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THE INUNDATION EFFECT OF SEA LEVEL RISE ALONG THE BARRIER COAST LAGOS ISLAND USING GEOSPATIAL ANALYSIS

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ABSTRACT

When considering impact studies of low-lying coastal areas, the important factor to evaluate is the state of the sea level in relation to land. Globally, sea level has been rising during the past century. From literatures available, most of the Nigerian coast will face the consequence of one to two(l to 2m) meters rise in sea level, which will result from the effects of climate change, resulting to a catastrophic effect on the human activities in these regions. A Geographic Information System (GIS) was used to examine the impact scenarios that sea level rise will have on both land area and population of the study area with a projected inundation zones. Results showed that there is a significant relationship between the income level and vulnerability to flood of inhabitants. This study provides relevant information concerning the implications of Sea Level Rise, which will be useful for coastal planners and managers to develop a framework to support sustainable development along the barrier islands, the coasts, in the light of rising sea levels. Based on findings, the following recommendations are made in respect to inundation effect due to sea level rise in Lagos Island Local Government of Lagos State. the implementations of planning laws and regulations should be monitored and the construction of additional drainages and adaptation to climate change issues is seriously advised.

KEYWORDS: Inundation, Mitigation, Adaptation, Scenarios

INTRODUCTION

Background of the study

Coastal inundation is the flooding of normally dry, low-lying coastal land, primarily caused by severe weather events along the coasts, estuaries and adjoining rivers. These storms, which include hurricanes and nor'easters, bring strong winds and heavy rains. The winds drive large waves and storm surge on shore and heavy rains raise rivers. A tsunami which is as a result of giant wave caused by earthquakes or volcanic eruptions under the sea or landslides into the sea, is another kind of coastal inundation but should not be confused with storm surge. Storm surge is one of the main causes of coastal inundation; it is the abnormal rise in water level, over and above the regular astronomical tide, caused by a severe storm such as a tropical cyclone or nor'easter. Large waves also raise coastal water levels and ride on top of the storm surge to cause extreme damage.

Barrier island is a long, thin, sandy stretch of land, oriented parallel to the mainland coast that protects the coast from the full force of powerful storm waves. Between the barrier island and the mainland is a calm, protected water body such as a lagoon or bay. In Lagos state the Barrier islands are dynamic systems, constantly on the move, migrating under the influence of changing sea levels, storms, waves, tides, and alongshore currents. In the United States, barrier islands occur offshore where gently sloping sandy coastlines, as opposed to rocky coastlines, exist. Consequently, most barrier islands are found along the Gulf Coast and the Atlantic Coast as far north as Long Island, New York. Some of the better known barrier islands include Padre Island of Texas, the world's longest; Florida's Santa Rosa Island, composed of sugar-white sand; Cape Hatteras of North Carolina, where the first airplane was flown; and Assateague Island near Maryland, home of wild Ponies.

The vulnerability of many of African countries has been discovered to be partly due to their natural susceptibility to extreme climate-related events such as floods, droughts, fires, storms and landslides. The risks were also consequences of the vulnerability of the population, and the inadequacies of existing infrastructure to adapt to or tackle the problem due to weak economies, governance, education and healthcare (Nicholls and Small, 2002).

People do reside near sea-coasts, rivers and in low-lying areas, accounting for about 2/3rd or more of the total population living in urban areas. Coastal areas are disproportionately urban, its population density experiences as much as three times (3x) the average population density. Rural areas in these regions are also much denser than average (McAllister *et al.,* 2005). Therefore, if cities and large cities in particular are coastal, we need to care about climate change in coastal regions.

Inundation events are among the more frequent, costly, and deadly coastal hazards that can impact coastal communities. In fact, riverine and coastal inundation causes the highest number of natural-hazard-related deaths. With coastal States supporting most of the population and generating about 83% gross domestic product, catastrophic loss from inundation events is greater in these States than in other areas of the country. In addition, future inundation risks may be exacerbated by local changes in climate and sea level. It is therefore important to know that the current inundation risks so as to understand the potential effects of changing conditions.

Aim

The aim of this research is to examine the impact scenarios that sea level rise will have on both land area and population of the study area. The objectives include;

i. Assess the socio-economic characteristics of the inhabitants and the extent of vulnerability to inundation.
ii. Simulate sea level rise scenarios with the aim of identifying inundation zones.

MATERIAL AND METHODS

Study area

Lagos Island is the principal and central local government area of the Metropolitan Lagos in Nigeria. It is part of the Lagos Division. As of the preliminary 2006 Nigerian census, the LGA had a population of 209,437 in an area of 8.7 km^2. It is located at latitude 6°25'N to 6°27'N and longitude 3°23'E to 3°25'E. The LGA only covers the western half of Lagos Island; the eastern half is under the jurisdiction of the LGA of Eti-Osa.

Lying in Lagos Lagoon, a large protected harbor on the coast of Africa, the island was home to the Yoruba fishing village of Eko, which grew into the modern city of Lagos. The city has now spread out to cover the neighboring islands as well as the adjoining mainland.

Lagos Island is connected to the mainland by three large bridges which cross Lagos Lagoon to the district of EbuteMetta. It is also linked to the neighboring island of Ikoyi and to Victoria Island. The Lagos harbor district of Apapa faces the western side of the island. Forming the main commercial district of Lagos, Lagos Island plays host to the main government buildings, shops and offices. The Catholic and Anglican Cathedrals as well as the Central Mosque are located here

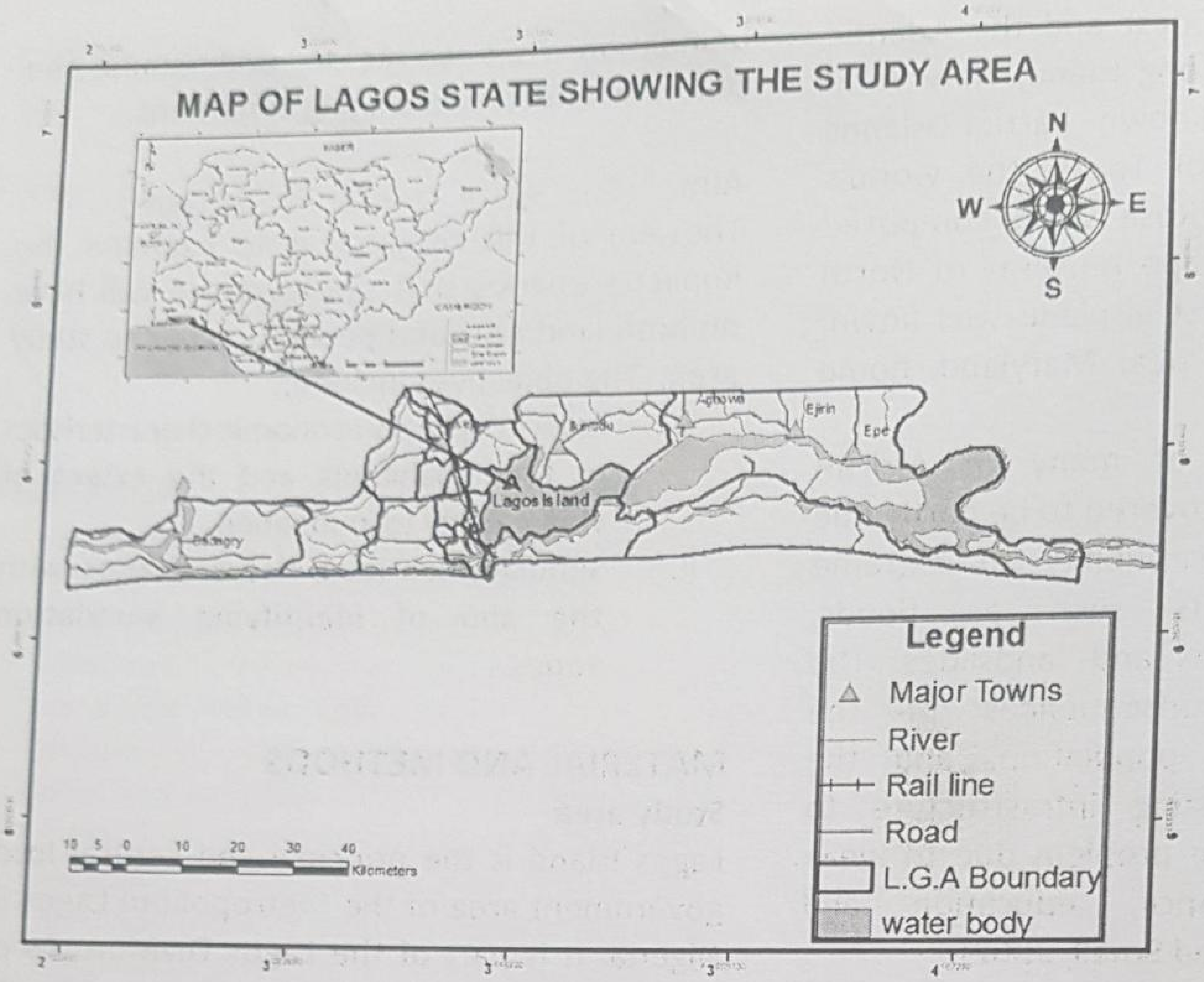

Figure 1: Study Area
Source: Digitized by author using Arc Map (2015)

Historically, Lagos Island (IsaleEko) was home to the Brazilian Quarters of Lagos where the majority of the slave trade returnees from Brazil settled. Many families lived on Broad Street in the Marina. The poorer eastern side of the island contains the main markets and the poorer housing. The island is extremely crowded and congested and attempts have been made to build new roads out over the lagoon in order to improve traffic flows (Ibe, 1990).

Climate system
In the Köppen climate classification system, Lagos has a tropical wet and dry climate (Aw) that borders on a tropical monsoon climate (Am). Lagos experiences two rainy seasons, with the heaviest rains falling from April to July and a weaker rainy season in October and November. There is a brief relatively dry spell in August and September and a longer dry season from December to March. Monthly rainfall between May and July is over 400 mm (16 in), while in August and September it is down to 200 mm (7.9 in) and in December as low as 25 mm (0.98 in). The main dry season is accompanied by harmattan winds from the Sahara Desert, which between December and early February can be quite strong. The highest maximum temperature ever recorded in Lagos was 37.3 °C (99.1°F) and the minimum 13.9 °C (57.0 °F).

Types and sources of data collection
Two methods of data collection were used in this research:

(a) **Primary sources of data collection:** Primary data were collected directly from the field and it includes physical observations, questionnaire and oral interview. Also information on their socio-economic was collected through primary field survey.

(b) **Secondary sources of data collection:** This involves data sourced from relevant literature materials which include: periodicals, maps on geographical, political, historical settings. Acquisition of relevant topographic maps of the study area were obtained from relevant authorities, ministries, departments, agencies and organizations.

Instrument for data collection

Structured questionnaires was prepared and administered to the residents of Lagos Island for the purpose of generating their responses arising from rising sea level along the barrier coast and its related problems.

- **Questionnaire administration**: This mechanism of data collection was initiated to be substantial for this study given the nature of the study area. In other words, important data needed for this study were obtained through the administration of questionnaires. Questionnaire was structured in order to achieve the objective one of the research work.
- **Personal/field observation:** This is where firsthand information relevant to the objectives of the work is obtained in the study area, it involve personal interview about the rising sea level in the area.
- **Geographical positioning system (G.P.S):** The field survey aspects involve the use of GPS to capture the geographical coordinates of the prone areas, with computer assisted surveying method the coordinates were used to develop Digital Elevation Model (DEM). Satellite imagery of Lagos Island was used, the positions in terms of X and Y coordinates of the area will be captured and reference on the map before on-screen digitization in order to provide flood prone map of the study area
- **Photography:** The field work involved the use of digital camera to present images of the study area. This was to support the study to display evidence about flood prone areas.

METHODS OF DATA ANALYSIS

Sampling procedure

The population of the area as project by (NPC, 2015) was 23,268. Population of the study area was used as sample frame for this research. Sample size was calculated from the total population using the National Average household size. Systematic random sampling was used to distribute the questionnaire at an interval of fifth house. Therefore; 23,268 / 6.7 was 3,473. This was used to estimate the sample size of l0% which is $\frac{10}{100}$ x 3,473 = 348, based on which 350 questionnaires were prepared and administered.

Geographical information system (G.I.S) mapping techniques

The mapping depend on the use of computer-assisted interpretation of Satellite imagery. Field survey was carried out to compliment the imagery; GPS coordinates were captured in the field to enable the GIS techniques to develop the terrain model of the area. Buffer width recommended by Palfrey and Bradley, (2002) was used to provide a buffer zone along the sea. This was performed to obtain, document and building sea level rise scenarios and assessment to identify inundation zones in the area. Quick bird High Resolution Satellite imagery map was used for physical identification of communities. Captured coordinates was referenced on the imagery and it enabled Identification of barrier coasts and delineation.

Simple frequency statistics was used to analysis the data collected. The Statistical Package for Social Sciences (SPSS) application software's was used for analysis.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of the Inhabitants

The household's occupation and the result are presented below in Figure 2 below. The study area is inhabited notably by traders (35.2%) and students (24.2%) and this invariably reflects the nature of the occupants of the environment

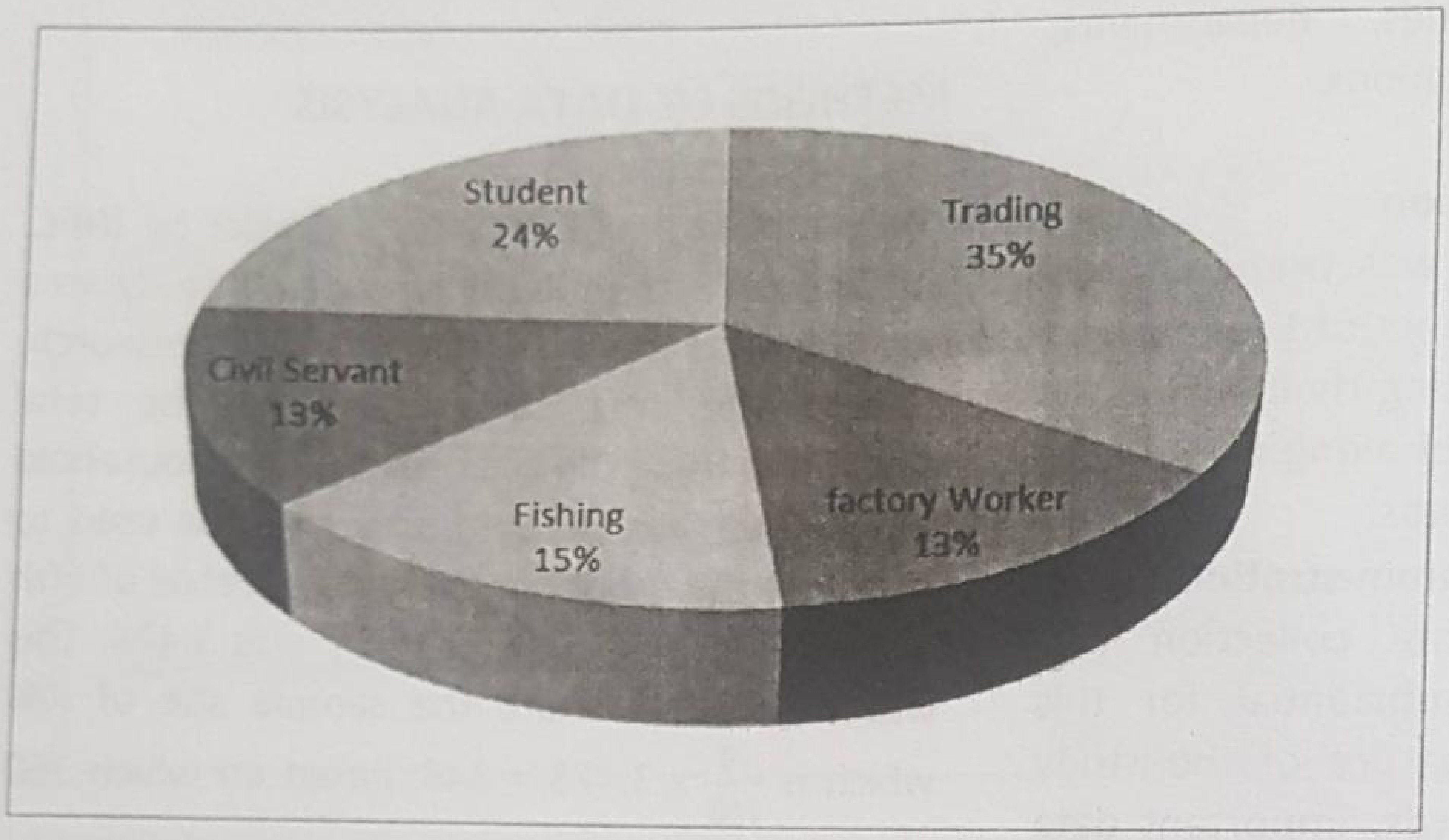

Figure 2: Occupation of the respondents

Source: Field Survey, 2015

The Figure 2, shows that the majority of the respondents are majorly engaged in trading 35.2%, 14.25% of them are fisher men, 13.2% of them are factory workers while 13.3% are also civil servant and 24.2% are students.

Figure 3 shows that respondent in the community earns a meager amount as salary. It was obtained that 34.1% earned below N18, 500, 31.9% (N18, 501-N22, 500), 6.6% (N22, 501-N30, 500), 4.4% between N30, 501 and N70, 000 and 2% above N70, 000. This revealed that the study area is notably inhabited by people of low income which could be classified as urban poor.

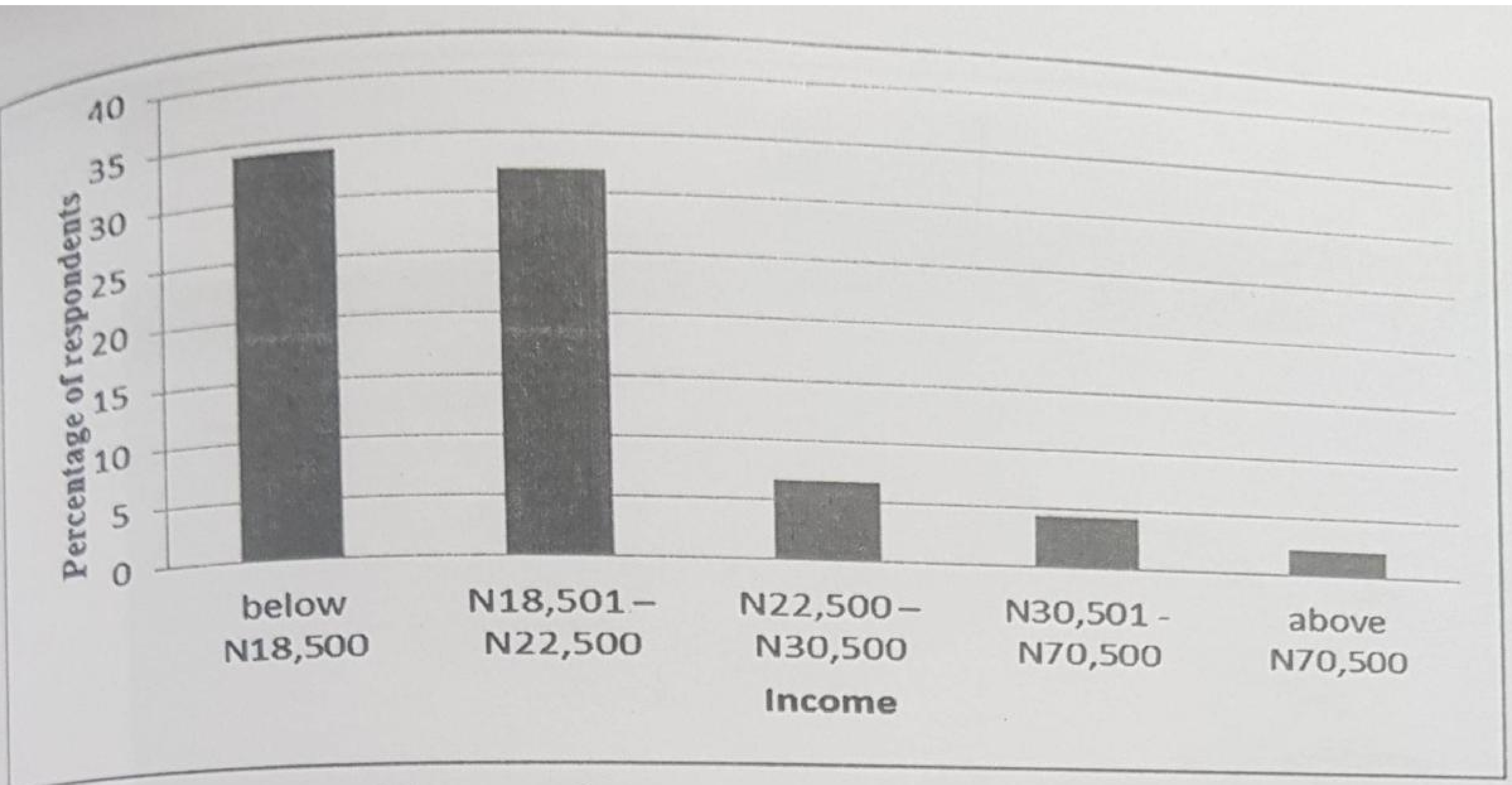

Figure 3: Monthly Income of the respondents

Source: Field survey, 2015

Environmental condition and flooding

Waste water channeling is poor in Lagos Island due to the fact that most of the roads are mostly ungraded and untarred thereby causing most of the drains in the housing plots to be channeled directly on the road. 47.3% of the respondents have poor drainages while 18.7% have good drainage.

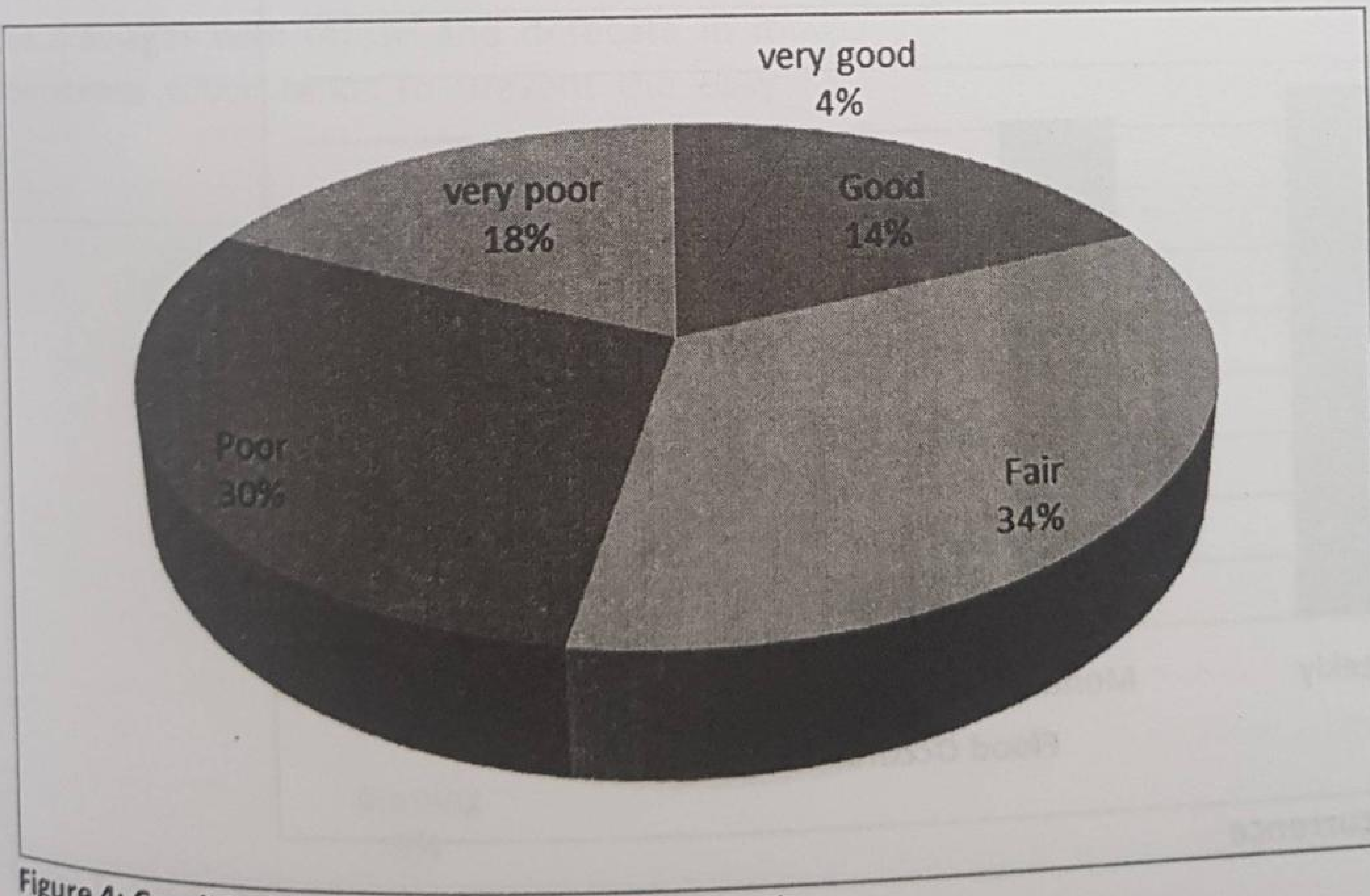

Figure 4: Condition of the environment (Flooding)
Source: Field Survey, 2015

Plate 1: Properties and access road submerged by flood
Source: Field Survey, 2015

Figure 5, it can be seen that flood often occurs during the raining season in the study area. From the analysis above, the prevalent is weekly (42.9%) and monthly (40.7%). This, however, shows that the environment is prone to flood.

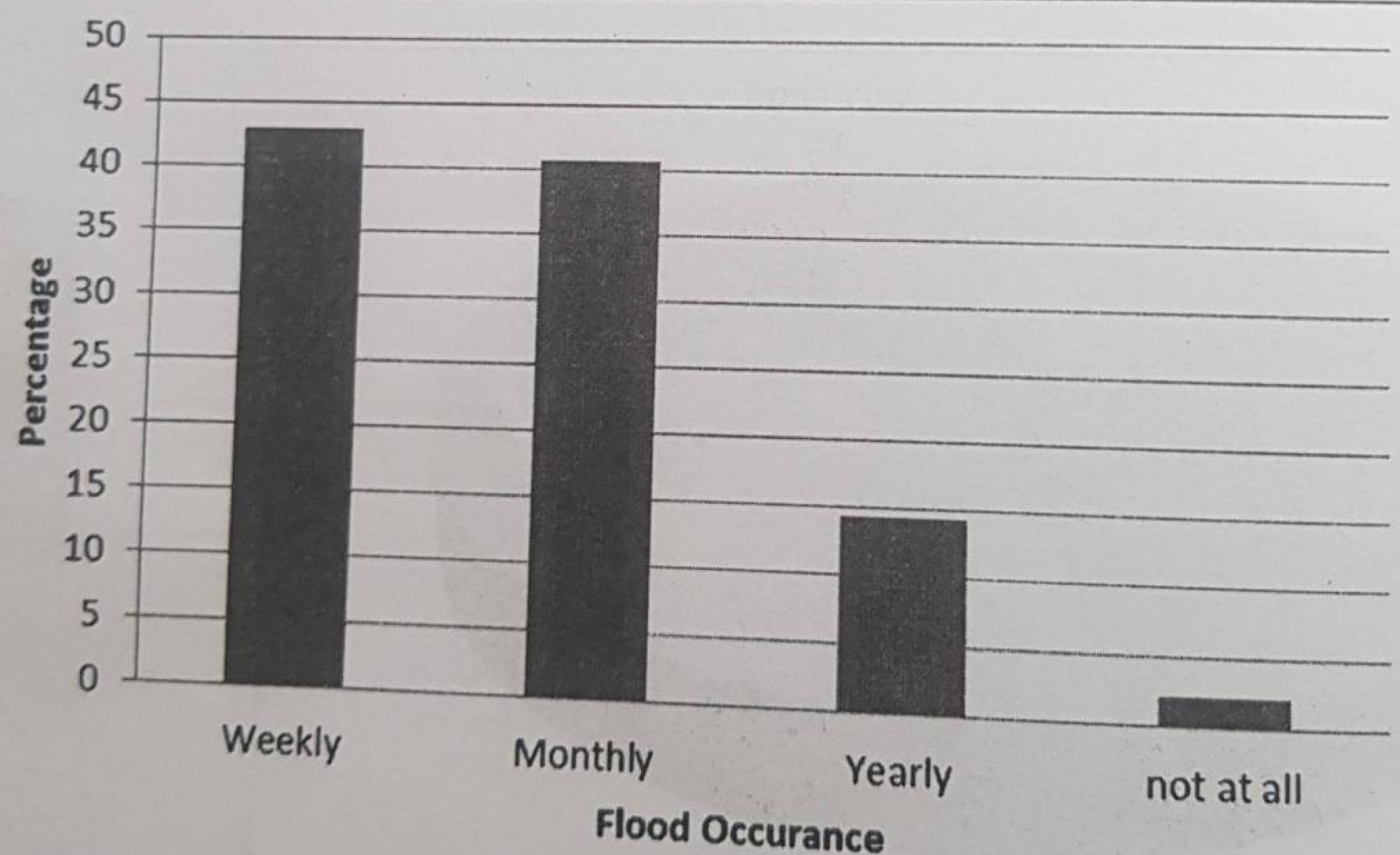

Figure 5: Flood occurrence

The analysis in Figure 6 indicates that 85.7% of the respondents depend on medicine stores for their health care, while 7.7% depends on hospital and 6.6% on clinic. This reveals that there is no adequate healthcare service in the study area.

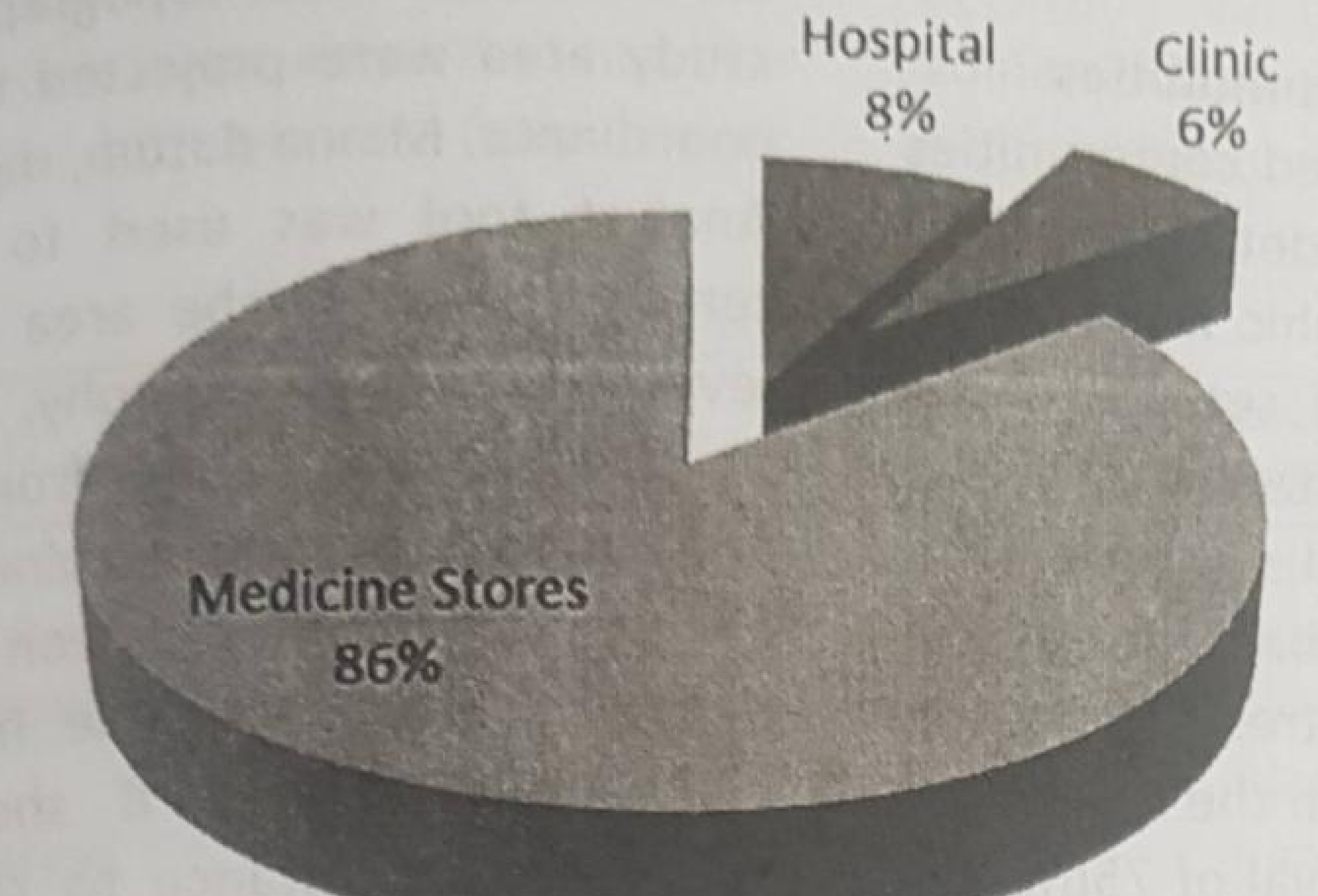

Figure 6: **Health Care Serices**
Source: **Field Survey, 2015**

From Figure 7, Majority of the drainages in good condition are majorly those along the minor roads while the others in fair and poor condition are those along the major roads. This is so because most people tend to litter the drainages with refuse and defecate in it sometimes which tends to prevent the easy flow of water. However about 54% of the city's waste are properly disposed off via appropriate waste disposal agencies, considerate efforts are being made to repair these drainages both by the government and people of the area.

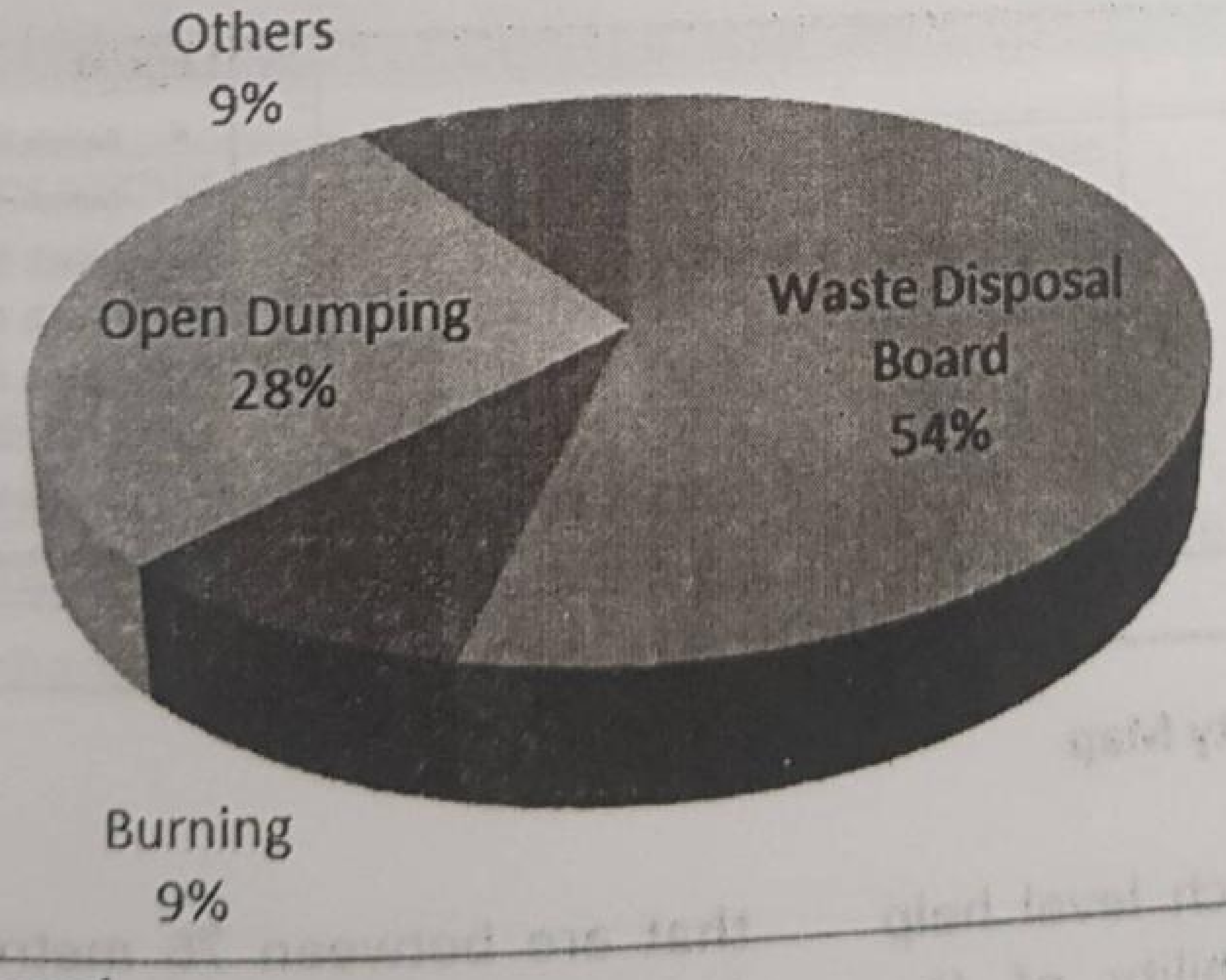

Figure 7: Waste Disposal
Source: Field Survey, 2015

Identifying Inundation Zones through Sea Level Rise Scenarios

Inundation vulnerability of communities

In order to identify the selected communities within high risk areas and to determine their level of vulnerability, Geographic Information System was used. A standard setback of 75 metres was used to create buffers around the water bodies using ArcGIS 10.1 software. The Town planning standard setback from the Atlantic Ocean was 150 metres, from the lagoon was 75 metres and from the creek was 30 metres. Therefore, an interval of 75metres was used to divide the study area's distance from water bodies into 5 levels. These levels were then scored to be able to determine quantitatively the level of vulnerability of the communities. Also, topographic sheets of the study area were projected to the geographic coordinate, Minna datum, digitized and the 3D Analyst tool was used to create a digital terrain model of the area into vulnerability levels based on topography.

The values obtained from the two criteria are added to obtain a vulnerability index for each of the communities on a scale of 0-10, 10 depicting areas with the highest degree of vulnerability. Figure 8 shows the various communities' distance to surrounding water bodies such as the Atlantic Ocean, Omu creek and the Lagos Lagoon.

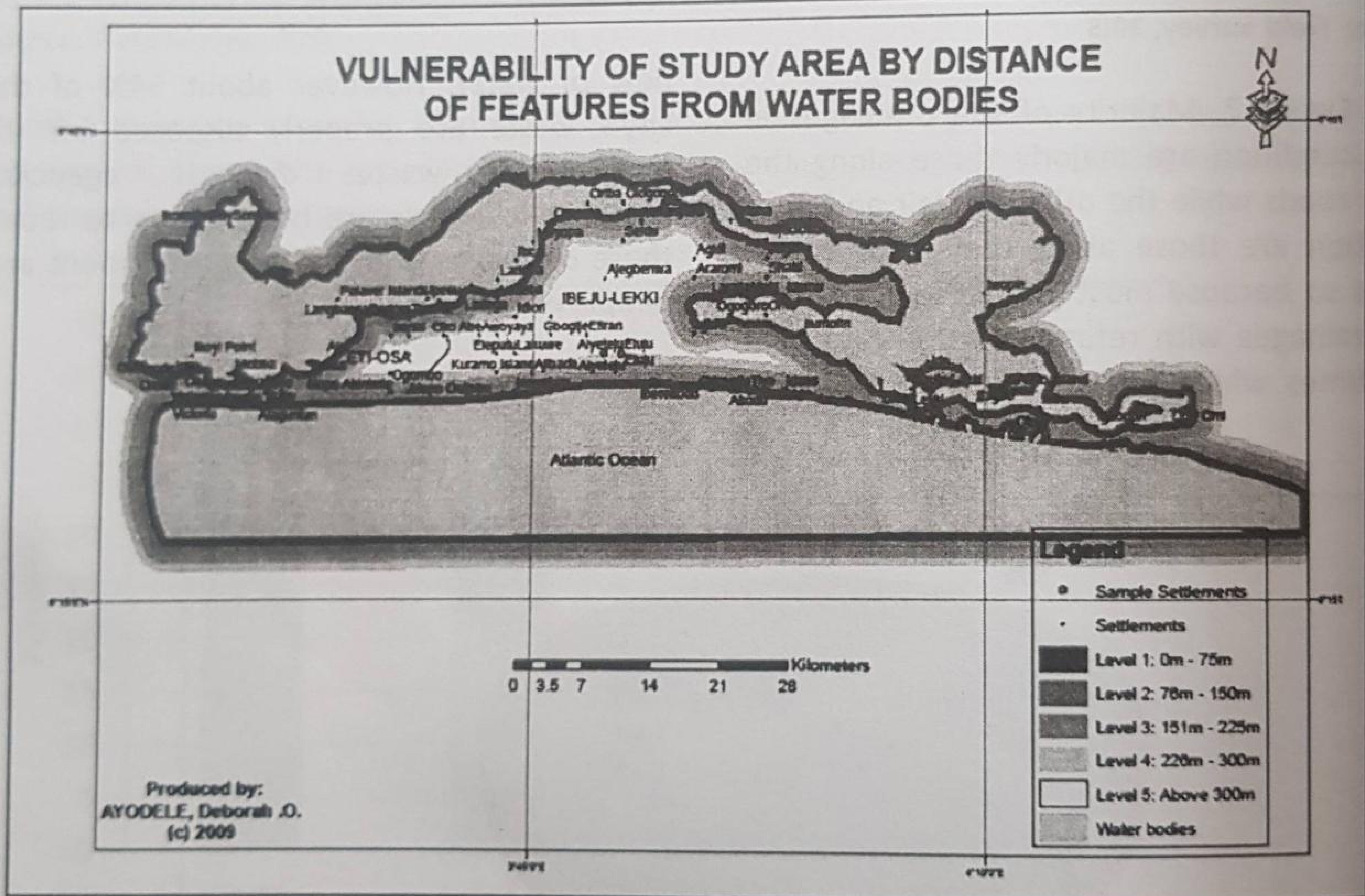

Figure 8: Sea Inundation Vulnerability Map

Communities that fall within each level help determine the overall vulnerability of the region. Level I comprises those areas that are between 0 metres and 75 metres from any water body. Level 2 comprises those areas that are between 76 metres and 150 metres from any water body. Level 3 comprises those areas that are between 151 metres and 225 metres from any water body. Level 4 comprises areas that are between 226 metres and 300 metres from any water body.

Level 5 comprises those areas that are at a distance of above 300 metres from water bodies. Table 1: Gives a tabular representation of the various settlements and their vulnerability levels according to their distances from water bodies.

S/N	Level I (0-75m)	Level 2 (76-150m)	Level 3 (151-225m)	Level 4 (226-300m)	Level 5 (Above 300m)
1	Tiye	Umanyure	Shabi	Seidu	Shangotedo
2	Ikorodu Bay	Tawmu	Maiyegun	Oregun	Oko Abe
3	Refuge Island	Oroke	Ajibade	Kuramo Island	Oguntedo
4	Palava Island	Moshere Ikoga	Araromi	Iranla	Ogombo
5	Orisha	Mpop Onijebu	-	-	Lakuwe
6	Orimedu	Mopo Akinlade	-	-	Idiore
7	Oriba	Maroko	-	-	Gbogiji
8	Orepete	Magbon	-	-	Eluju
9	Omu	Ladeba	-	-	Eleputu
10	Ologogoro	Jinadu	-	-	Efiran
11	Okunegun	Jaguna	-	-	Awoyaya
12	Okepe	Ogoyo	-	-	Ararami
13	Ojulokun	Ilado	-	-	Arapagi
14	Ofin	Ikuata	-	-	Ajebenwa
15	Ode Omi	Ikate	-	-	Agidi
16	Moyopa	Igoro	-	-	-
17	Mobido	Idomu	-	-	-
18	Meki	Ide	-	-	-
19	Lekki	Idaso	-	-	-
20	Lngbosa	Badore	-	-	-
21	Lamija	Victoria Island	-	-	-
22	Ladeba	-	-	-	-
23	Ladega	-	-	-	-

Table 1: Communities within each inundation vulnerability zones
Source: Authors' GIS analysis

The above results show that 50.5% (more than half) of the study area has very high vulnerability to the coastal hazards resulting from climate change, 23.1% has high vulnerability, and 4.4% has moderate vulnerability, while 17.6% of the area has very low vulnerability. This is illustrated in Figure 8.

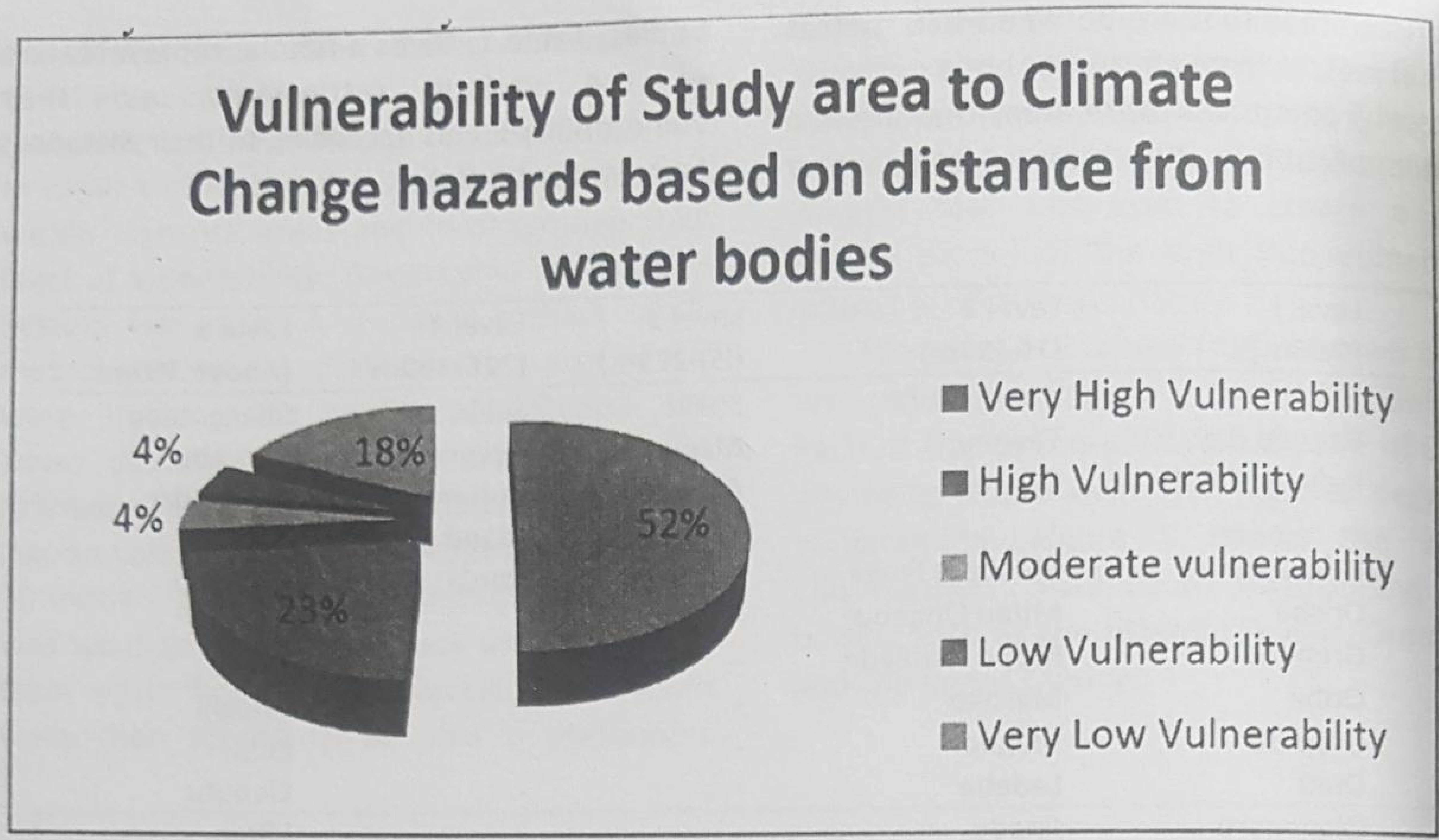

Figure 9: Vulnerability levels of the communities from water bodies

Source: Field Survey, 2015

Height of the area above sea level

This involves using topography as a factor that increases the vulnerability of the coastal community under study to coastal hazards. The area under study is on the average below sea level. Digital terrain modeling was used to determine the topography of the area i.e. the height of different places above sea level.

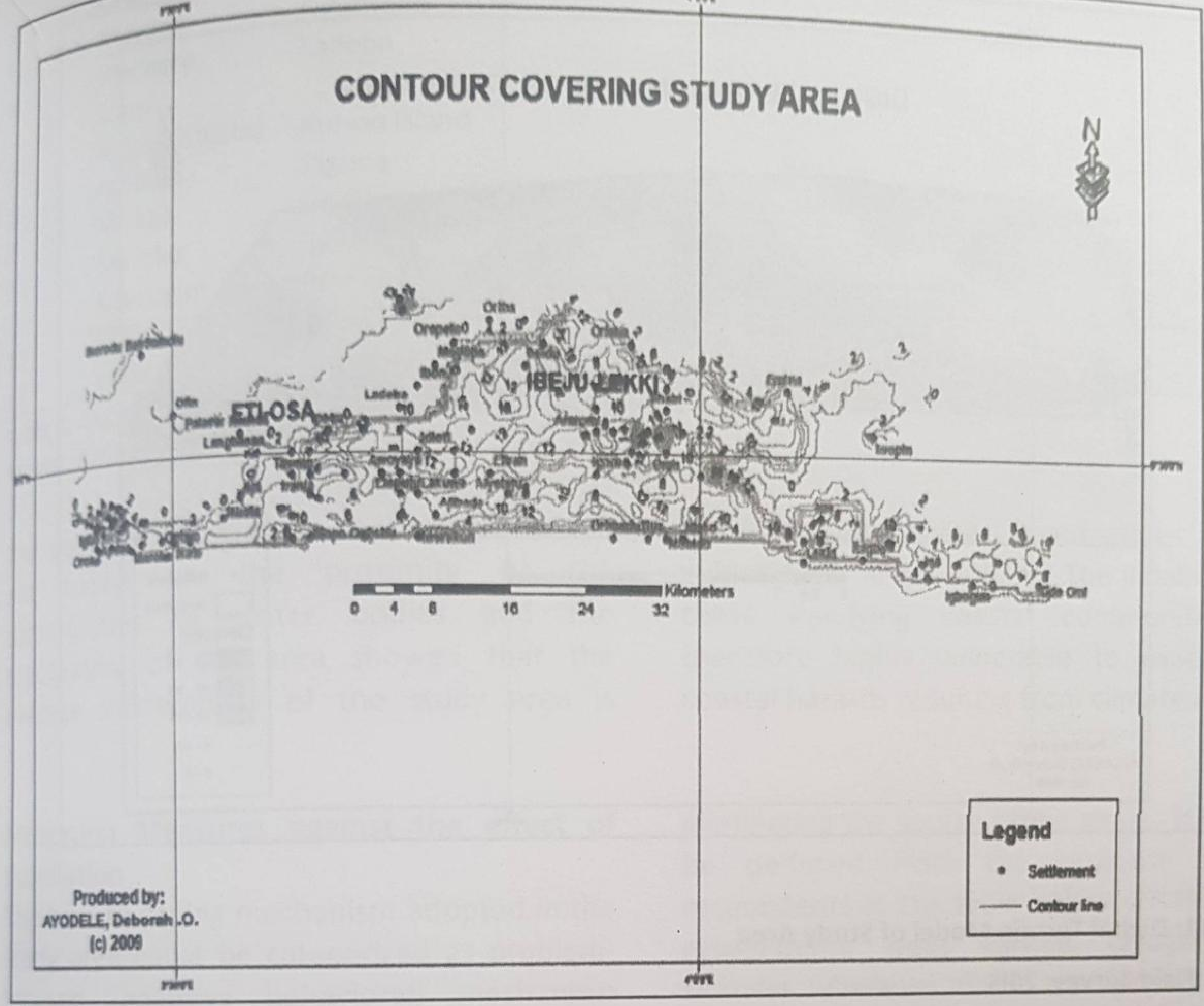

Figure 10: Contour Covering Study Area

Source: Field Survey, 2015

Figure 10 shows the contour of the study area which was used to generate the region's digital terrain model of figure 4.10. From the digital terrain model of the study area the regions were divided into 5 different levels based on their heights above sea level.

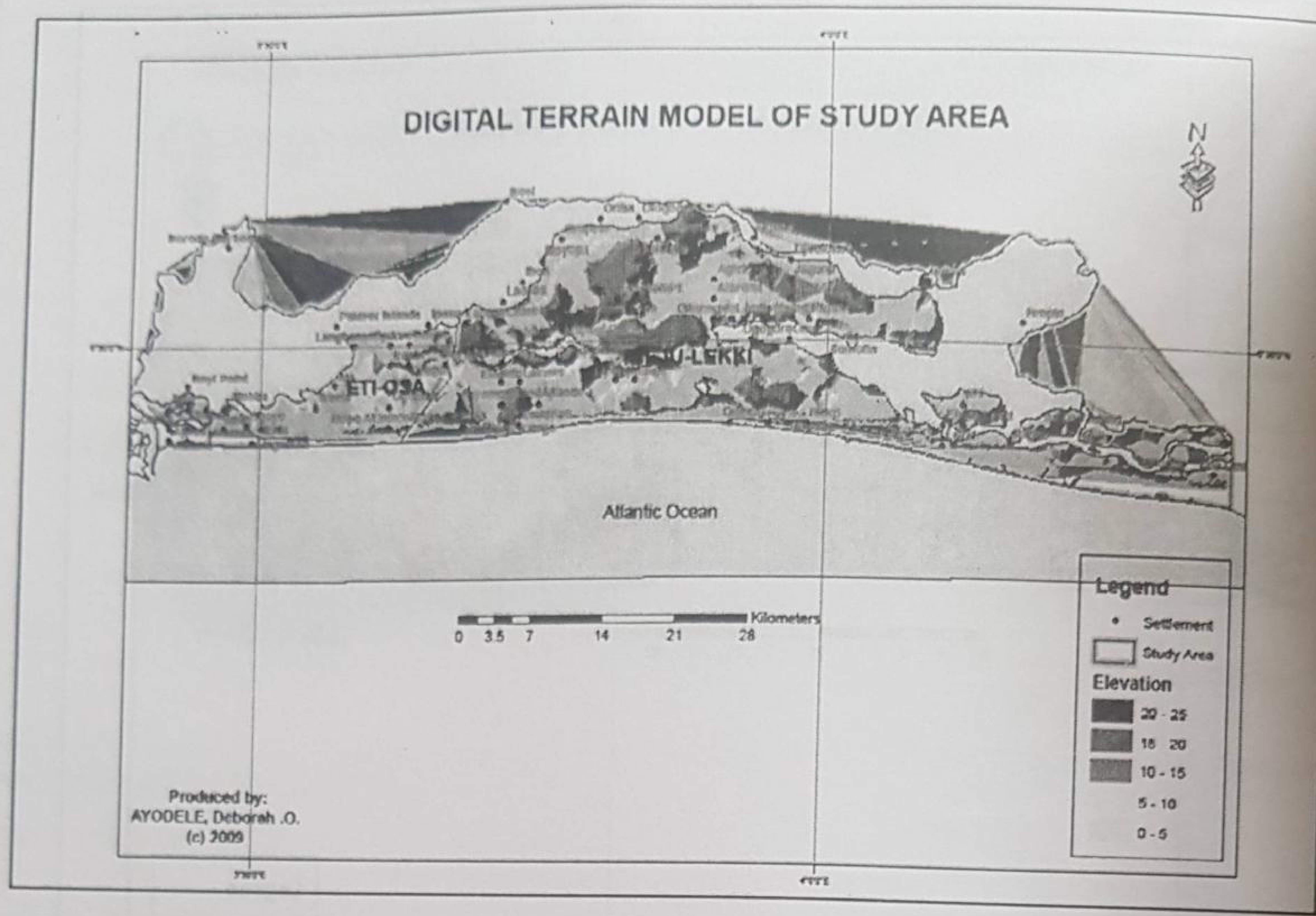

Figure 11: Digital Terrain Model of Study Area

Source: Field Survey, 2015

From the contour of the study area (Figure 11), the digital terrain model of the study area was obtained from which the study area was divided into 5 different levels based on their heights above sea level. It is clearly distinguished in the Table 2.

S/NO	Level1 (0m-5m)	Level 2 (5m-10m)	Level 3 (10m -15m)	Level 4 (15m -20m)	Level 5 (20m-25m)
1	Victoria	Umanyure	Seidui	-	-
2	Tiye	Tawmu	Ogogoro	-	-
3	Ikorodu Bay	Ojuolokun	Iluomofin-Ikosi	-	-
4	Shangotedo	Ogombo	Arapagi Oloko	-	-
5	Refuge Island	Ode Omi	Ajegbenwa	-	-
6	Palaver Island	Mopo Akinlade	Aiyeteju	-	-
7	Oroke	Meki	Agidi	-	-
8	Orimedu	Lamija	-	-	-
9	Oriba	Lakuwe	-	-	-
10	Orepere	Ladega	-	-	-
11	Ologoforo	Shabi	-	-	-
12	Oko Abe	Risha	-	-	-
13	Okpa	Omu	-	-	-

	Ofin	Okunegun	-	-	-
14	Mayopa	Oguntedo	-	-	-
15	Moshere	Ladeba	-	-	-
16	Ikoga				-
	Mopo Onijebu	Kurmo Island	-	-	
17	Mobido	Jaguna	-	-	-
18	Mobba	Ita Oko Island	-	-	-
19	Maroko	Igoro	-	-	-
20	Maiyegun	Idomu	-	-	-
21	Magbon	Idiori	-	-	-
22	Lekki	Ide	-	-	-
23					-

Table 2: Vulnerability of the communities based on their height above sea level
Source: Authors' GIS analysis

The vulnerability analysis of the area carried out based on the proximity of the communities to water bodies and the topography of the area showed that the average vulnerability of the study area is 83.5%, with some communities having vulnerability levels of 100%. The inhabitants of these low-lying coastal communities are therefore highly vulnerable to exacerbated coastal hazards resulting from climate change.

Mitigation Measures against the effect of Inundation

The type of coping mechanism adopted in the study area could be categorized as problem-focused (adaptive behavioral) mechanism whereby people using problem-focused strategies in dealing with the cause of their problem. They do this by finding out information on the problem and learning new skills to manage the problem. Problem-focused coping is aimed at changing or eliminating the source of the stress. This could be deduced from the response of the respondents in the table below. 37.4% of the respondents treat various categories of sickness whenever there are flooding in the area while 34.1% engaged in clearing of drainages so as to allow passage of run-off water. However, 12% of the respondent relocates for a while or look for other means of coping till the flooding subsides.

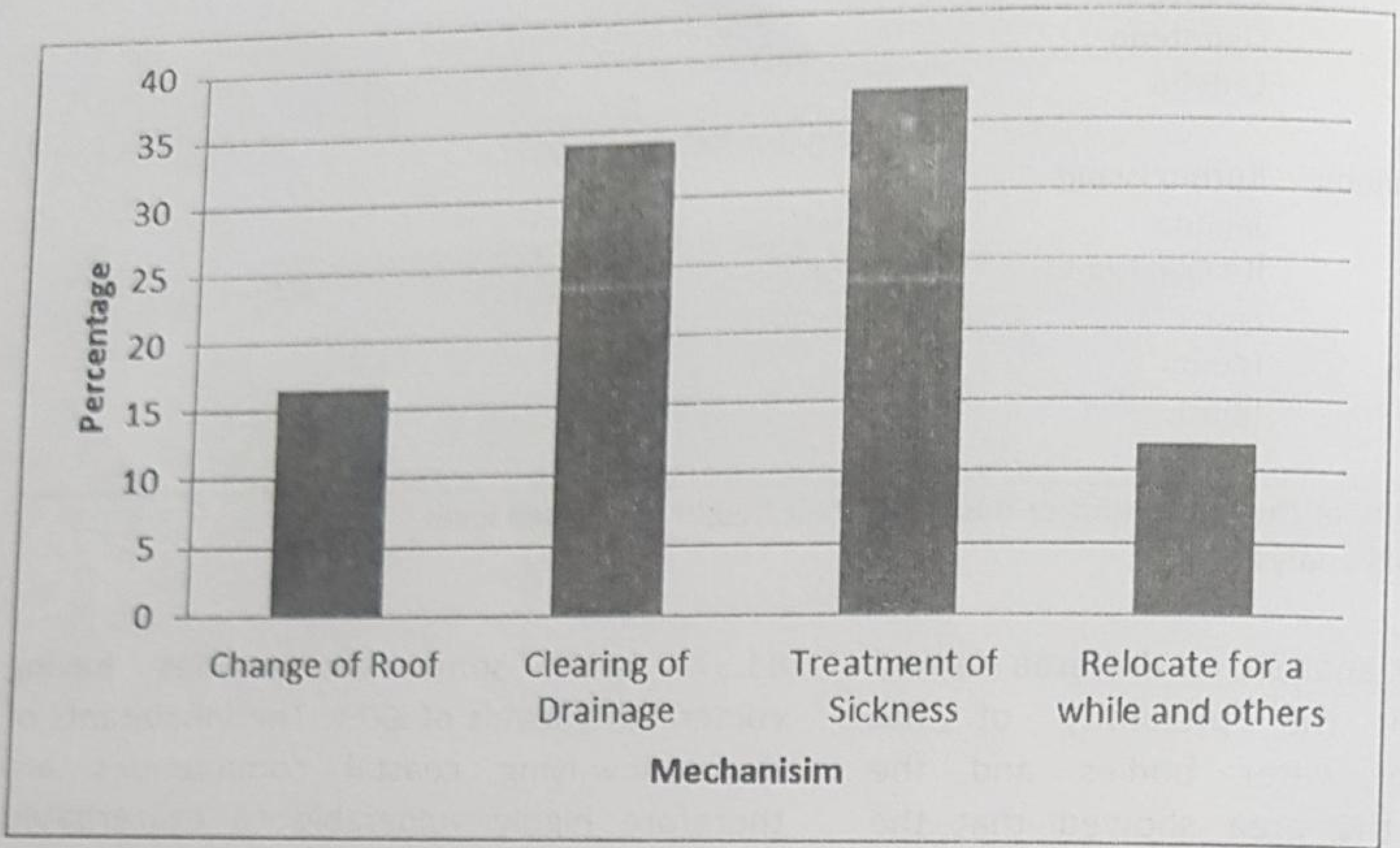

Figure 14: Adaptive Mechanism
Source: Field Survey. 2015

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary of Findings

The study is aimed at examining the extent of inundation effect that has arisen as a result of rising sea level along the barrier coast of Lagos Island. It was discovered that after proper analysis of field work the inhabitant of the area are at a greater risk to Inundation. This is so because.

Flooding and coping mechanism

Residents in the study area have been found to be more prone to flood on a monthly or weekly basis during the raining season, they have also been strongly affected by the effect of flood with majority of their property displaced during the event also diseases have been recorded as a result of flood. Some of the coping mechanisms in the area include community effort in evacuating drainages, individual repairs of dwellings and personal treatment of sickness as a result of flood. This could be categorized as problem – focused coping mechanism among others.

CONCLUSION

In accessing the socio-economic characteristics of the study area with their vulnerability to flooding, results from analysis show that there is a significant relationship between them. This indicates that the level of income of the inhabitants determines the level of effect the flood will have on them if the sea level rises. Field survey indicates that the government in its own way is making current effort on flood control in the study area coupled with personal effort of inhabitants either through construction of drainages, or channelization to minimize the impact of flooding. The community as a whole is doing less as observed from the survey carried out on the field. This analysis is very necessary as it provides a starting point to solving issues related to sea level rise and also gives useful information for planners of the coastal environment to develop strategies for effective and sustainable use of the coastal environment.

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