TIMBOU-AFRICA PUBLICATION INTERNATIONAL JOURNAL FEBRUARY, 2025 EDITIONS.

INTERNATIONAL JOURNAL OF AFRICAN SUSTAINABLE DEVELOPMENT RESEARCH
VOL. 7 NO. 2 E-ISSN 3027-1436 P-ISSN 3027-2041

ASSESSING THE STATE OF ENVIRONMENTAL JUSTICE IN MAKAMA WARD OF BAUCHI CITY USING GEOGRAPHIC INFORMATION SYSTEM

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DOI: https://doi.org/10.70382/tijasdr.v07i2.031

ABSTRACT

The basic understanding is that there is clear relationship between the social minority and lower income areas and the exposure to contemporary environmental impacts. It was observed that majority of the lower income households in Makama Ward of Bauchi city were under poor quality environment, while high-income areas enjoyed more favourable environment. Traditional methods usually used in carrying out assessment of EJ

Introduction

Physical development policies, programmes and projects have brought their benefits in cities. These developments magnify many existing inequalities between income and ethnic groups", (Soja, 2010), highlighting the phenomenon of spatial segregation. The result of spatial segregation is an uneven spread of urban environmental amenities and burdens. This matter raised the movement for urban Environmental Justice (EJ). The US EPA (2011) defines EJ as "fair treatment and meaningful involvement of all people regardless of race, national origin or income class with respect to development, implementation and enforcement of environmental laws, regulations and policies". The term Environmental Justice is otherwise called Environmental Equity because it has to do with fair and proportional distribution of environmental benefits and burdens in a city regardless of social status of the people living in the city.

do not take into account multiple environmental quality indicators of EJ concurrently, and depict the spatial context of disproportions in urban environmental amenities and burdens. The GIS method was utilized in this thesis because, through the spatial distribution of environmental quality factors are able to simplify complex information about the state of EJ. In conclusion, the index maps were sufficient to expose the complexity of the spatial distribution of the variables that were studied. It enabled the identification of level of disproportions of social and environmental quality in Makama through the range of index maps developed. The GIS method made it possible to more adequately expressing interrelationships between urban environmental quality and social class. Similar techniques can be incorporated to provide better technical basis to planners hence achieving just and sustainable urban areas. Future researches related to EJ should aim at including more other critical indicators of EJ like crimes, sanitation, housing, electricity etc., which are common to developing country especially in Nigeria.

Keywords: Environmental Justice, Makama Ward, Bauchi City, Geographic Information System, Assessment.

The urban environment has to be managed to preserve the relative privileges of different social groups that reside there by ensuring EJ (European Union 2010). However, many cities in the developing countries (like Bauchi city) are still experiencing environmental injustice. (Adeola 2001).

The paper stems from the need for experts of the related field to develop methods to deal with the challenges of answering more imperative but complex questions: e.g., "How do we measure the distribution of multiple or cumulative impacts of policies on poorer groups in urban areas? (Stephens, 2007). Environmental Justice in a city can only be dealt with when it is considered as a multi-dimensional issue because it requires an integrated analysis and representation of diverse environmental stressors and resources in their socio-spatial distribution (Wheeler, 2004; Lakes and Klimeczek, 2011). Therefore, the study set out to apply the GIS method in Makama Ward of Bauchi city in order to address this challenge.

Aim and Objectives

The aim of the study is to determine the state of Environmental Justice in Makama Ward of Bauchi town using a GIS synoptic analysis method.

The objectives of the research are as follows:

1. To identify social vulnerability and environmental quality indices for Environmental Justice analysis in Makama Ward;
2. To assess the spatial pattern of disproportionate spread of urban environmental amenities and burdens in different neighbourhoods within Makama Ward;
3. To determine the level challenges of spatial disproportions of urban environmental amenities and burdens in Makama Ward;
4. To make recommendations for promoting Environmental Justice in Makama Ward.

Scope and Limitations

Assessment of the relationship between environmental quality and income status with the understanding of the EJ implications, is assumed as practical by narrowing down to the Ward- level, which is a smaller heterogeneous part of a city. This is because relative results precision differ depending on the degree of urban space that is taken into account. The smaller the geographic scale the greater precision and measurability than when considering the urban space at a larger scale (Paul, *et al.* 2005).

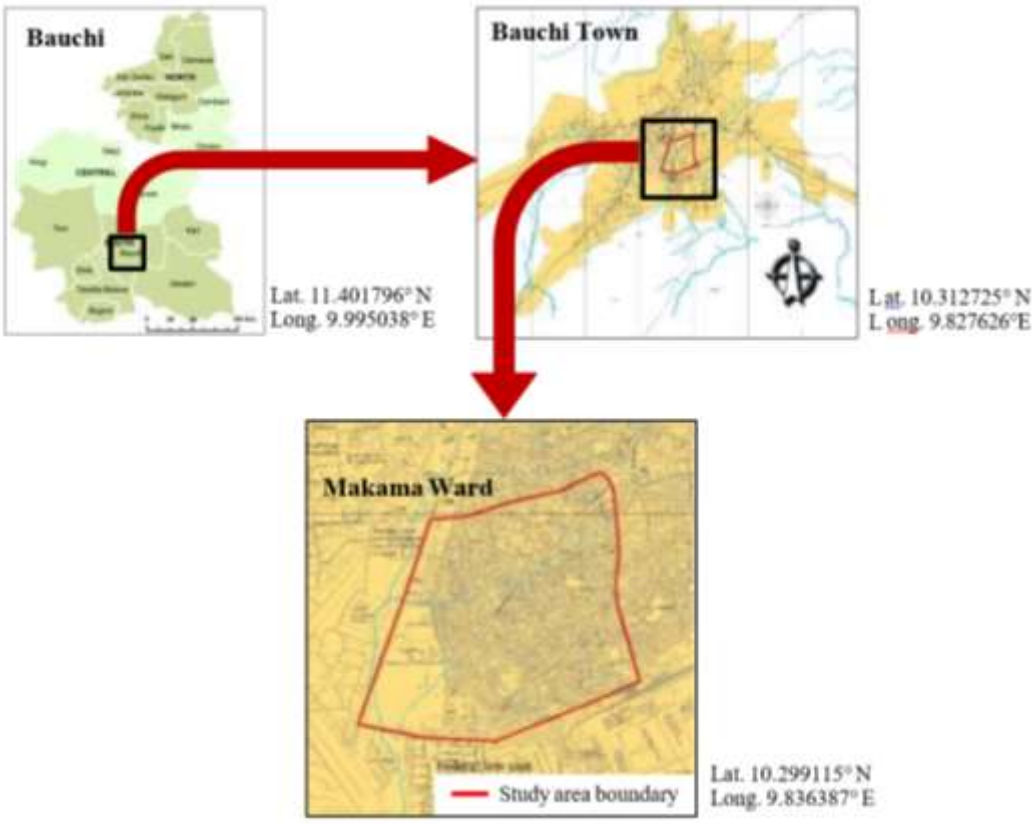
Makama is a heterogeneous Ward that was used for the study because it is one of the Ward in Bauchi town that contains the three (3) income groups in distinct areas. This provides the room for comparing social status and the distribution of environmental benefits and burdens over the entire Ward at detailed level.

The Environmental Quality indicators used in this study are: water supply, open-air sewage, waste accumulation and collection, provision of roads and drainages, and Healthcare Services – presence of Hospital & Clinics.

Significance of the Study

The study will demonstrate to professionals the application of GIS method in assessment of Environmental Justice. The study will help create awareness on environmental disproportions of amenities and burdens in Makama Ward of Bauchi city and guide authorities and professionals in targeting specific policies to affected areas. Also a step towards providing more comprehensible knowledge-base for integrating Environmental Justice into related fields (Planning, EMT, Environmental Health etc.).

Fig. 2. The Study Area Location



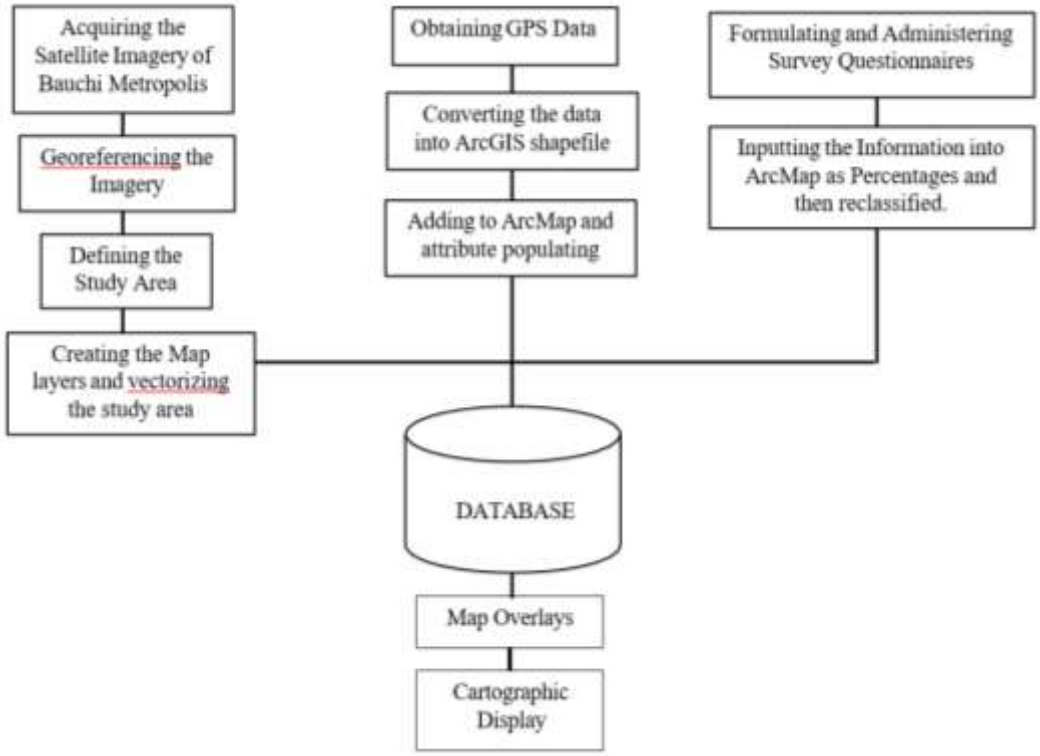
Method of Data Collection

To understand the conditions of environmental justice in a particular location requires a systematic mapping effort. The final result depends on the aggregation of initial parameters which contribute to the construction of cartographic partial synthesis, and finally to the composition of a synoptic map.

Maps throughout this study were developed using ArcGIS 10.3 software (ESRI Inc, 2013). ArcGIS and ArcMap are the intellectual property of ESRI which are used in the spatial analysis. All images used here are obtained using the Google Earth Pro, v7.0.2. (Google Inc, 2016). Other graphic sketches are done using CoralDraw x4. Data analysis and Charts are done using MS Excel 2013.

The study adopted the mixed method which includes public knowledge and expert knowledge on determining the state of environmental justice. The spatial point data was acquired using Garmin 75XL handheld GPS receiver. The Cartographic Model shows the stages of operation from the beginning of the production of the cartographic display on figure 8 below:

Fig. 3. Cartographic Model



The Sample Frame

The sample frame was obtained from the number of residential buildings in the study area. The total number of residential households within the study area was 7303 households. The counting of residential households was achieved through GIS-based Aerial Interpolation technique using the ArcMap 10.2 program. After the digitization of the whole study area, the program was able to perform an automated counting of all households polygon shapefiles within the specified containment which is Makama Ward.

The Sample Size

Twenty percent (20%) of the total number of building/plots were taken based on Krejcie & Morgan (1970), that is, 0.02 multiplied by 7303 households. The required sample size for 7303 residential households in the study area is One hundred and fifty (150) households. Since the interest was not in the population of the residential households, preliminary survey of the sampled 150 households was carried out.

Sampling Technique

The sampling technique used involves two stages. First is the use of the Residential Block Group method (RBG). The RBGs consist of clusters of continuous residential

blocks, which represent smaller geographical area for which the sample data were collected at a detailed level.

They were formed by streets, roads, streams, and other visible physical feature shown on the RBG map (Fig. 7). This grouping of residential blocks is considered necessary because of the homogeneity of the phenomena under investigation.

The RBGs were numbered beginning with the number one "1". The block groups are summary units used for the purpose of capturing data in a more detailed scale. One other important advantage of the RBG method, in the case of this type of research, is the simplicity of its cartographic presentation as shown in Fig. 7.

The Residential Block Group Delineation Criteria

The minimum size of an RBG polygon is 30,000 square feet (2787 square meters) for polygons bounded entirely by roads, or 40,000 square feet (3716.1216 square meters) for other polygons. There was no maximum size for a single RBG.

Exceptions to the minimum polygon sizes were made where the polygon was partly bounded by must-hold features like the streams which needed to be maintained as RBG boundaries.

Polygon shapes were measured to eliminate extremely narrow slices as potential RBGs. This was done by comparing the ratio of the perimeter of the polygon to the area of the polygon, with the ratio of the perimeter of a circle to its area.

Features were ranked according to their importance as RBG boundaries based on

- The type of boundary,
- The feature with which it coincide,
- The existence of other land use areas (such as Schools, Petrol Stations etc.),
- At least one side of a potential RBG had to be a road feature,
- Extensions from dead-end roads/streets were used to split oversized RBG polygons into separate blocks; such extensions were made wherever road features protruded into a large polygon.
- An RBG shall contain not less than 300 households.

Map of the delineation of RBGs was derived using Geographic Information System (GIS) program. The program was used to identify, with separate numbers, potential RBG polygons that fell within the size range of typical RBG. The program generally produced a serpentine pattern of RBG numbers beginning in the upper right of each study area (Fig. 12). The program was able to ensure numeric geographic comparability for those blocks that had retained the same boundaries. The program assigned all non-residential

polygons to a single RBG. The automated delineation resulted in a total of 30 residential block groups

Second is the trekking or canvassing individual blocks in a geographic sequence. This is a standard method of listing and conducting a door-to-door administration of questionnaires (U.S Census Bureau 1990).

Proceeding in a clockwise direction, the Field Assistant identified the location of all households to the right, and located and indexed these on the survey map. They administered questionnaires for the selected households within the RBGs and also recorded solid waste accumulation, street drainage and open-air sewage conditions. All roads had to be trekked so that hidden housing units were not missed. Each individual block was identified on the survey map, and Field Assistants were instructed to write the block number on the questionnaires as they administered them to the selected households. The sample size for the study was one hundred and fifty (150) households, and there were thirty (30) RBGs. A questionnaire is administered to every forty ninth (49th) household.

Map Index Construction

As already emphasized, this research relied on the indicators available for the study area, which enable analysis in detailed scale of survey data. Seven (7) initial environmental parameters were chosen:

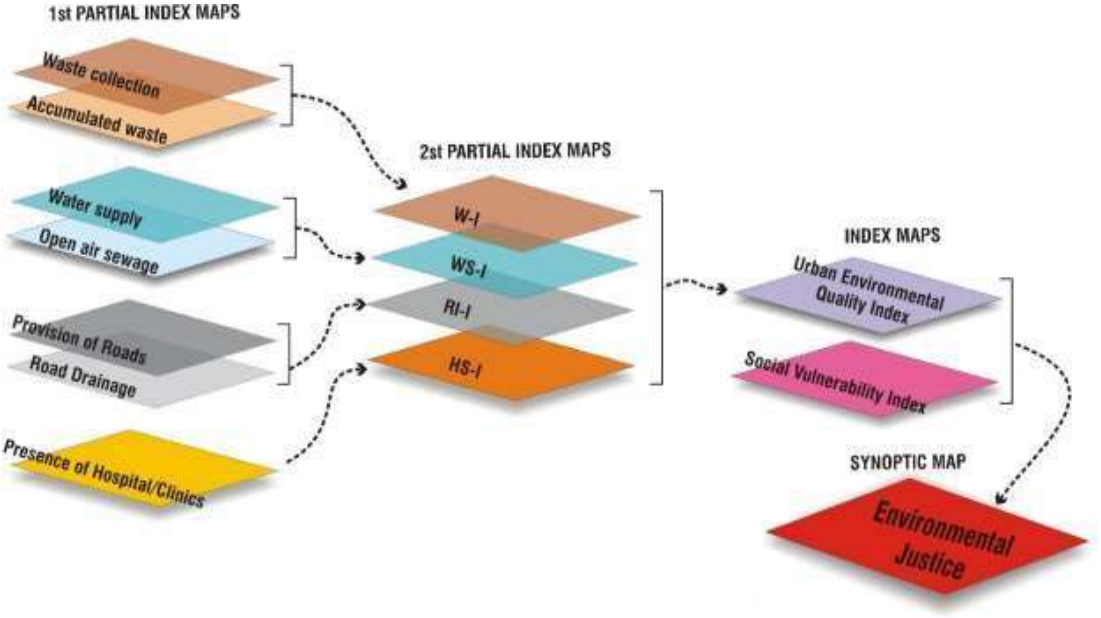
1. Waste collection in the vicinity;
2. Waste accumulation in the vicinity;
3. Water supply per household within the vicinity;
4. Open air sewage per household or within the vicinity;
5. Provision of roads;
6. Road drainage;
7. Presence of Hospital and Clinics.

From a thematic analysis, these parameters comprise four (4) second partial indices:

1. Waste Index – **W-I**
2. Water supply and Sewage Index – **WS-I**
3. Road Infrastructure Index – **RI-I**
4. Healthcare Services Index – **HS-I**

These partial indices comprise a synoptic index of Urban Environmental Quality of the study area. The last stage in obtaining the map of Environmental Justice is the integrated analysis of Urban Environmental Quality and the Social vulnerability indices. The steps are summarized in the diagram shown in Figure 7.

Fig. 4. Computation Scheme of Indexes for the Environmental Justice Synoptic Map



Each of the stages requires the correct geo-statistical treatment of the available indicators and relies on specific methods for the composition of partial and synoptic indices. The records will be described in here. Generally each indicator is transformed into a percentage rate or different categories and subsequently reclassified into three classes so that they can be crossed in a matrix analysis. Each class receives different grades which represent the exposure to more or less environmental stressors and as a final point to the subjection to higher or lower rate of environmental justice. In total thirteen (13) maps will be generated and analyzed in an integrated basis in order to assess Environmental Justice for the study area.

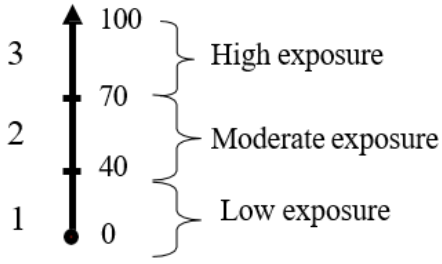


Fig. 5. The Index Code: Exposure Ranking Scale based on the presence of environmental burdens and stress

The exposure ranking scale is a standard for comparison of environmental quality, (U.S EPA). From survey data, percentages of exposure is derived from the averages of the

respondents for each questions of all the indicators under study. Increasing upwards on the ranking scale, all households that fall within 0 – 40% presence of environmental burden/stress is coded with "1", which means that the households are least exposed to the presence of stress and poor environmental quality.

Results

This section displays the cartographic results and performs a related discussion of the main evident data in order to reflect on the difficulties and gains pertinent to the pursuing of the research intent. Thirteen maps are represented here in different scales according to the stages of their development. The thirteen (13) index maps are shown at scale 1:240 meters.

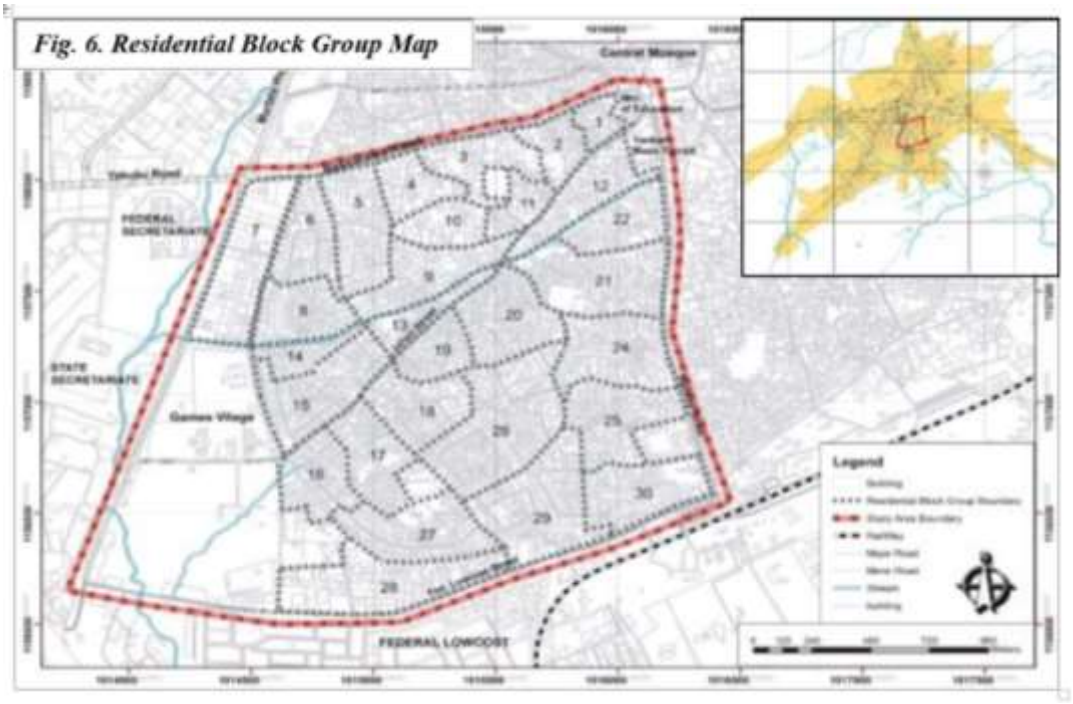


Table 1. Final Waste Index Map Key: Exposure to environmental stressors

Map Key	Category	Description
Low	3	A significant parcel of the residents have access to waste collection and is not exposed to accumulated garbage.
Moderate	2	Few of the residents have no access to waste collection and/or are exposed to accumulated garbage.
High	1	Most of the residents have no access to waste collection and/or are exposed to accumulated garbage.
No data	0	Comprise non-residential buildings, which are not within the scope of the sample frame.

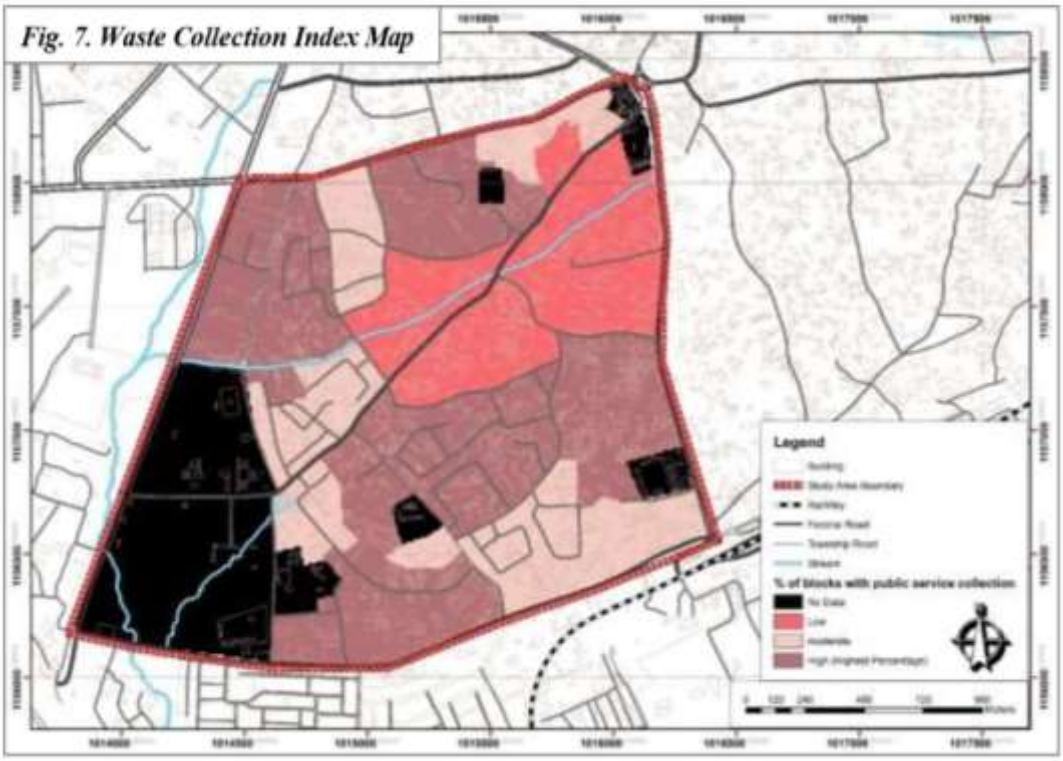


Fig. 7. Waste Collection Index Map

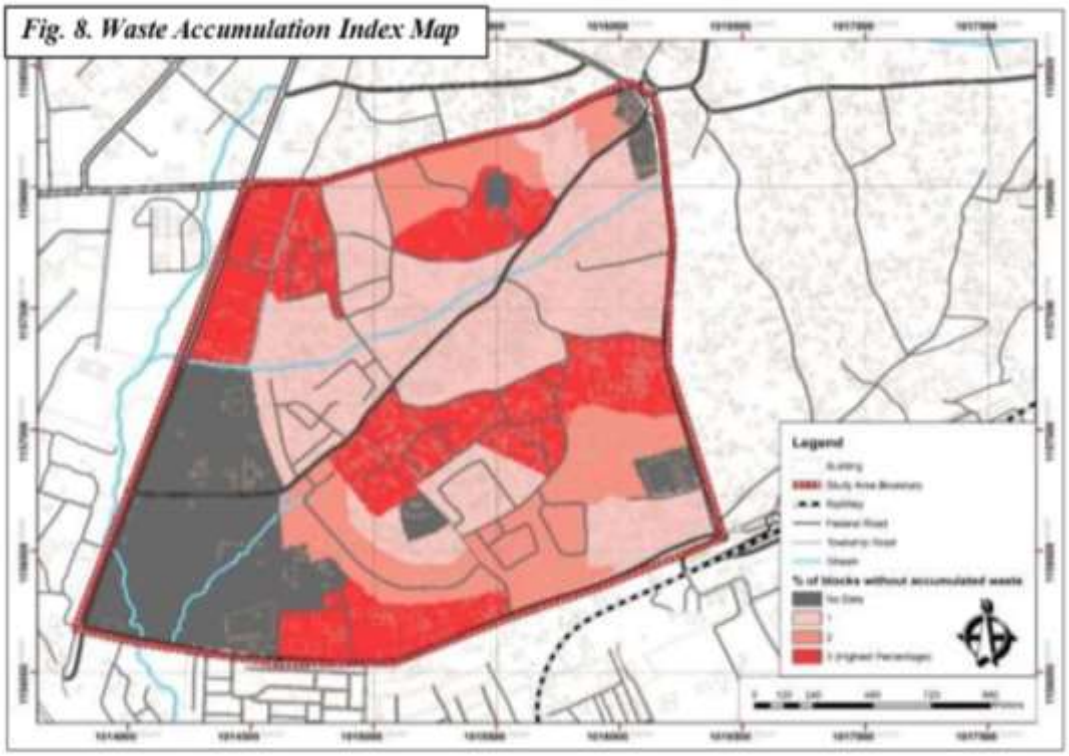


Fig. 8. Waste Accumulation Index Map

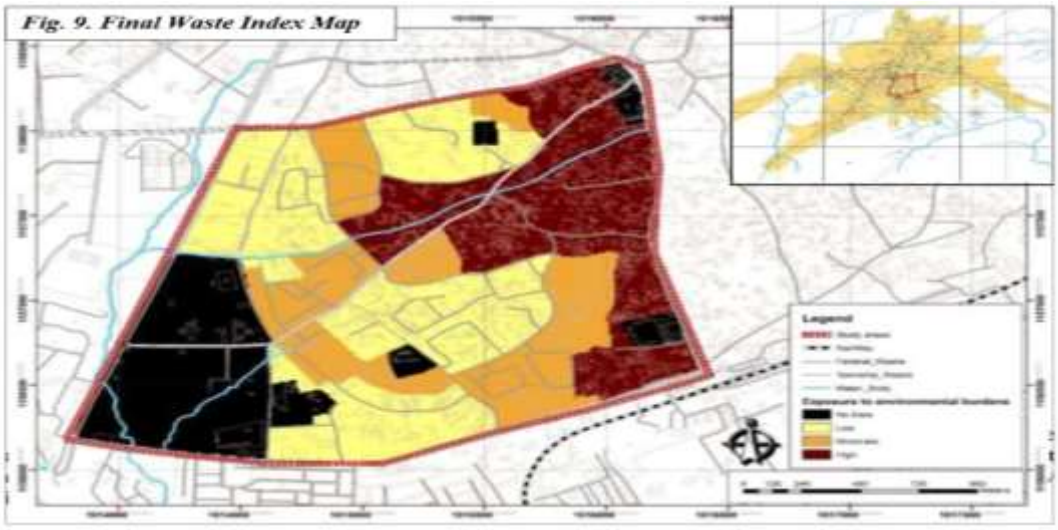
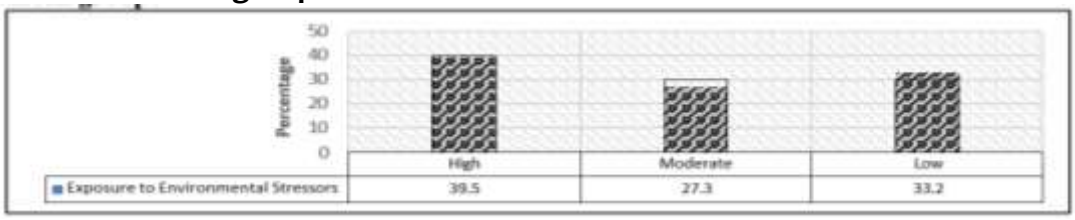


Fig. 10. Land area exposure to environmental stressors related to waste in the residential block groups



The rates demonstrate that, despite the presence of residential waste collection, in the most deprived neighbourhoods there is a considerable gap in the services of waste collection. Still, the neighbourhoods that do not have proper collection facilities are indiscriminately disposed on bear ground and on undeveloped plots (Plate 1), which are found consistently in the areas of lower social status.

Plate 1. Accumulated waste found along roadsides

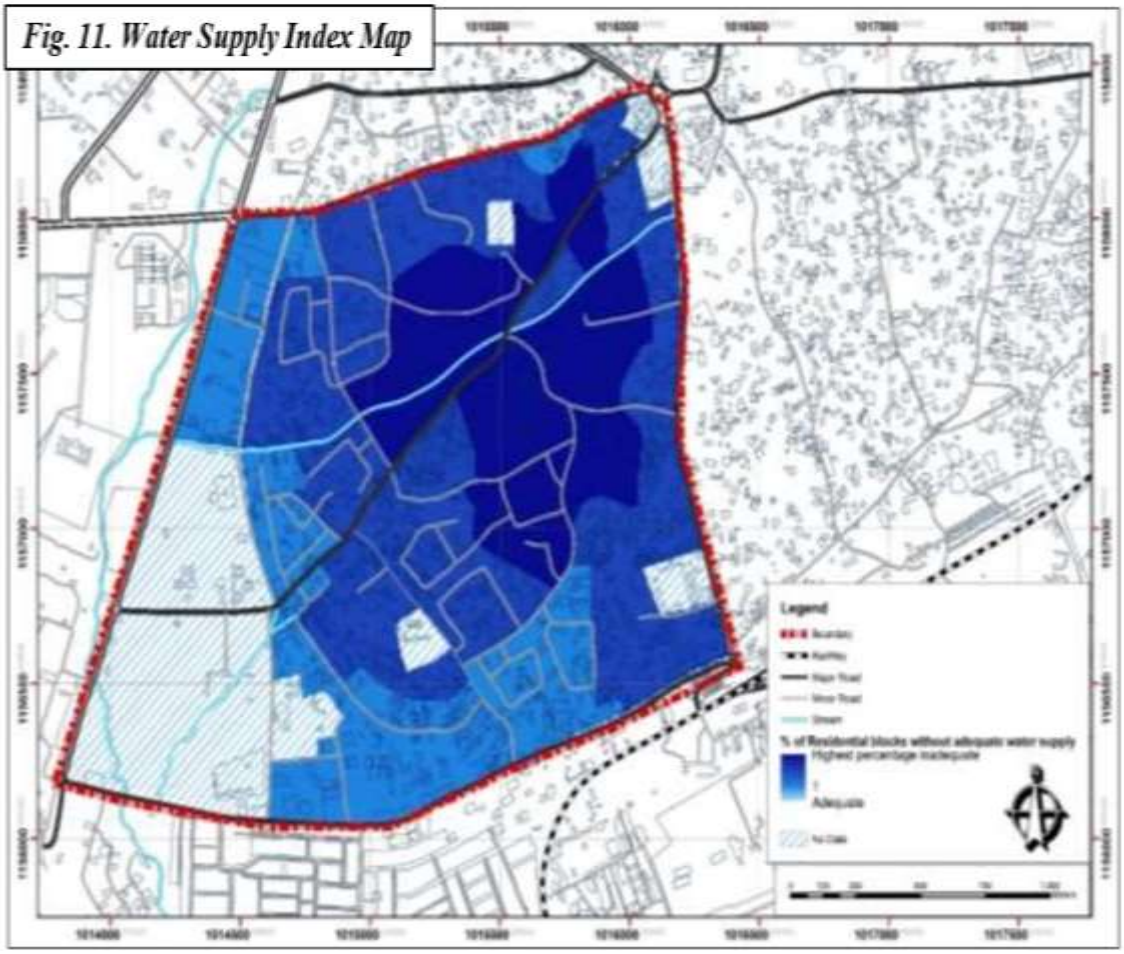
Water and Sewage Index

The Fig. 19 and 20, comprise the partial index contained within the Water and Sanitation Index Map.

Table 2. Final Water & Sewage Index Map Key: Exposure to environmental stressors

Map Key		Category	Description
Low		1	A significant number of the residential buildings have safe water and clean environment and are not exposed to open air sewage
Moderate		2	Few residential buildings have no access to safe water supply and sanitation and/or are exposed to open air sewage
High		3	Most of the residential buildings have no access to safe water supply and sanitation and/or are exposed to open air sewage
No data		0	Comprise non-residential buildings, which are not within the scope of the sample frame.

Fig. 11. Water Supply Index Map



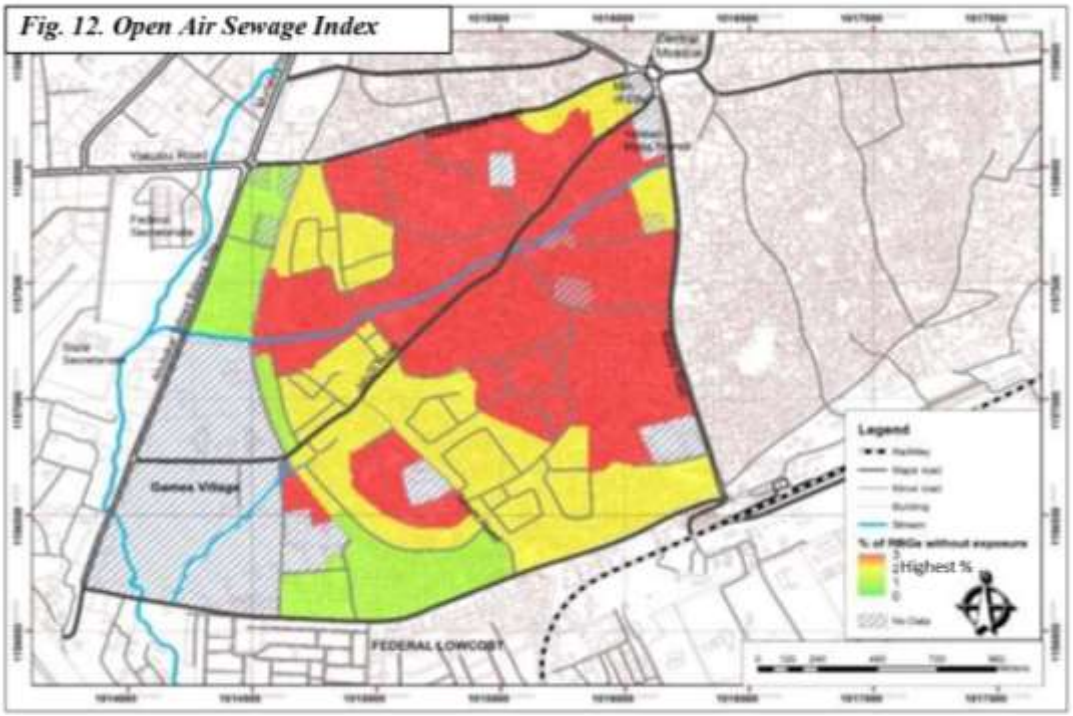


Fig. 12. Open Air Sewage Index

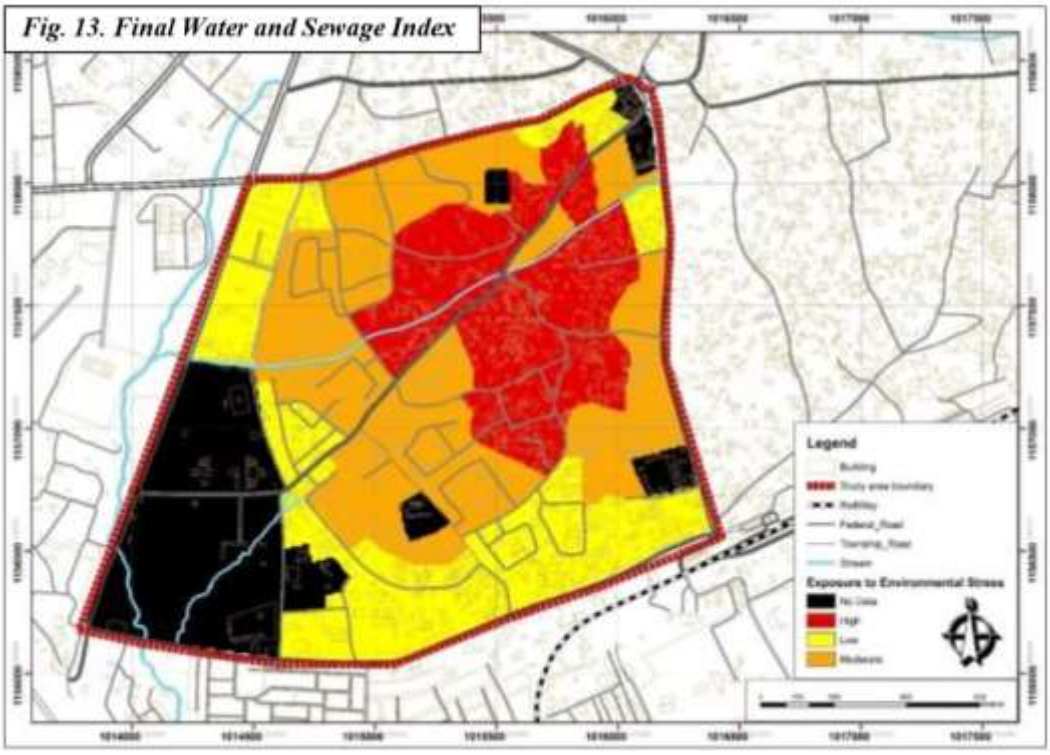


Fig. 13. Final Water and Sewage Index

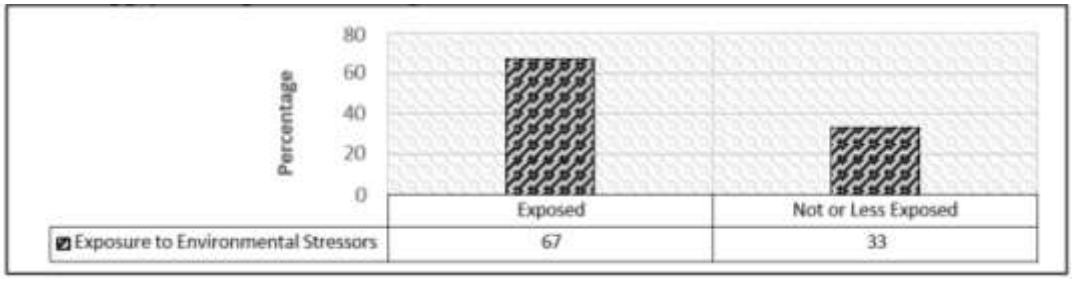
The water supply map shows households with water supply sources that are less than 30 minutes away. The result showed that roughly majority of households in the study

area do not have access to adequate water supply that is, from water borne in pipe, protected public wells or water vendors. Generally, from the result of the analysis, households with inadequate water supply was 66% of the Ward. The result includes a total of 66% without adequate access to the water supply in the study area. These are concentrated in the most vulnerable location of the study area.

Plate 2. Health threatening Open-air sewage in the vicinity

The results for the index regarding the topic of Water and Sewage reflects the conditions highlighted, particularly in the final waste index. The low and average income households within the study area of Makama Ward, which takes the highest proportion of the study area, bear the highest open-air sewage exposure. A total of 4898 households out of 7303 are exposed to environmental stress related to water and open-air sewage bearing 67% of exposed residential buildings. Inadequate water supply and sewage in the high income class area is less severe with a total number of 2410 households (33%) that are not exposed to environmental stress.

Fig. 14. Percentage of households with/without exposure to environmental stressors related to water supply and open-air sewage



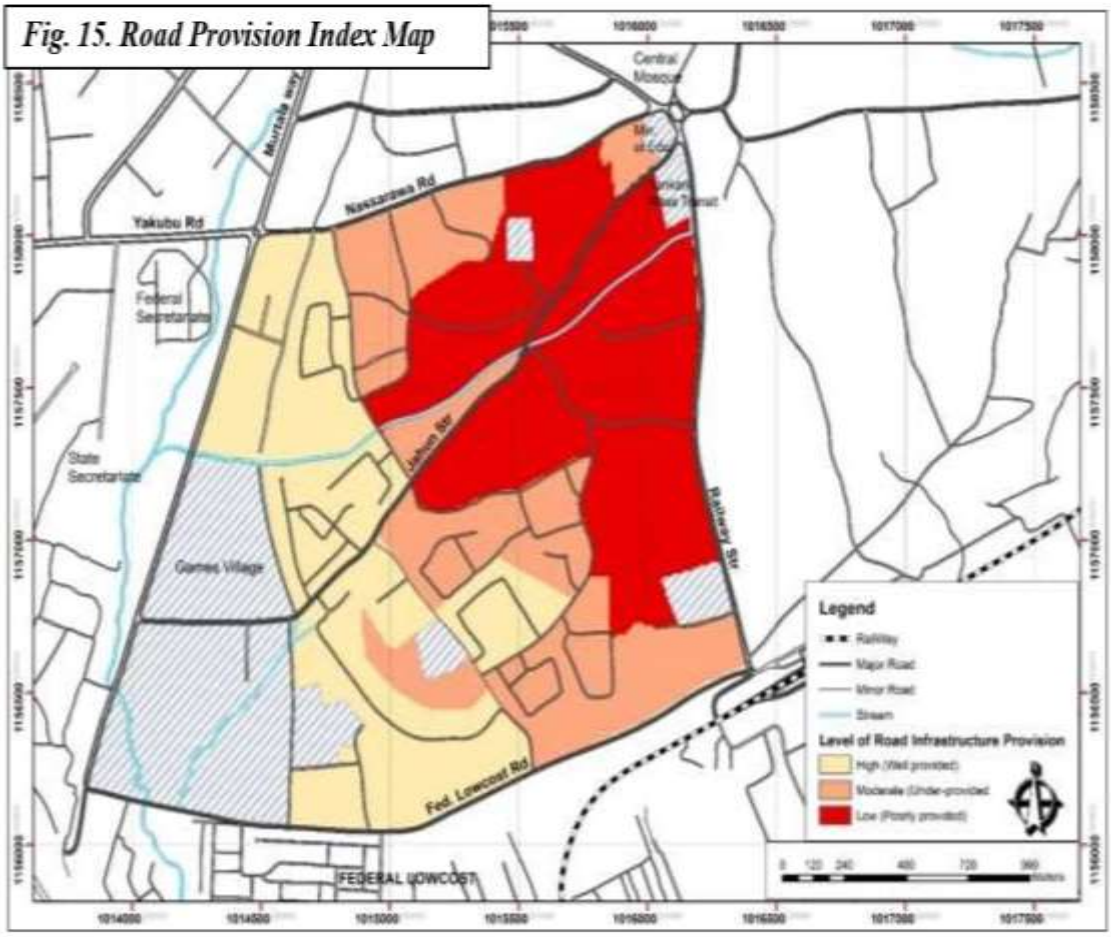
Road Infrastructure Index

The Fig. 25 and Fig. 26, comprise the partial index contained within Fig. 27.

Table 3. Final Road Infrastructure Index Map Key: Exposure to environmental stressors

Map Key		Category	Description
Low		1	A significant number of residential block groups have access to road provision and are benefited by good road drainage.
Moderate		2	Few block groups have no access to road provision and/or are not benefited by good road drainage.
High		3	The majority of the block groups have no access to roads and are not benefited by road drainage.
No data		0	Comprise non-residential buildings, which are not within the scope of the sample frame.

Fig. 15. Road Provision Index Map



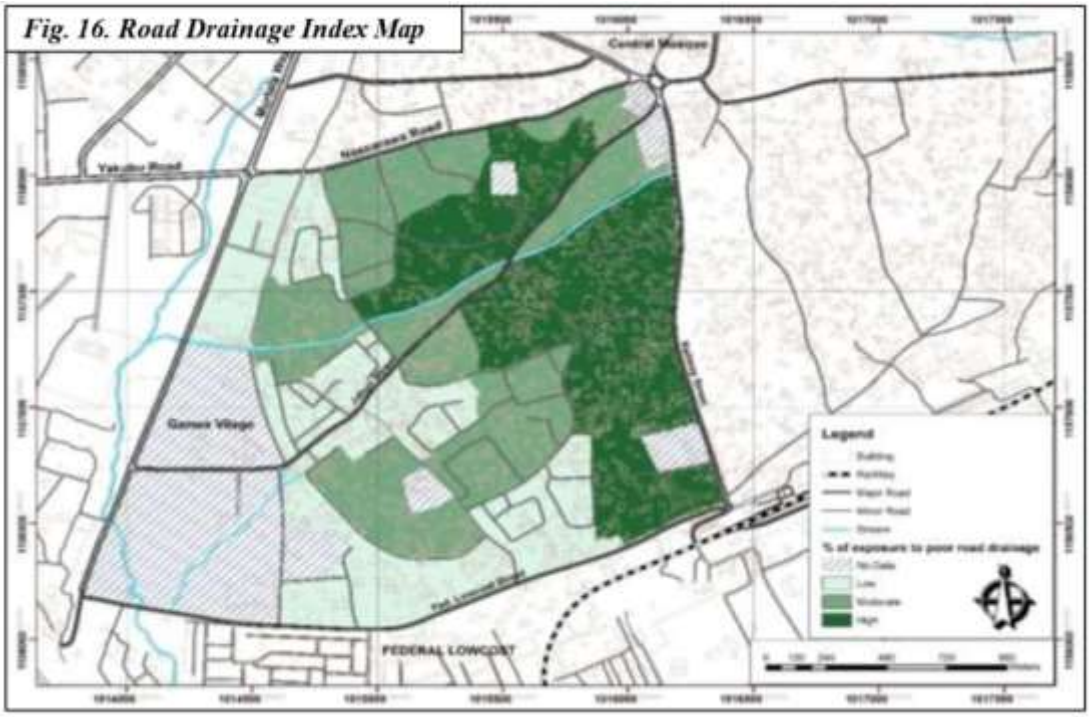


Fig. 16. Road Drainage Index Map

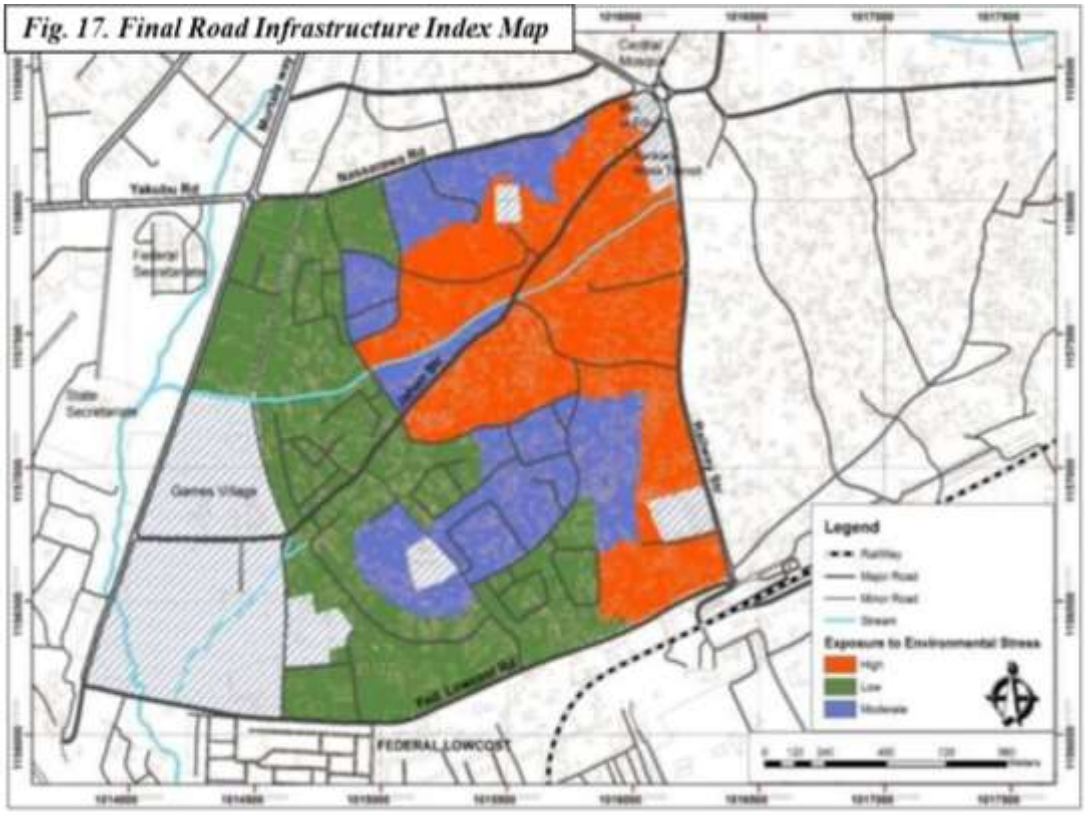


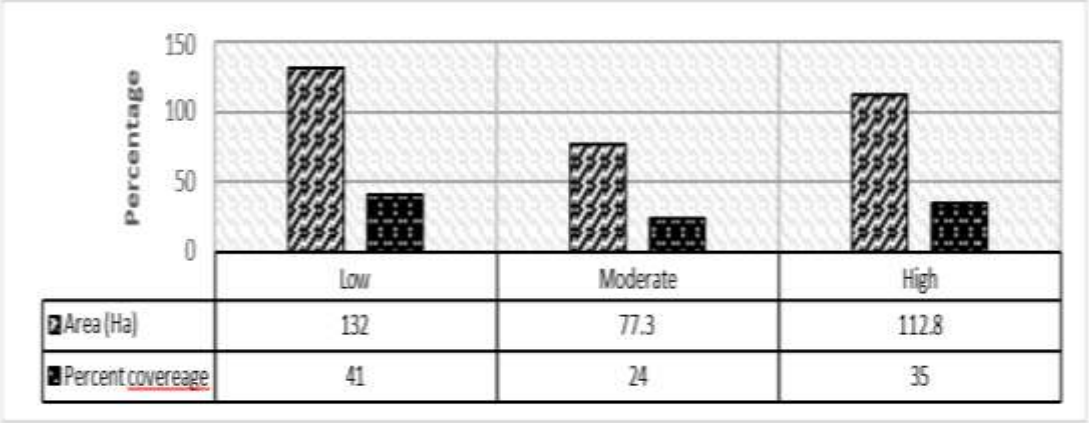
Fig. 17. Final Road Infrastructure Index Map

Access to roads in this study was defined mainly for type-specific use (residential households) to available to the households. Availability of roads provide relative advantages consequent upon which the users locate to enjoy the advantages. A disproportion of this or the very absence of roads for accessibility will amount to environmental stress. The analysis which was carried out for road infrastructure in this Thesis, was based on the percentage of provided roads, accessibility, and the drainage condition of particular roads.

According to the research of the households surroundings characteristics and the group of residential blocks as conducted by the field assistants which surveyed the condition of road drainage, nearly half of the low income areas (36%) is completely devoid of the services of neighbourhood roads as shown in the Fig. above. A Higher percentage of land area is well provided with roads within the high income block groups. Nevertheless, due to the more dense nature of households where the low income group is concentrated, more households throughout the study area are exposed to poorly provided roads.

The analysis of accessibility enlightens the understanding on the provision of roads benefits in urban life. According to the method used, the collected results show that the study area has a substantial deficit in the provision of roads.

Fig. 18. Percentage of residential block groups exposed to the environmental benefit/burden of Road provision and drainage



Healthcare Services Index – HS-I

According to the research of the households surroundings characteristics found in the Bauchi Reviewed Master Plan 2035 and from the field surveys conducted, the presence of public and private Hospitals and Clinics within the RBGs, nearly half of Makama households (49%) is completely devoid of the services of public Hospitals, a deprivation which is shared with the high vulnerability area (low income class) as shown by Fig. 31.

Fig. 19. Percentage of households exposed to the presence/absence of public and private healthcare services in the vicinity

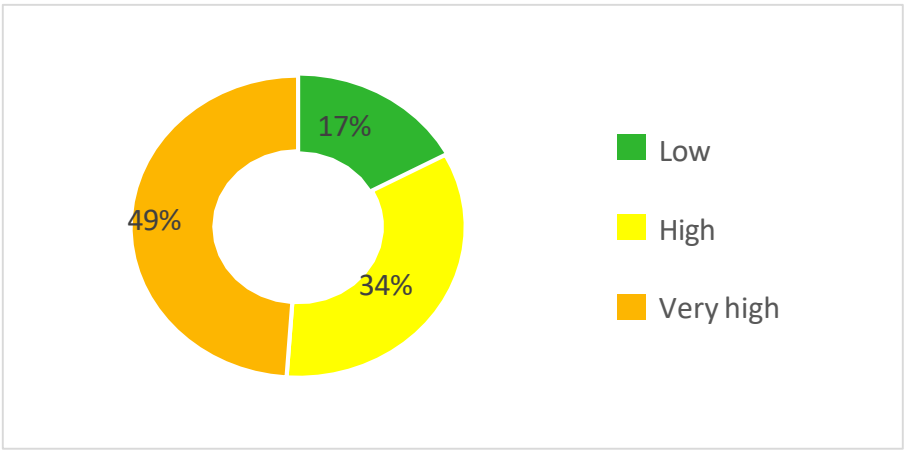
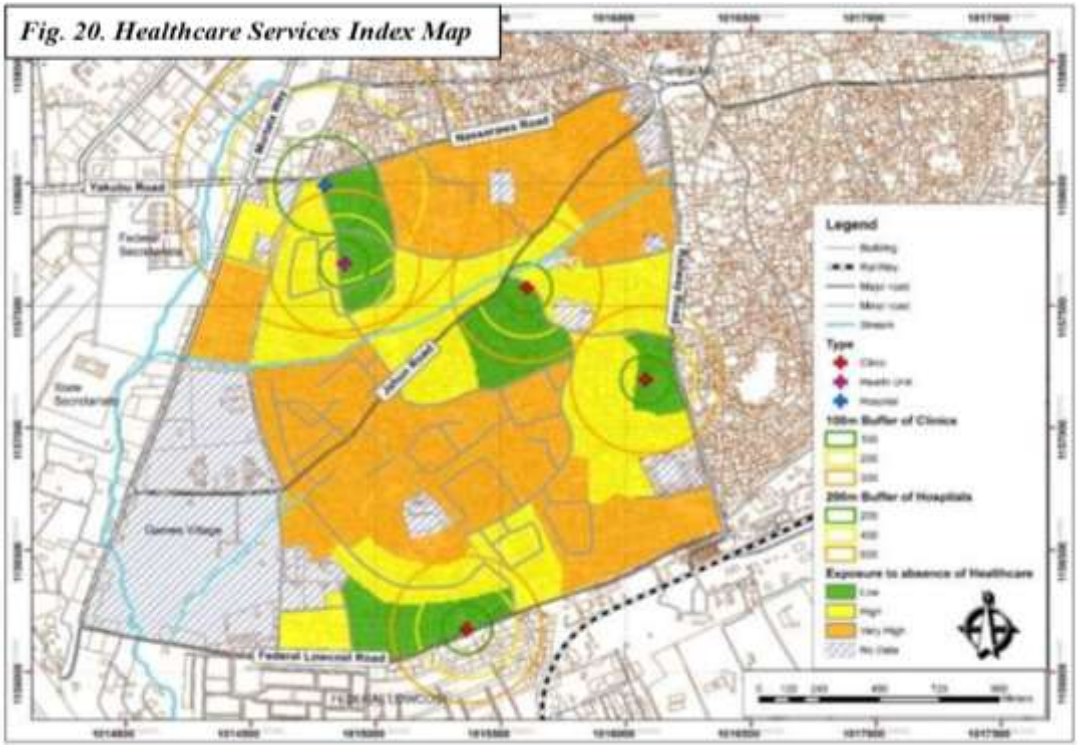


Table 4. Healthcare Services Index Map Key: Exposure to environmental stressors

Map Key		Category	Description
Low		1	Few households have access to healthcare services and benefited by Clinics and a private Hospital.
High		2	A significant number of households have no access to healthcare services and are not benefited by any Clinic or Hospital.
Very high		3	The majority of the households have no access to healthcare services

Fig. 20. Healthcare Services Index Map



Urban Environmental Quality Index

The environmental analysis carried out in RBG level in Makama combined the three partial indices (W-I, WS-I, and RI-I) in order to compose an integrated Urban Environmental Quality Index (UEQ-I). The results gathered for each environmental indicator were spatially depicted and combined to create a synoptic index. The results of the environmental favourability analysis are illustrated in Fig. 8.

Table 5. Urban Environmental Quality Index Map Key

Map Key		Category	UEQ-factor (Number of exposure)
Very Favourable		1	< 2
Favourable		2	2 – 3
Unfavourable		3	4 – 5
Least favourable		4	> 5

Fig. 21. Urban Environmental Quality Index Map

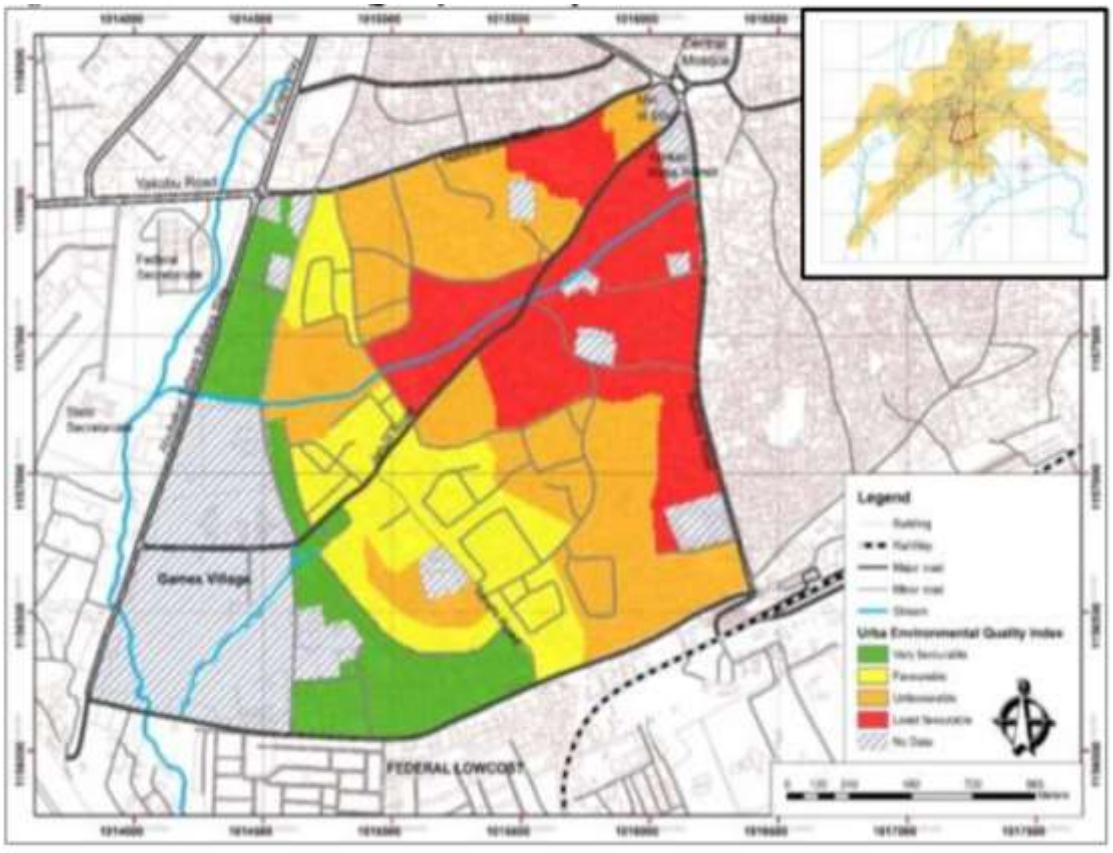
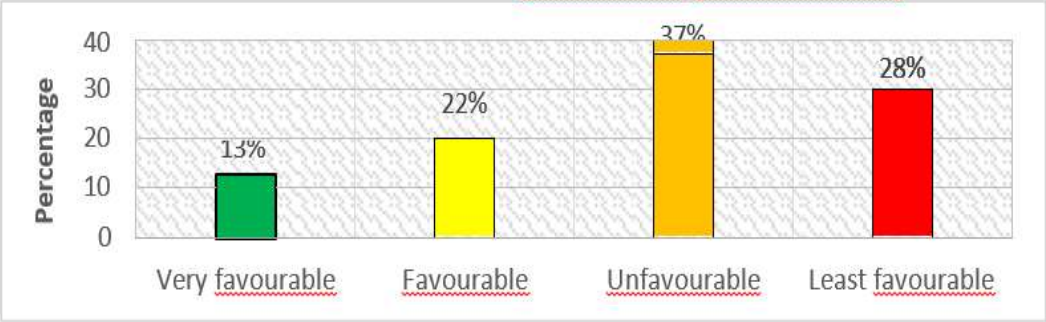


Fig. 22. Households subsumed to favourable/unfavourable Environmental Quality



In order to better understand the characteristics of the dwellers that inhabit the RBGs qualified with the highest rates of environmental quality and also with those who have the worst conditions encountered, they were further reclassified into four (4) categories and then grouped according to the indexed categories. The categories 1 and 2 were grouped to characterize the absence of environmental stressors, while the category 3 and 4 characterized environmental stress and the absence of environmental benefits. Only nine (9) RBGs of the study with a number of eight hundred and sixty three (863) households are classified with absence of the considered environmental stressors, meaning that all other RBGs have more than one environmental burden. Almost all the indices pointed that the lower income area is exposed to high environmental burden and stress.

Social Vulnerability Index (SV-I)

The areas that concentrate the household segments most vulnerable to poverty are mainly located at the eastern corner of the study area. It was observed that although the Makama Ward presents low rates of vulnerability from an overall view, a significant portion of the households live in conditions of very high social vulnerability, meaning that the low income areas are more densely populated.

Table 6. Social Vulnerability Map Key: Exposure to Social Vulnerability

Social Vulnerability	Map Key	Category	Description
Low		1	Few households have a low vulnerability to environmental stressors.
Moderate		2	A significant parcel of households are of a minimum vulnerability.
High		3	The majority of households are highly vulnerable.
No data		0	Comprises non-residential buildings, not within the sample frame.

Source: Self Survey, 2017

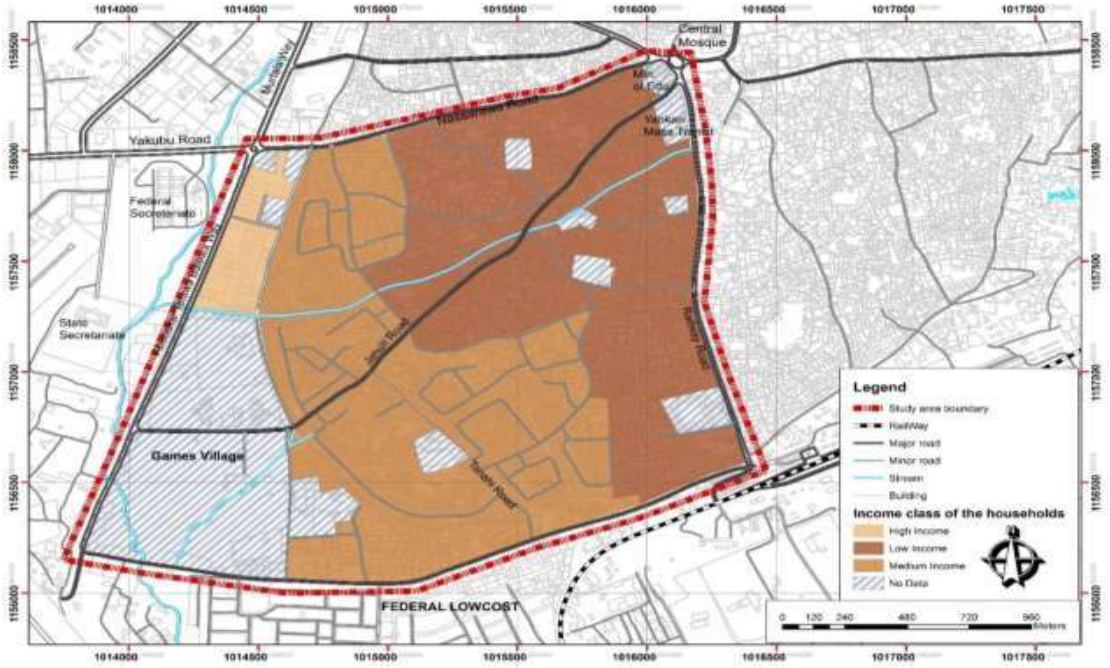
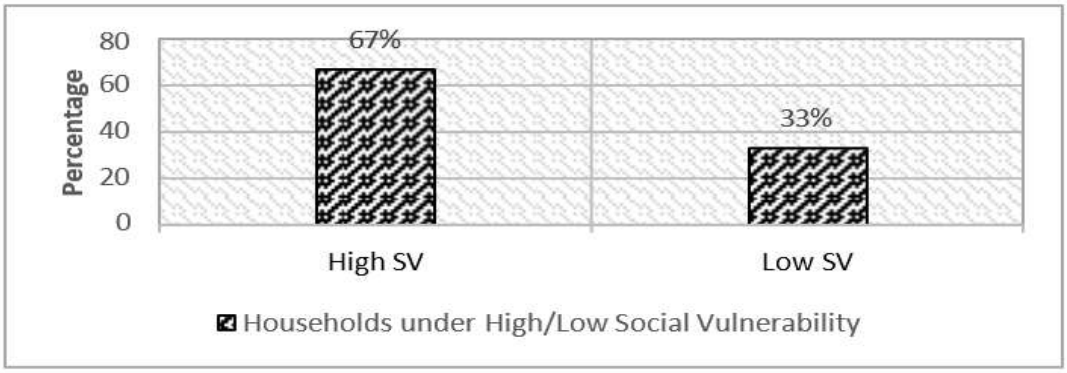


Fig. 23. Social Vulnerability Map

Fig. 24. Percentage of households subsumed to high/low Social Vulnerability



Environmental Justice Index

The results provided by the UEQ-I and SV-I are jointly analyzed in order to verify the pattern in the distribution of income and environmental characteristics. Before generating the EJ- I, an initial integrated analysis of the socio-spatial distribution of environmental burdens and amenities offers insight of the spatial overlap of income classes.

With the purpose of exploring the relationship between low income status and the exposure to contemporary environmental impacts, the created UEQ-I map are crossed with the reclassified SV-I map, thus generating the EJ-I map (Fig. 39).

Table 1. Environmental Justice Matrix Analysis

UEQ-I / SV-I	Very Favourable	Favourable	Unfavourable	Least Favourable
Low				
High				
Very High				

Source: Adopted from Guilherme Henrique Braga Klaussner 2014

Table 2. Environmental Justice Index Map Key

Environmental Justice: Overlaid Environmental Quality Index on the Social Vulnerability Index		
Least favourable		Multiple exposure to environmental stressors within high social vulnerability class.
Unfavourable		Multiple exposure to environmental stressors within high and low social vulnerability class.
Favourable		Few exposure to environmental stressors within high, low, and very low social vulnerability class.
Very Favourable		No exposures to environmental stressors; within the lowest vulnerability class

Source: Field Survey, 2017

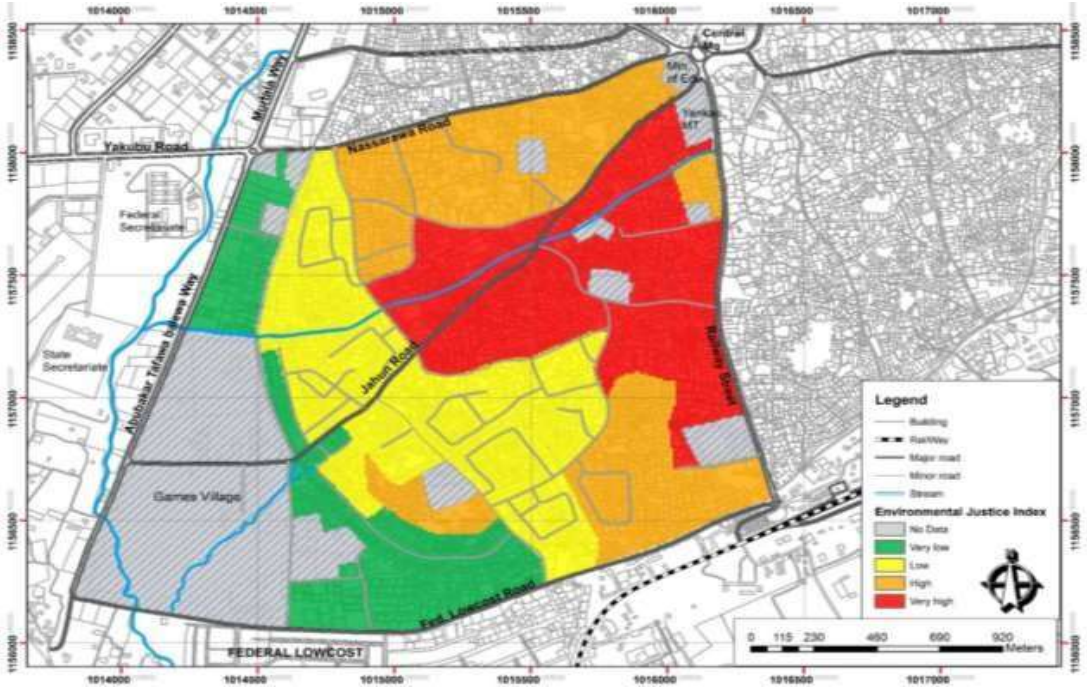
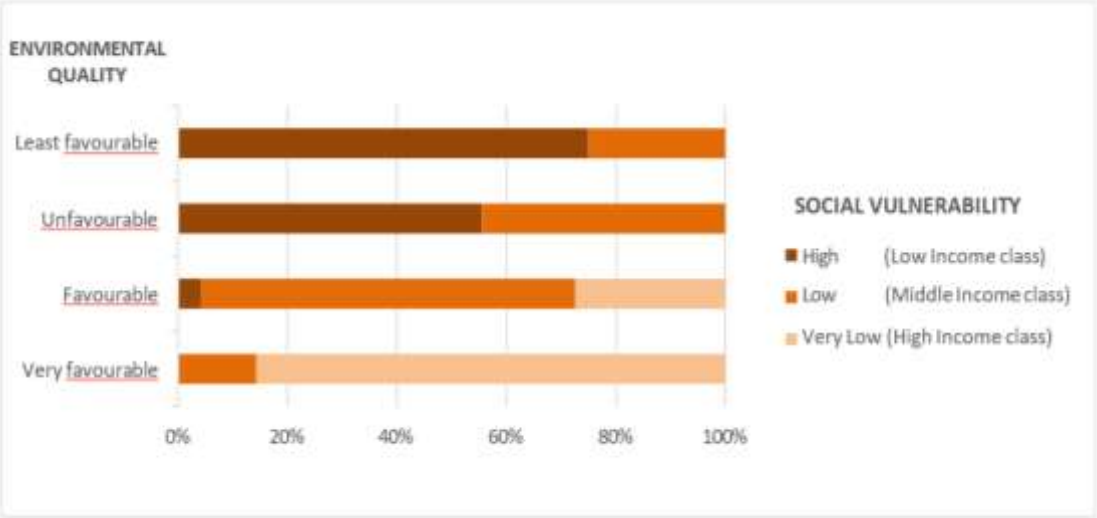


Fig. 26. Environmental Justice Index Composite Map

Fig. 1. Social Vulnerability vs. Urban Environmental Quality: Percentage of Households Exposure per Income Class



Source: Field Survey, 2017

From the group of households in RBGs that are classified as 'Very Low' social vulnerability, comprising the best social sections, more than 80% of the high income group enjoy very favourable environmental quality and only about 5% of the low income group enjoy favourable environmental quality. The opposite is evident when analyzing the high social vulnerability class. Over 70% of this low income class live in the least favourable environmental circumstances while only about 30% of the middle income groups are subsumed under least facourable environmental conditions. There are few RBGs classified as 'high', 'Low' and 'Very Low' social vulnerability that are under the favourable environmental quality and its overlay with the UEQ-I led to a triple-bar result (Fig. 37).

The Fig. 39 highlights the cases where the social vulnerability indices occur as 'High' overlaid on the RBGs classified as 'Unfavourable' and 'Least Favourable' for UEQ-I. This offers insight of where the most environmental injustice cases are located. By overlaying the number of environmental burdens on the social vulnerability data, it is clear that the less favourable and unfavourable environmental quality often overlap the class of high social vulnerability (i.e. the low income class).

The final Environmental Justice mapping clearly identifies a well-defined mosaic of same class Groupings, slightly intermixed. The worst rates of environmental justice are clustered in the east part of Makama Ward spreading across the boundaries to the west ends. One also sees Residential Block Groups with poor rates of environmental justice clustered in the central part of the study area. A spreading pattern of the worst qualified RBGs is noticeable.

As a result of the EJ analysis the following considerations can be woven. Few of the RBGs, precisely those households under the High social vulnerability bear most of the environmental burdens and absence of the basic social amenities investigated. The vast majority of households throughout the Ward is largely deprived of essential environmental services including those of them living along the water stream that divides the studied area in half. Only few households, of the low social vulnerability class, living around the east parts of the study area enjoy a more natural condition and environmental benefits such as clean corridors, well provided roads and drainage treatment for sewage flow. In a general outlook, this characterizes a high urban environmental injustice in Bauchi city.

Summary

Almost half of the high income area enjoy very favourable environmental quality of all the indicators studied. Only very limited parcel of the low-income enjoy favourable environmental quality and suffers from lack of access to majority of the urban amenities studied. In the low- income areas we discovered higher percentage of:

i. Unhealthy open-air sewage
ii. Daily water queuing due to very limited supply
iii. Accumulated waste and absence of collection system.
iv. Poor/complete absence of roads and drainage system
v. Very limited access to Hospitals/Clinics

The highest percentage of poor environmental quality were found in the lower-income areas exposing that there is high level of environmental injustice in Makama Ward.

Discussion

The method and technique used for constructing the Urban Environmental Quality and Environmental Justice indices demonstrated a plain synthesis potential of the socio-environmental context in the study area. Various results have been collected and all support the fact that there is a relationship between low income status and the exposure to contemporary environmental stressors in Makama Ward. Many of the RBGs showed low levels of environmental quality for all analyzed parameters. The range of maps enabled the depiction of spatial spread of social and environmental characteristics in the Ward, thereby fulfilling the third 3rd objective of the study.

The map indices were sufficient to answer the complexity of the spatial spread of the variables studied, thus expressing clearly where social and environmental pressure areas lie. It is thereby impossible to reject the relevance of Environmental Justice as a subject to be highly considered for future research in the field of urban management.

Also, as a derivative study, the necessity of acknowledging the contribution of the techniques that nourish this study cannot be overemphasized. Several different studies were consulted in order to set sufficient balance for the simulation of the index and inserting the subject of EJ into the context of GIS. Thus it was possible to achieve the desired secondary objective three (3).

Conclusion

Using the GIS method to understand the state of EJ in Makama Ward has established an integrated analysis approach that is a key aspect of this research. The index maps were sufficient to expose the complexity of the spatial distribution of the variables that were studied. It enabled the identification of level of disproportions of social and environmental quality in Makama through the range of index maps developed.

The GIS method has proven capable of more adequately expressing interrelationships between urban environmental quality and social class. Similar techniques can be incorporated to provide better technical basis to planners hence achieving just and sustainable urban areas.

Future researches related to EJ should aim at including more other critical indicators of EJ like crimes, sanitation, housing, electricity etc., which are common to developing country especially in Nigeria.

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