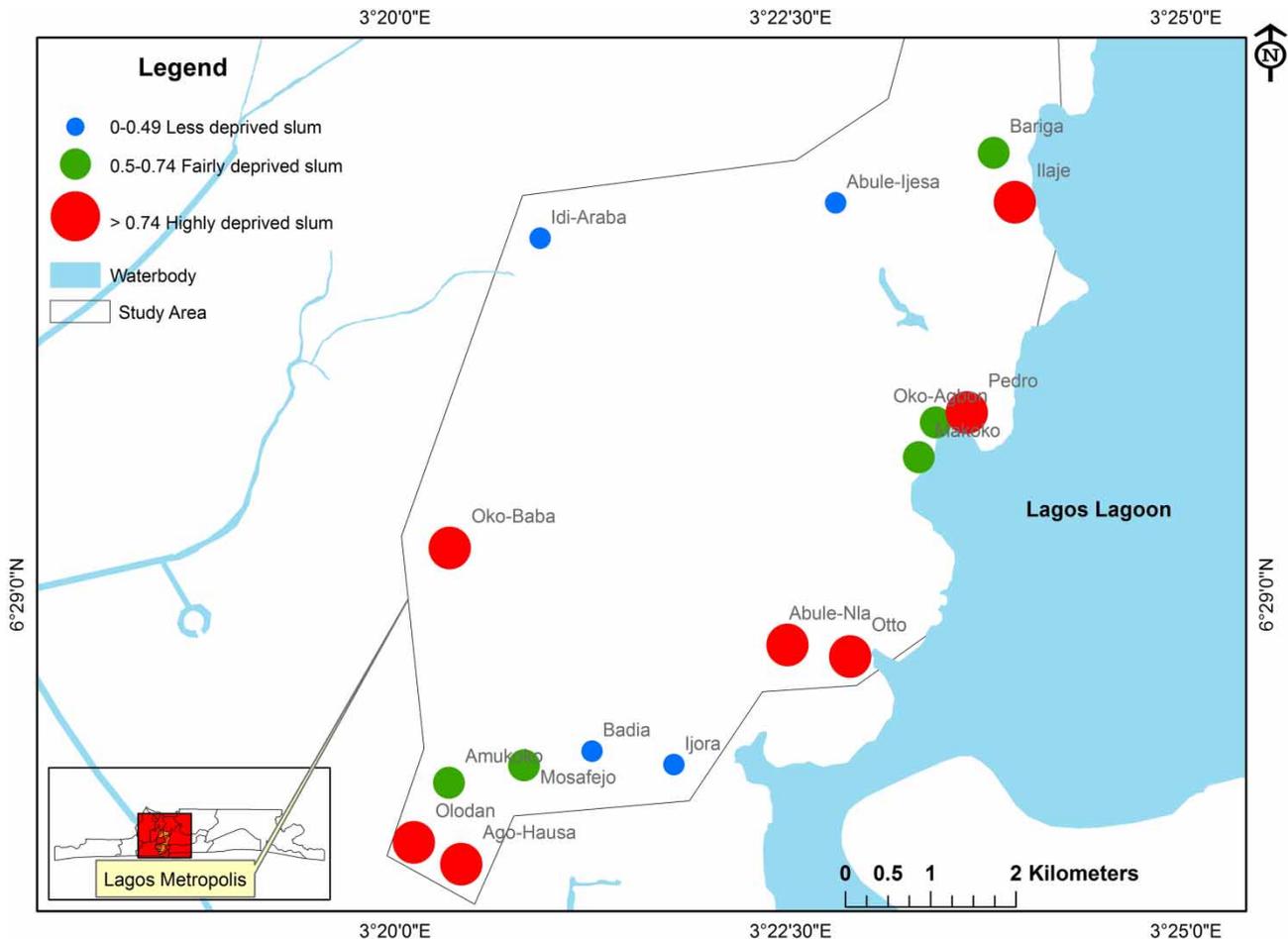
Figure 7 │ Waste pile indicator of the slum deprivation index.

from five slum settlements, namely Oko-Baba, Ilaje, Oko-Agbon, Abule-Nla, and Badia.

The outcome of the WaSH component of the SDI shows that 18.75% of the slums are highly deprived in the study area. Regarding the DPE component of the SDI, 31.25% of the slums are highly deprived. The findings revealed that Oko-Baba recorded the worst overall SDI, specifically for WaSH and DPE in the study area. Concerning the specific indicators, the results indicate that 37.5, 12.5, and 56.25% of the slums are highly deprived in water, sanitation, and hygiene, with the worst SDI recorded from Abule-Nla, Oko-Baba, and Oko-Agbon respectively. Regarding specific DPE indicators, 50, 37.5, 43.75, and 31.25% of the slum settlements are highly deprived concerning the dwelling, waste disposal, waste pile, and stagnant water respectively. Ilaje recorded the worst SDI for all the indicators in the study area.

The study is significant because it will assist policy-makers in identifying specific slums needs, assessment and services that require urgent attention for proper planning and resource allocation in WaSH and DPE sectors for improved healthy living in slum settlements. The study provides a better understanding on the patterns of WaSH and DPE indicators for easy information dissemination both to the public and relevant agencies.

The study concluded that the area is characterized by poor dwelling and environmental conditions, limited spaces, and poor access to sanitation and hygiene practices. The study noted that a significant proportion of the slums are highly deprived based on the overall results of the SDI from Oko-Baba, Ilaje, Oko-Agbon, Abule-Nla, and Badia. The study recommends policies intervention by the relevant policymakers for prioritization in the provision of adequate

Figure 8 │ Stagnant water indicator of the slum deprivation index.
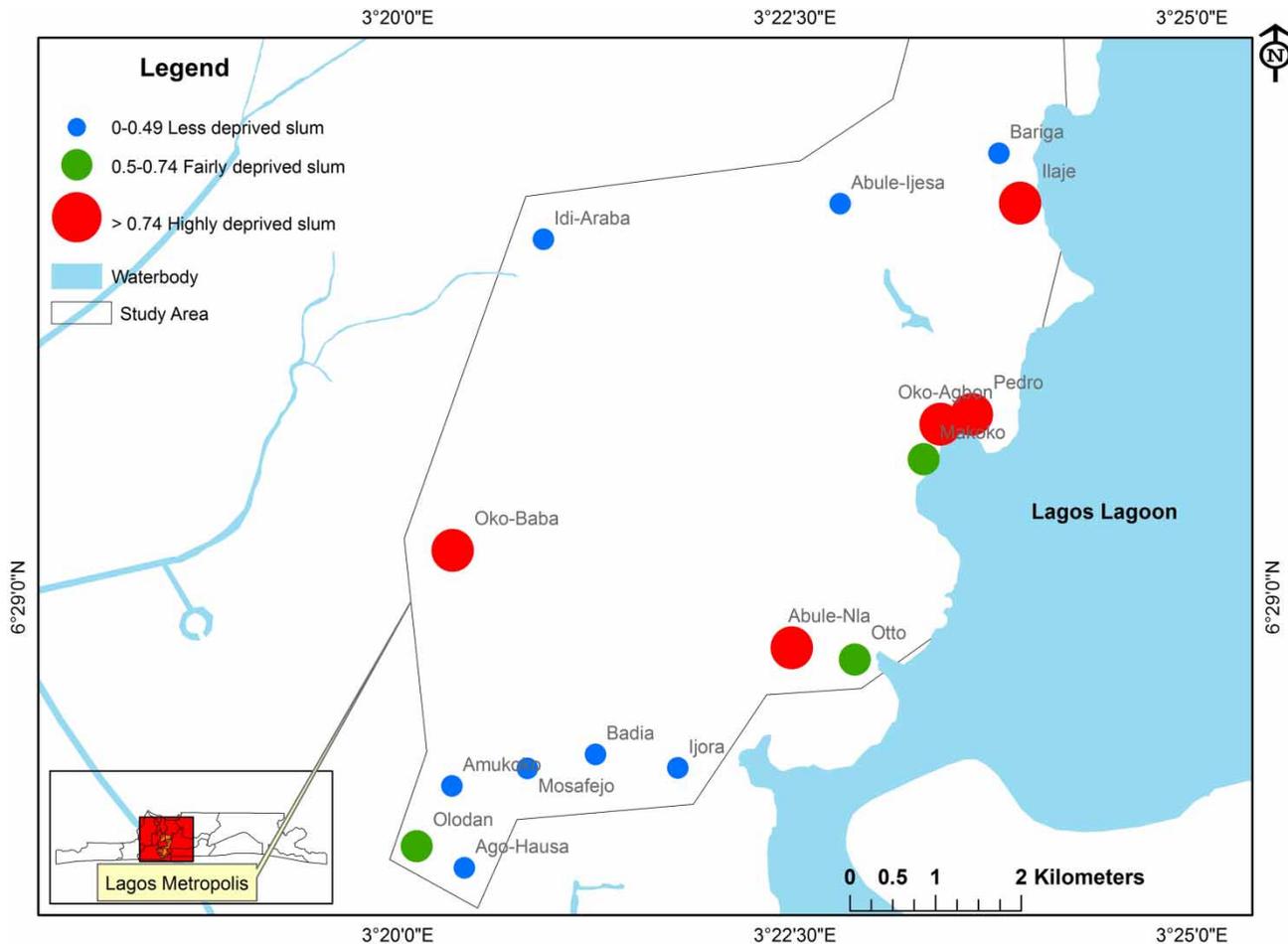
water supply, decent sanitation, and hygiene facilities in highly deprived slums. We equally advocated for proactive strategies that will stimulate investment in decent and affordable housing units, provision of waste disposal, and storm drainage infrastructure. Also, the need for sustained urban renewal programs in the deprived slums for improved service delivery and healthy slum settlement were proffered.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Adebayo, A. K. & Iweka, A. C. O. 2014 Sustainable infrastructure upgrade in slum settlements of Lagos, Nigeria: the role of the

architect. *Environmental Research, Engineering and Management* **68** (2), 53–60.

Adetoyinbo, A. & Babatunde, A. 2010 Quality of hand-dug wells in selected locations in Lagos Coastal Aquifer, Nigeria. *Report and Opinion* **2** (3), 51–54.

Ahmed, R. & Mustafa, U. 2016 Quantification of socio-economic deprivations of urban slums: a case study of Faisalabad. *Pakistan Journal of Applied Economics* **Special issue**, 153–165.

Akinwale, O. P., Oyefara, J. O., Adejoh, P. E., Adeneye, A. A., Adeney, A. K., Musa, Z. A., Oyedeji, K. S. & Sulyman, M. A. 2014 The benefits of using settlement-engaged research approach to promote a healthy lifestyle in three Nigerian urban slums. *South African Journal of Infectious Diseases* **29** (1), 48–50.

Alam, M. Z., Rahman, M. A. & Al Firoz, M. A. 2013 Water supply and sanitation facilities in urban slums: a case study of Rajshahi City corporation slums. *American Journal of Civil Engineering and Architecture* **1** (1), 1–6.

Ayeni, A. O. & Soneye, A. S. O. 2011 Mapping population water poverty of Akoko Northeast settlement, Nigeria. In: *Environmental Research and Challenges of Sustainable Development in Nigeria* (A. T. Salami & O. O. I. Orimoogunje, eds). Obafemi Awolowo University Press, Ile-Ife, Nigeria, pp. 81–90.

Badaru, Y. U., Abubakar, A. S., Spencer, O., Adejoke, A. O. & Salihu, S. O. 2014 Assessment of housing conditions for a developing urban slum using geospatial analysis: a case study of Durumi. Garki-2, Gishiri, and Jabi of the city of Abuja, Federal Capital Territory of Nigeria. *IISTE – Journal of Environment and Earth Science* **4** (20), 1–15.

Bartram, J., Lewis, K., Lenton, R. & Wright, A. 2005 Focusing on improved water and sanitation for health. *The Lancet* **365** (9461), 810–812.

Benach, J., Yasui, Y. & Borrell, C. 2003 The public health burden of material deprivation: excess mortality in leading causes of death in Spain. *Preventative Medicine* **36**, 300–308.

Butler, D. C., Petterson, S., Phillips, R. L. & Bazemore, A. W. 2013 Measures of social deprivation that predict health care access and need within a rational area of primary care service delivery. *Health Services Research* **48** (2 Pt 1), 539–559. doi:10.1111/j.1475-6773.2012.01449.

Carstairs, V. & Morris, R. 1991 *Deprivation and Health in Scotland*. Aberdeen University Press, Aberdeen.

Cesaroni, G., Agabiti, N., Rosati, R., Forastiere, F. & Perucci, C. 2006 An index of socioeconomic position based on 2001 Census, Rome. *Epidemiologia e Prevenzione* **30** (6), 352–357.

Corburn, J. & Hildebrand, C. 2015 Slum sanitation and the social determinants of women's health in Nairobi, Kenya. *Journal of Environmental and Public Health* **2015**, 1–6. doi:10.1155/2015/209505.

Eibner, C. & Sturm, R. 2006 US-based indices of area-level deprivation: results from health care for communities. *Social Science Medicine* **62** (2), 348–359.

Fadare, S. O. & Olawuni, P. O. 2008 Domestic water supply and health of households in the three residential densities in Osogbo, Osun State, Nigeria. *Ethiopian Journal of Environmental Studies and Management* **1** (2), 35–43.

Fukuda, Y., Nakamura, K. & Takano, T. 2007 Higher mortality in areas of lower socioeconomic position measured by a single index of deprivation in Japan. *Public Health* **121**, 163–173.

Gulyani, S., Bassett, E. M. & Talukdar, D. 2014 A tale of two cities: a multi-dimensional portrait of poverty and living conditions in the slums of Dakar and Nairobi. *Habitat International* **43**, 98–107.

Hunter, P. R., Toro, G. I. R. & Minnigh, H. A. 2010 Impact on diarrhoeal illness of a settlement, educational intervention to improve drinking water quality in rural settlement in Puerto Rico. *BMC Public Health* **10** (1), 219. doi:10.1186/1471-2458-10-219.

Hutton, G. & Chase, C. 2016 The knowledge base for achieving the sustainable development goal targets on water supply, sanitation, and hygiene. *International Journal of Environmental Research and Public Health* **13** (6). doi:10.3390/ijerph13060536.

Jeyakumar, A. & Ghugre, P. 2017 Assessment of personal hygiene and sanitation using composite index among adolescent girls and their households in urban slums of Pune, Maharashtra. *Journal of Water, Sanitation, and Hygiene for Development* **7** (2), 323–330.

Kimani-Murage, E. W. & Ngindu, A. M. 2007 Quality of water the slum dwellers use: the case of a Kenyan slum. *Journal of Urban Health* **84** (6), 829–838.

Lorant, V. 2000 Mortality socio-economic inequalities for small-areas in Belgium: assessing concentration. *Revue d'épidémiologie et de santé publique* **48**, 239–247.

Mahabir, R., Crooks, A., Croitoru, A. & Agouris, P. 2016 The study of slums as social and physical constructs: challenges and emerging research opportunities. *Regional Studies, Regional Science* **3** (1), 399–419.

Messer, L. C., Laraia, B. A., Kaufman, J. S., Eyster, J., Holzman, C. & Culhane, J. 2006 The development of a standardized neighborhood deprivation index. *Journal of Urban Health* **83** (6), 1041–1062.

Nolan, L., Bloom, D. E. & Subbaraman, R. 2017 *Legal Status and Deprivation in India's Urban Slums: An Analysis of Two Decades of National Sample Survey Data*. Discussion Paper Series IZA DP No. 10639. Institute of Labor Economics, Bonn, Germany.

NPC (National Population Census) 2006 Details of the breakdown of the national and state provisional population totals. *Official Gazette* **96** (2), 1–42. Federal Republic of Nigeria, Abuja.

Odumosu, T., Balogun, Y. & Ojo, K. 1999 Location and regional setting of Lagos State. In: *Lagos State in Maps* (Y. Balogun, T. Odumosu & K. Ojo, eds). Rex Charles and Connell Publications, Sango, Ibadan, pp. 1–3.

Okoye, P. U., Ezeokonkwo, J. U. & Mbakwe, C. C. 2017 Survey of housing conditions and improvement strategies in Okpoko

peri-urban settlement of Anambra State, Nigeria. *Architecture Research* **7** (4), 168–183.

Owusu, G. 2010 Social effects of poor sanitation and waste management on poor urban settlement: a neighborhood-specific study of Sabon Zongo, Accra. *Journal of Urbanism* **3** (2), 145–160.

Pampalon, R., Hamel, D. & Gamache, P. 2009 A deprivation index for health planning in Canada. *Chronic Diseases in Canada* **29**, 178–191.

Patel, A., Koizumi, N. & Crooks, A. 2014 Measuring slum severity in Mumbai and Kolkata: a household-based approach. *Habitat International* **41**, 300–306.

Sajjad, H. 2014 Living standards and health problems of lesser fortunate slum dwellers: Evidence from an Indian city. *International Journal of Environmental Protection and Policy* **2** (2), 54–63.

Salmond, C. E. & Crampton, P. 2012 Development of New Zealand's deprivation index (NZDep) and its uptake as a national policy tool. *Canadian Journal of Public Health* **103** (8), S7–S11.

Salmond, C., Crampton, P. & Sutton, F. 1998 NZDep91: a New Zealand index of deprivation. *Australian and New Zealand Journal of Public Health* **22** (7), 835–837.

Shaban, A. & Sharma, R. N. 2007 Water consumption patterns in domestic households in major cities. *Economic and Political Weekly* **21**, 2190–2197.

Singh, P. K. & Hiremath, B. N. 2010 Sustainable livelihood security index in a developing country: a tool for development planning. *Ecological Indicators* **10** (2), 442–451.

Townsend, P. 1987 Deprivation. *Journal of Social Policy* **16**, 125–146. doi.org/10.1017/S0047279400020341

Townsend, P., Phillimore, P. & Beattie, A. 1988 *Health and Deprivation: Inequalities and the North*. Croom Helm, London.

Tramontina, B. 2017 *Analyzing Spatial Distribution Patterns of Visual Indicators of Slum Conditions: Case of Rajarghat, Kolkata, India*. MSc Thesis, School of Graduate Studies and Research in Partial Fulfillment of the Requirements for the Degree Master of Science, Department of Geography and Regional Planning, Indiana University of Pennsylvania, USA.

UNDP (United Nations Development Programme) 1992 *Human Development Report*. Oxford University Press, New York.

UN-Habitat 2011 Building urban safety through slum upgrading. United Nations Human Settlements Programme, Nairobi, Kenya, pp. 1–104.

UN (United Nations) 2015 *The Millennium Development Goals Report 2015*. United Nations, New York.

Weeks, J. R., Hill, A., Stow, D., Getis, A. & Fugate, D. 2007 Can we spot a neighborhood from the air? defining neighborhood structure in Accra. *Ghana. Geo-Journal* **69** (1), 9e22.

WHO & UNICEF 2014 *Wash Targets and Indicators Post-2015: Recommendations From International Consultations Comprehensive Recommendations*. WHO/UNICEF Joint Monitoring Programme (JMP), Geneva, Switzerland, p. 12.

WHO (World Health Organization)/UNICEF JMP 2019 *Progress on Household Drinking Water, Sanitation, and Hygiene 2000–2017. Special Focus on Inequalities*. United Nations Children's Fund (UNICEF) and World Health Organization, Geneva, Switzerland.

Yamane, T. 1973 *Statistics: An Introductory Analysis*, 3rd edn. Harper and Row, New York.