

# Fuzzy Based Spatial Risk Evaluation of Plastic Pollution: A Case Study of Anambra State of Nigeria

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## Research Article

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# **Abstract**

Natural systems, human health, and artistic sensitivities are all threatened by plastic pollution in most developed and developing countries. Plastic has emerged as a major global threat with rivers serving as sink for transported plastics, emanating from the terrestrial environment as a result of human activities. Anambra State in Nigeria is arguably the business hub of the South-eastern part of Nigeria, with a massive output of plastic wastes daily from individuals, commercial activities and industries. Owing to an inefficient waste management system, plastic leakage into her drainage networks is a critical environmental challenge. The aim of this study is to geospatially model the vulnerability associated with the various plastic leakage factors to the environment. To achieve this aim, data on different thematic variables which include plastic waste density, slope, land-use, drainage density and distance to drainage network of the study area were modelled, Geographic Information Systems (GIS) was used to delineate the variables in order to obtain final risk map for the study area. The result of the study indicates that a total area very high risk is 1840.03 km<sup>2</sup>, this constitutes about 40.11% of the study area. Local Governments Areas (LGA) located in the southern part of the study area is more susceptible to plastic waste leakage, this could be linked to factors like high dense population and increasing rate of urbanization in the region. It is recommended that waste collection should be frequent, strategic and higher priority should be attached to the high risked area from this study. Anambra State Government also needs to work together with plastic recycling companies, for effective collection of plastic wastes in the areas classified as hotspots in plastic litter accumulation as one of the mitigation measures.

## **1.0 Introduction**

Pollution could be said to be man's introduction of chemicals or energy into the environment that are likely to endanger human health, impair resources and ecological systems, degrade structures and amenities or interfere with lawful uses of the environment (Ramamohana, 2017). When materials accumulate in places where they are not desirable, pollution arises. Heavy pollution loads have been imposed on natural resources as a result of industrial development accompanied by population and consumption growth (Nasrabadi et al., 2010). Any outflow of material or energy into water, land, or air that causes or may cause severe or persistent harm to the Earth's ecological balance or decreases the quality of life is referred to as environmental pollution. Pollution is frequently classified as either point source or nonpoint source. In 2015, pollution claimed the lives of 9 million people throughout the world (Beil, 2017 and Carrington, 2017). Pollutants can cause either primary or secondary harm to the environment, such as small disturbances in the delicate equilibrium of the biological food web that are only evident over a lengthy period of time (Gheorghe, Iuliana and Barbu, 2011). Non-persistent pollutants are non-permanent or biodegradable and break down easily (You et al., 2018).

Plastic pollution is the buildup of plastic items and particles in the environment (e.g., plastic bottles, bags, and microbeads) that harms animals, wildlife habitat, and humans (Parker, 2018). People all around the world are on a never-ending quest for a better quality of life. As a result, there has been a rise in the consumption of products and services leading into waste creation. Plastics have become an inextricable

aspect of human lives, with their widespread usage in a variety of industries and ever-expanding uses providing significant societal advantages (Olanrewaju and Oyebade, 2019). The focus on plastic pollution studies in seas recently may have been due to the fact that its buildup and effects were more visible in these ecosystems (Ryan et al., 2009). Plastic pollution is widespread and growing in both land and marine habitats across the world. Global plastic output was predicted at 299 million tonnes in 2013 up 3.9 percent from 2012 (Plastic Europe, 2015). Plastics are light and buoyant, making them easy to move large distances in a variety of settings making them widespread pollutants (Coe and Rogers, 1997). The majority of plastic in the environment is non-biodegradable and lasts a long time as waste (European Commission DG Environment, 2011). Plastic pollution is mostly carried by rivers which transport plastics from the terrestrial environment and human activity centers to the shore and oceans. Humans have generated  $8.3 \times 10^9$  tons of plastic since the 1950s, with 60% of it ending up in landfills or as litter. (Geyer, Jambeck and Law, 2017). According to Jambeck et al. (2015) In 2010, 192 coastal nations (representing 93 percent of the world population) generated an estimated  $275 \times 10^6$  tons of plastic garbage.

Plastics may be classified into three classes in ecotoxicological settings based on particle size following bulk degradation, physical breakdown, and mechanical breakdown. They are macro-plastics with a diameter more than 5mm, micro-plastics with a diameter less than 5mm, and nanometer-sized plastic particles with a diameter less than 100nm (Axelsson and Sebille, 2017; Koelmans, 2015; Andrade, 2011; Wang et al., 2016 and Kalogerakis et al., 2017). Plastic despite having a good number of benefits, plastic damages species in nature, assists in the transportation of pollutants and hazardous substances, and has an impact on ecosystem processes and services (Teuten et al., 2009; Rochman et al., 2015; Eerkes-Medrano and Thompson, 2018). Due to the durability of plastics it ends up in the environment and degrades slowly if not managed properly (Palm and Svensson, 2018). Plastics may be eaten and respired by both big and tiny creatures and bioaccumulation allows them to move down the food chain. (Bouwmeester, Hollman and Peters, 2015; Rochman et al., 2015).

Plastic leakage refers to the quantity of macro-, micro-, and nano-plastics that are not retained in a circular loop or appropriately handled at the end of their useful lives and so leak into the environment (IUCN, 2020). Sub-Saharan Africa has had a major problem with waste management (Asase et al., 2009) mostly due to a lack of recycling infrastructure, qualified staff and other related factors. Annual mismanaged plastic waste was calculated in a study by Lebreton and Andrade (2019) which indicated that Asia produces about 52 metric tonnes of plastic waste per year, Africa about 17 metric tonnes per year, Latin America about 7.9 metric tonnes, Europe about 3.3 metric tonnes, US and Canada raises 0.3 metric tonnes and Oceania rabout 0.1 metric tonnes per year (Sheth, 2019; Jambeck et al., 2015).

Nigeria produces around 42 million tonnes of solid garbage per year (0.49–0.95 kg per capita per day. plastic trash accounts for around 20% of total solid waste (Akinola et al., 2014). Demographic experts believe that Nigeria's high rate of urbanization, which is among the greatest in the world, has the potential to exacerbate environmental deterioration, which has led to Nigeria's unequal distribution and handling of plastic trash. Floods cause seasonal devastation in Nigeria, particularly in crowded metropolitan centers where plastic bottles, plastic bags, and other waste products have clogged drainage systems obstructing

the free flow of water whenever it rains (Olanrewaju and Oyebade, 2019). According to a survey conducted by PCI Film Consulting, Nigeria's packaging sector contributed about 12% of the \$4 billion achieved by Middle East and African markets in the previous five years. From 1996 to 2014 the total volume of plastics imported into Nigeria was projected to be 23.4 million tons (including plastics from motor vehicles from 1980 to 2010). Plastics produced in Nigeria are made from imported raw materials or recycled trash and so cannot be considered a new contribution source to the total volume of plastic produced in Nigeria (Elias and Omojola, 2015).

Data reveals that GDP has a significant influence on plastic consumption, as seen by the fact that yearly per capita plastic consumption in Nigeria, Kenya, and Ghana was 4.4-8 kg/year from 2009 to 2015, whereas it was 13-19 kg/year in Algeria, Egypt, and Morocco, and 24.5 kg/year in South Africa (Babayemi et al., 2018; Jain, 2019; EUROMAP, 2016). Nigeria's time trend shows a continuous increase in importation, 554,513 tonnes was imported in 1996 while 2010 about 2.93 metric tonnes was imported (17kg/cap/year). Imports of polymer construction products, such as roofing sheets, PVC tanks, PVC tiles, and PVC plumbing supplies, were particularly notable. Between 1996 and 2017, Nigeria imported around 19.87 Mt (worth \$23.1 billion), accounting for about 16.9% of overall African consumption (Babayemi et al., 2018). Primary polymers (HS codes 3901–3914) are the most common plastic materials imported into Nigeria, accounting for 15.8 Metric tonnes while plastic products (HS codes 3915–3926) account for around 4 metric tonnes, 75 percent of all plastic imported into the nation was made up of primary polymers and plastic as a product. Primary polymers are mostly utilized in the manufacturing of packaging materials and domestic products such as cooking utensils, chairs, tables, and footwear. Imported goods, such as automobiles and electronics, account for the second and third highest levels of plastic use. These were about 2.9 Mt and 2.6 Mt, respectively, and were not imported under a plastic-related HS code (Babayemi et al., 2018).

Anambra State (the study area) arguably is the business hub of the South-eastern part of Nigeria, and has a massive output of plastic wastes daily, this have affected the beauty of the natural environment. Single-use plastics contribute significantly to this leakage, ill-disposed plastic bags are found all over the towns of her Metropolis. LGA within the metropolitan areas are faced with plastic waste pollution in their waters which affect aquatic life. Plastic bags is one of the most used forms of plastic in the study area, a recent study shows that 62.5 percent of individuals, reuse their plastic bags on a regular basis, whereas 35 percent dispose them after single use; 4.1 percent was reported to reuse big plastic bags as waste containers. The research also found that 55 percent of respondents do not support a reduction in the use of plastic bags, compared to 45 percent who support a reduction in the use of plastic bags. The study also reported that 7 percent and 8 percent respectively use an average of four to six bags and more than six bags (Iheukwumere et al., 2020). An average of three bags each day results in a total of 21 bags in seven days and around 90 bags in a month. The study area having proliferation of plastics as a result of increased human population, operations of businesses and industries needs to consistently monitor the impact of human activities on the ecosystem. Finding ways to stem this land-sourced plastic waste leakage requires understanding of its sources, and environmental aiding factors, therefore GIS based

investigation on plastic leakage concentration is essential to identify areas that require more attention for plastic leakage reduction against low plastic leakage areas (Chukwuma et al., 2019).

The use of GIS have been a resourceful tool in proffering waste management ideas, some research work have been done to advance the management of waste in different locations in Nigeria: Uzoezie et al. (2018) used the QGIS platform to geospatially model suitable site for plastic waste collection points in the University of Calabar, Calabar, Nigeria. Njoku (2012) applied GIS in selecting suitable sites for collection of solid wastes in Ikenegbu extension layout in Owerri, Nigeria. Jimoh et al., (2019) worked on a GIS based appraisal of waste disposal for environmental assessment and management in Mainland Area of Lagos State, Nigeria. Chukwuma et al (2019) applied geospatial technology in delineating vulnerable areas to plastic pollution in parts of Serdang in Malaysia. The study used statistical data on plastic generation to produce the plastic waste density thematic layer; this layer could be improved using field data of plastic accumulation spots as done in this study. Despite the endeavors of several research work in Nigeria in waste management using GIS, to the best of the author's knowledge no study have considered the application of GIS in assessing vulnerable areas in Nigeria to plastic waste litter and eventually the production of leakage map as done in this study. Globally, there is dearth of literature in vulnerability assessment of plastic leakage using land based features that models plastic leakage. This study is therefore essential in the decision making to preserve aquatic animals, for higher agricultural output and productivity; and in application of strategic waste management especially for high risked areas located in the coastal region, this is critical in mitigation of plastic leakage to the ocean, of which the study area is a case in point. The aim of this study is geospatially model the vulnerability or risk posed by plastic accumulation in an area, by integrating geospatial related features in the model, using Anambra state as a case study. The following specific objectives were considered in the realization of the research aim: to analyse spatial distribution of plastic wastes in the study area; to geospatially model the risk associated with the various plastic leakage points and to proffer solutions to the impact of plastic mismanagement for the study area.

## 2.0 Materials And Methods

The process and method used to evaluate the risk of the study area to plastic leakage using ArcGIS are described in the Figure 1.

### 2.1 Study Area

Anambra State is a state in the South-eastern part of Nigeria. It is located between latitudes 5°40' N and 6 ° N, and longitudes 6°35E and 7°25E. It is bounded by Delta State to the west, Imo State and Rivers State to the South, Enugu State to the East and Kogi State to the North. National Population Commission during the 2006 population census recorded that the state had a total population of 4,177,821 with male constituting 2,174,641 and female 2,003,180 fraction of the population. The state has a land mass of approximately 4,588km<sup>2</sup>, the population density of approximately 860/km<sup>2</sup> (2,200/sq. mi). The stretch of more than 45km between Oba and Amorka contains numerous populated

villages and small towns. The research area is crossed by a good number of waterways, including River Niger and various tributaries, therefore rendering it vulnerable to leakage to light-weight deposits of plastic wastes through natural and man-made drainages. Figure 2 shows administrative map of Anambra State of Nigeria.

## **2.2 Data Collection and Management for the study**

Data on plastic waste litter leakage points was obtained from field survey via trips to the study area and on site data assessment. The Land use map was derived through the Landsat 8 imagery, it was downloaded from the European Space Agency website. The road network raster of the study area was derived from extract.bbbike.org. The Digital Elevation Model was derived from the United States Geological Survey explorer website. Anambra state's shapefile was downloaded from diva-gis.org. The study was carried out with the use of the different software in order to achieve the aim and objectives of the study: ArcGIS 10.8 was used to import coordinates of point shape-file of plastic accumulation spots into ArcGIS environment. GPS coordinates software was used to take the locations of plastic accumulation points. Microsoft Excel was used in taking tabular analysis of the plastic hotspots locations. The study was carried out with the use of different hardware: Mobile camera, HP colour Printer, Dell inspiron Laptop, Notebook etc.

## **2.3 Data Analyses and Processing**

To geospatially model the risk arising from plastic accumulation and leakage, this study considered 5 geospatial variables which include plastic waste accumulation, slope, drainage density, land use and distance to drainage networks. This section goes further to discuss how the various data obtained for the study was processed to delineate the thematic map layers for the various geospatial variables. The data on waste accumulation was obtained through visit to strategic locations of plastic wastes hotspots, and conduction of field surveys. Figure 3 shows some plastic waste accumulation spots or points in the study area.

### **2.3.1 Plastic Waste Accumulation**

Plastic litter accumulation sites located closer than a distance of 5 meters to the municipal drainage network was considered nearly leaked, while those in a drainage system is considered leaked. To analyze plastic waste litter hotspot in the state, the following strategies were adopted. The plastic waste accumulation is ranked into three levels; small litter (<500 items), Medium size litter (between 500 to 1500 items), Large litter accumulation (>1500 items). The plastic characteristics are identified as Plastic Bottle Water (PBW), Plastic Soft Drinks Bottle (PSDB), Plates commonly referred as take-away plates (P), Sachet Water (SW). Identification of the major sources of plastic littering was observed considering littered spots and locations, sources identified are residential area, commercial areas, and bus stops etc. Locations of the littered spots were obtained through GPS coordinate readings. Field sampling and trip to the study area was made in order to obtain data on plastic littering by end users in order to develop a plastic waste density map. Spatial distribution analysis of leakage locations were derived through mobile GPS locators

which was processed and done in Microsoft Excel software and geocoded in the ArcGIS 10.8, the proximity of the various plastic accumulation sites was used to generate GIS based risk assessment of plastic leakage through the drainage network.

## 2.3.2 Drainage Density

Environmental Impact Assessment of Anambra's drainage network would help to identify impacts of plastic leakage through natural and man-made drainage system, and hence the degree of risk of plastic leakage. Using the DEM, the drainage network was derived and used in the creation of the drainage density model. The entire length of channel in a drainage basin divided by the total area is known as drainage density  $D_n$ , which is represented by equation (1):

$$\{D\}_{n} = \frac{\sum L}{\{A\}_{\text{basin}}} \quad \text{Where } \sum L \text{ is the length of all streams of the catchment, } A_{\text{basin}} \text{ is the catchment}$$

From the DEM the hydrological networks were created and used to generate the drainage density map. The Fill, Flow Path, Flow Accumulation operations was used in the preparation of the raster dataset as preliminary operations in order to construct the model. The Flow Length operation was used to evaluate the weighted distance upstream and downstream; the Stream Link operation was used to assign unique values to the raster linear network sections; the Stream order was used to assign numeric order to raster segments containing stream branches. And then, the raster dataset was transformed to a vectorized stream network; the hydrological stream network of the research area is the resulting geospatial model. The drainage density models the propensity for light weight material such as plastics deposited within a geographical space to be carried from one point to another. The higher the drainage density in a region, the higher the plastic leakage propensity in the region through the drainage network.

## 2.3.3 Land use

Based on the set objective of the site selection processes the Land-use map was derived through the Landsat 8 imagery which was downloaded from the European Space Agency. The map was used as a base map for modelling the potential for plastic leakage in the research area. Forest zone, aquatic body, urban regions, low vegetative zones, and bare soil were the five categories on the map. The main GIS data set processing operations was conducted in ArcGIS 10.8. Using the image processing tool, a multilayer composite of band 1 to 5 of the imagery was obtained, the resulting raster was clipped together and the raster dataset mosaicked. The research area shapefile was used to derive the precise area from the Landsat Imagery. The ArcGIS Image Classification Toolbox was used to collect training samples for water, forest, urban, agricultural and bare land areas. In the classification of land use, the Maximum Likelihood Classification algorithm was used. The land use has varying degrees on plastic leakage propensity; urban areas for instance has higher tendency to plastic leakage compared to forest.

## 2.4 Risk Mapping of the Study Area to Plastic Leakage

To geospatially model the risk of the study area to plastic leakage, we employed Fuzzy logic to integrate the geospatial variables of plastic leakage in a GIS environment. Fuzzy logic is a very useful tool which is

applicable in a vague environment. It helps to deal with uncertainties and related issues when making decision. The delineated maps of the geospatial variables were put into fuzzy membership classes based on their influence in plastic leakage and this was done to create a basis for their integration.

## 2.4.1 Fuzzification of thematic maps

The Fuzzy Membership tool is a tool in GIS environment that reclassifies the features input data to a 0 to 1 scale, this is usually based on the likelihood of being a member of a specified set. The value of 0 is given to those locations that are definitely not a member of the specified set, while the value of 1 is given to those values that are certainly a member of the identified set, and the whole range of likelihoods among 0 and 1 are given to some level of possible membership. The input values can be transformed by any number of functions and operators available in the ArcGIS Spatial Analyst extension that can reclassify the values to the 0 to 1 possibility scale. For the purpose of this study, two membership classes of Fuzzy Large and Fuzzy MS Small were used. The Fuzzy Large function is used when high input values of a particular variable has the major influence in the system, while the Fuzzy MS Small function is used when small input values of a particular variable has the major influence in the system. The equation of the Fuzzy Large transformation function used is shown as:

$$\mu(x) = \frac{1}{1 + (\frac{x - f_2}{f_1})^2}$$

$\mu(x)$  is the membership value of category  $x$

$f_2$  is the midpoint and

$f_1$  is the spread of the function

The MS Small function has two equations depending on the product of  $a * m$ .

when  $x > a * m$ :

$$u(x) = (b * s) / (x - (a * m) + (b * s))^2$$

where:  $m$  = the mean

$s$  = the standard deviation

$a$  = a multiplier of the mean

$b$  = a multiplier of the standard deviation

The  $a$  and  $b$  multipliers are input parameters.

when  $x \leq a * m$ :

$$u(x) = 0.3$$

The slope geospatial variable was put into the Fuzzy Large membership function. This was done based on the assumption that slope points which are greater than  $40^\circ$  are at very high risk, slope points greater than or equal to  $30^\circ$  are at High risk, slope points greater than or equal to  $25^\circ$  are at Moderate risk, slope points greater than or equal to  $20^\circ$  are at low risk and slope points less than or equal to  $15^\circ$  are at very low risk. The assumption is based on the fact that in comparison to flat slopes, steeper slopes present an easier mode for plastic waste litter transport into drainage lines via runoff during rainfall. The landuse geospatial variable was put into the Fuzzy Large membership function. The landuse map had categorical values and as such had to be reclassified into numeric values of the range 1-5 before fuzzification. The highest value of 5 was given to urban areas due to the fact that the activities of urban areas have the greatest effects on plastic leakage. The landuse map of the study area shows that LGAs such as Onitsha South, Onitsha North, Awka South and Awka North has a high level of urbanization which will have a significant impact on plastic leakage in such areas. Identified pathways for plastic leakage in a watershed are storm overflows, waste water effluents, urban runoff, river discharge and atmospheric deposition; these pathways are all linked and dependent on the drainage density of a watershed. The Drainage Density raster variable was put into the Fuzzy Large membership function, this was done based on the assumption that areas with increased drainage density would be more susceptible to flooding and consequently lead to plastic leakage, therefore they are at higher risk to plastic leakage than areas with lower drainage density. The distance to drainage network was put into the Ms Small fuzzy membership function. This was based on the assumption that the lesser the distance to drainage network would mean higher risk to plastic leakage than locations with increased distance to drainage network. The accumulation of plastic waste in locations less than 5m from drainage from drainage network is assumed to be leaked while accumulation of plastic waste in locations more than 5m away from drainage network is assumed as not leaked. Waste Density of the study area was put into the Fuzzy Large membership function, this was done based on the assumption that areas with higher waste density points are considered to be at higher risk to plastic leakage than locations with lower plastic waste density points.

## 2.5 Fuzzy Overlay

The various fuzzified map of the slope, land use, waste density, distance to drainage network and drainage density of the study area were overlaid using the fuzzy overlay function tool from the spatial analyst toolbox in ArcGIS 10.8 to achieve the risk ranking of the study area. The obtained risk map was classified using the classification method of Geometric Interval into five classes of Very low risk, Low risk, Medium risk, High risk and Very high risk.

## 3.0 Result And Discussion

### 3.1 Analysis of Digital Elevation Model (DEM)

The result of Digital Elevation Model (DEM) raster derived from the United States Geological Survey website and the representation of the bare ground showing the topographic surface of the earth

excluding trees, buildings and any other surface objects was derived. The digital elevation model was used to derive the slope map of the study area. The slope of the study area is the topographic map showing changes in the elevations on a highly detailed level which includes excavated slopes and natural slopes, on the slope map the isolines or the lines having same elevation indicates height differences. The slope of the study area is derived through the use of the slope tool in the ArcGIS which identifies the steepness at each cell of the Digital Elevation Model raster. The Higher the slope value the steeper the terrain and the lower the slope value then the flatter the terrain.

## **3.2 Land Use Classification**

The Landsat imagery was clipped using a shapefile for Anambra State, the clipped imagery used in land classification based on the set objective of the site selection processes, the Land use map was derived through the Landsat 8 imagery. The Classified Landuse map above shows that Anambra state has a vast urban area located towards the southern part of the state. The classified landuse map also shows availability of water ways in the state.

## **3.3 Analysis of Road Network**

The road network of study area was obtained and processed to delineate the distance to drainage networks. This was done based on the assumption that all roads in the study area have a drainage network. The distance to drainage network geospatial variable for risk mapping of plastic leakage was created from the road network using the Distance Tool (Euclidean Distance) in the GIS environment.

## **3.4 Waste Density**

The plastic waste density of the study area was classified using the Geometrical Interval. Waste Density of the study area was put into the Fuzzy Large membership function. The fuzzified map in Figure 4 shows highest waste density in Awka South, Awka North, Anambra East, Onitsha South and Onitsha North LGA.

## **3.5 Slope of The study area**

The slope was delineated from the Digital Elevation Model of the study area. Figure 5 shows the fuzzified slope of the study area. The slope of the study area ranged from 0 to 43.457 degrees. Anambra West and Ogburu Local Government Areas have mainly flat slopes ranging from 0 – 0.238 degrees while Awka South, Anaocha and Nnewi South LGA have mainly steep slopes ranking from 12.835 degrees to 43.466 degrees.

## **3.6 Drainage Density of the Study Area**

The drainage density of the study area was delineated from the DEM, Figure 6 shows the fuzzified map of the drainage density. The drainage density of the study area ranged from 0 to  $2.569 \text{ m}^{-1}$ . Higher density  $1.214 \text{ m}^{-1}$  to  $2.569 \text{ m}^{-1}$  was observed in Awka North, Onitsha South, Onitsha North, Ogburu,

Anambra East, Orumba South, Awka South Local Government Areas. Then lower density ranging from  $0 \text{ m}^{-1}$  to  $0.076 \text{ m}^{-1}$  was observed in Njikoka, Aguata, Anaocha, Idemili South, Idemili North LGA.

## 3.7 Land Use of the Study Area

Land use map of the study area was likewise classified using the Geometrical Interval, with Urban receiving the weight limit of 5 due to the fact that the activities of urban areas have the greatest effects on plastic leakage. For fuzzification, the Fuzzy Large membership function was employed, and the resulting map is displayed in Figure 7.

## 3.8 Distance to Drainage Network

The distance to drainage network of the study area was delineated from the road network of the study area, it varied from 0 to 8,202.983398m. The fuzzified distance to the drainage network is shown in Figure 8 below. Awka South, Onitsha North, Nnewi North, Nnewi South, Aguata, Oyi LGAs shows lowest distance to drainage network of 0 – 291.7m while Anambra West, Ogbaru LGA shows highest distance to drainage network.

## 3.9 Final Risk Map

The various fuzzified factor maps of the variables were overlaid using the fuzzy overlay tool in the GIS environment to derive the final risk map of Anambra State. The final risk map of in Figure 9 indicates that the total area of the study area is  $4587.54 \text{ km}^2$ . The map shows the total area at very low risk is  $1081.01 \text{ km}^2$  which is 23.56% of the study area. The total area at low risk is  $795.58 \text{ km}^2$  which is 17.34% of the study area.  $606.37 \text{ km}^2$  of the study area is classed as medium risk category, which is 13.22% of the total area.  $264.55 \text{ km}^2$  of the study area is classed as high risk which is 5.77% of the study area. Total area of the study area at very high risk is  $1840.03 \text{ km}^2$  which is 40.11% of the study area. LGAs located in the Southern part of the study area are more susceptible to plastic waste leakage, The final risk map showed Onitsha North Local Government Area has an area of  $20.70 \text{ Km}^2$  out of its  $27.9 \text{ Km}^2$  at very high risk to plastic leakage, Onitsha South LGA has  $7.16 \text{ km}^2$  out of its  $16.93 \text{ km}^2$  area at very high risk to plastic leakage, Awka South LGA has  $117.84 \text{ km}^2$  of its area at very high risk to plastic leakage. Nnewi North has  $57.75 \text{ km}^2$  of its area at very high risk to plastic leakage, while Nnewi South has  $143.19 \text{ km}^2$  of its area at very high risk to plastic leakage, this could be attributed to higher density of drainage network and urbanization in the area, the area is known for high commercial trade and industrial activities. Anambra West LGA has lower ratio of areas at risk with  $85.07 \text{ km}^2$  at very high risk compared to  $386.83 \text{ km}^2$  at very low risk to plastic leakage, Ayamelum has  $98.28 \text{ km}^2$  of its area at very high risk compared to its  $252.60 \text{ km}^2$  of very low risk area, Ogbaru LGA has just  $47.32 \text{ km}^2$  of its area at very high risk to plastic leakage, these areas have a common attribute of low urbanization compared to the central and southern part of the study area.

## 4.0 Conclusion

This project attempted to identify plastic leakage from land-based sources to the ocean using variables correlated with plastic sinks in a given region. Multiple maps focused on geo-environmental variables, and public use data were geocoded in an ArcGIS environment and modeled for Anambra state using geospatial technology. The development of the risk map was occasioned from the combination of numerous thematic variables, the plastic waste density of the study area, slope, classified land-use map, drainage density and distance to drainage network of the study area. Based on the result obtained in the study and observation made, it is recommended that Anambra state being a business hub and densely populated, that waste collection and management strategy should prioritize high risked regions to plastic leakage based on this study, this is critical to mitigate the leakage of plastic wastes to waterbodies. Development of strategic plastic recycling programs will also enhance utilization of the wastes, for sustainable blue economy and circular economy. This study is critical in agricultural development of aquatic sector; it will help in mitigating environmental factors affecting the productivity of the blue economy in the region.

## Declarations

**Funding:** No funding was received for this study

**Competing Interests:** The authors hereby declare that there is not conflicting interest in this study

**Availability of data and materials:** Data will be made available on demand

**Code availability:** Not applicable

**Authors Contributions:** Emmanuel Chibundo Chukwuma and Louis Chukwuemeka Orakwe conceived and designed the experiments; Ejikeme Emmanuel Emenike, performed the experiments; Ejikeme Emmanuel Emenike, Chukwuma Chris Okonkwo and Emmanuel Chibundo Chukwuma analyzed, interpreted the data; and wrote the manuscript. All authors read and approved the final manuscript

**Ethical Approval and Consent to Participate:** No ethical issues in this work

**Consent to Publish:** All the authors consented to publish this work

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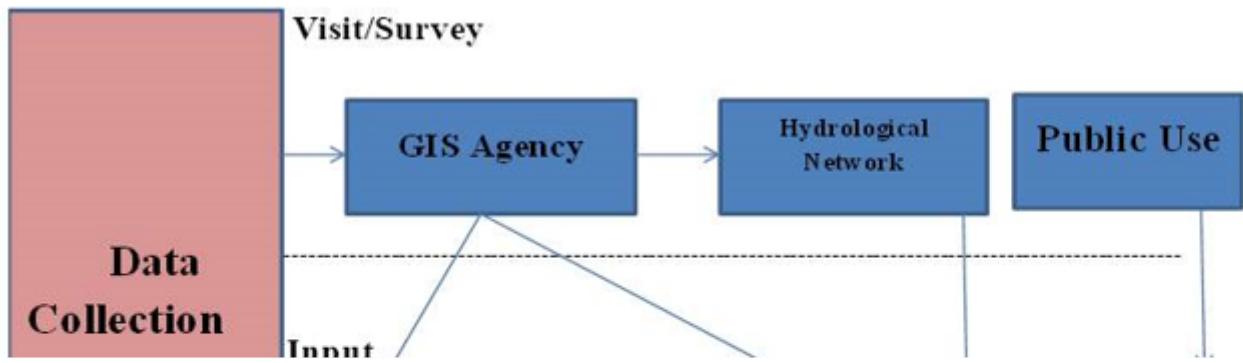
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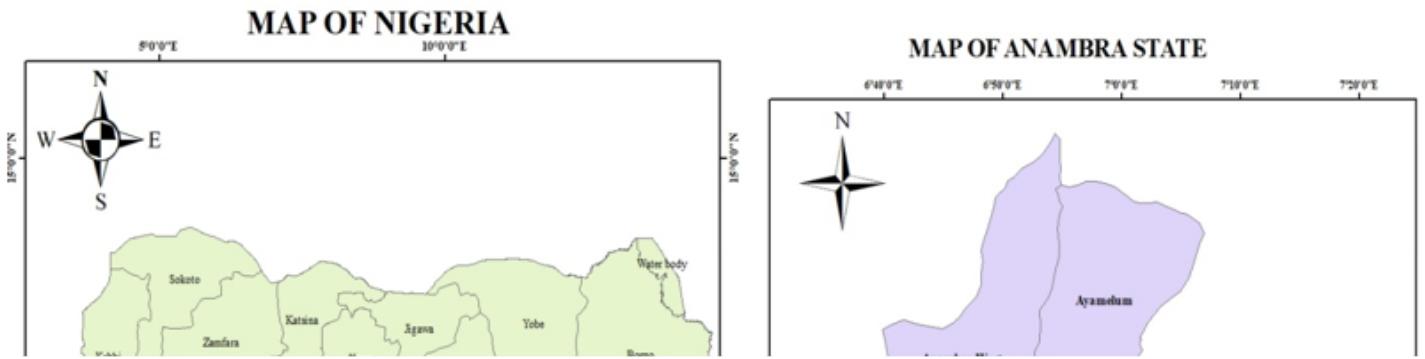
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## Figures



**Figure 1**

Flowchart showing the Research Methodology

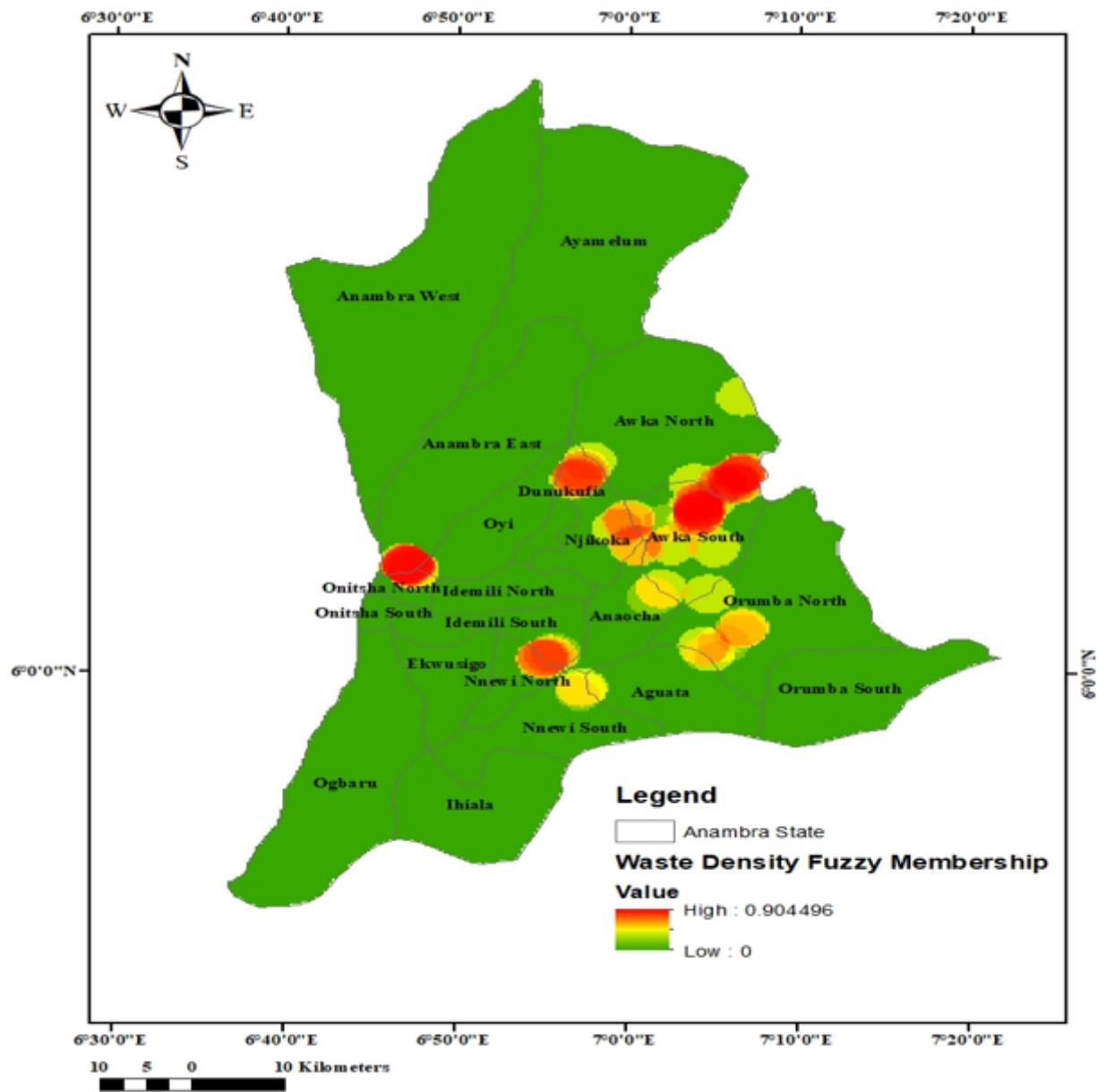


**Figure 2**

Administrative Map of Nigeria showing Anambra State

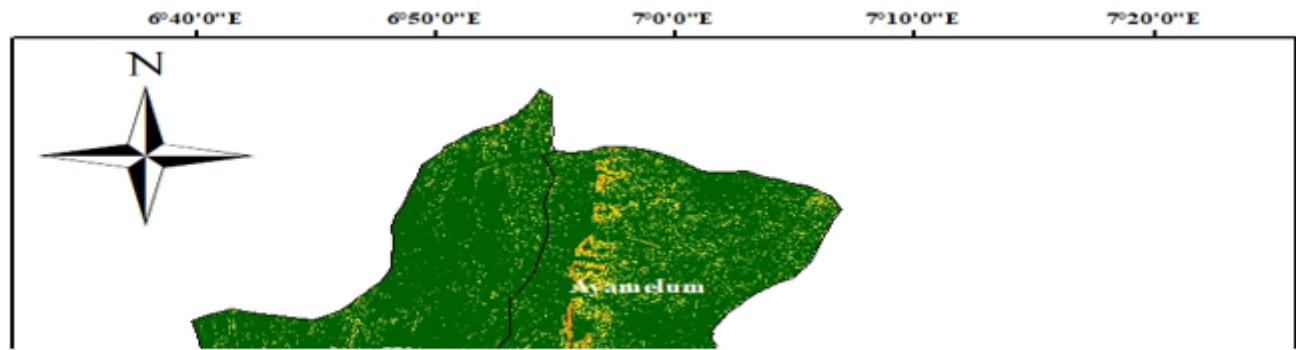
**Figure 3**

Typical plastic waste accumulation points in proximity to municipal drainage.



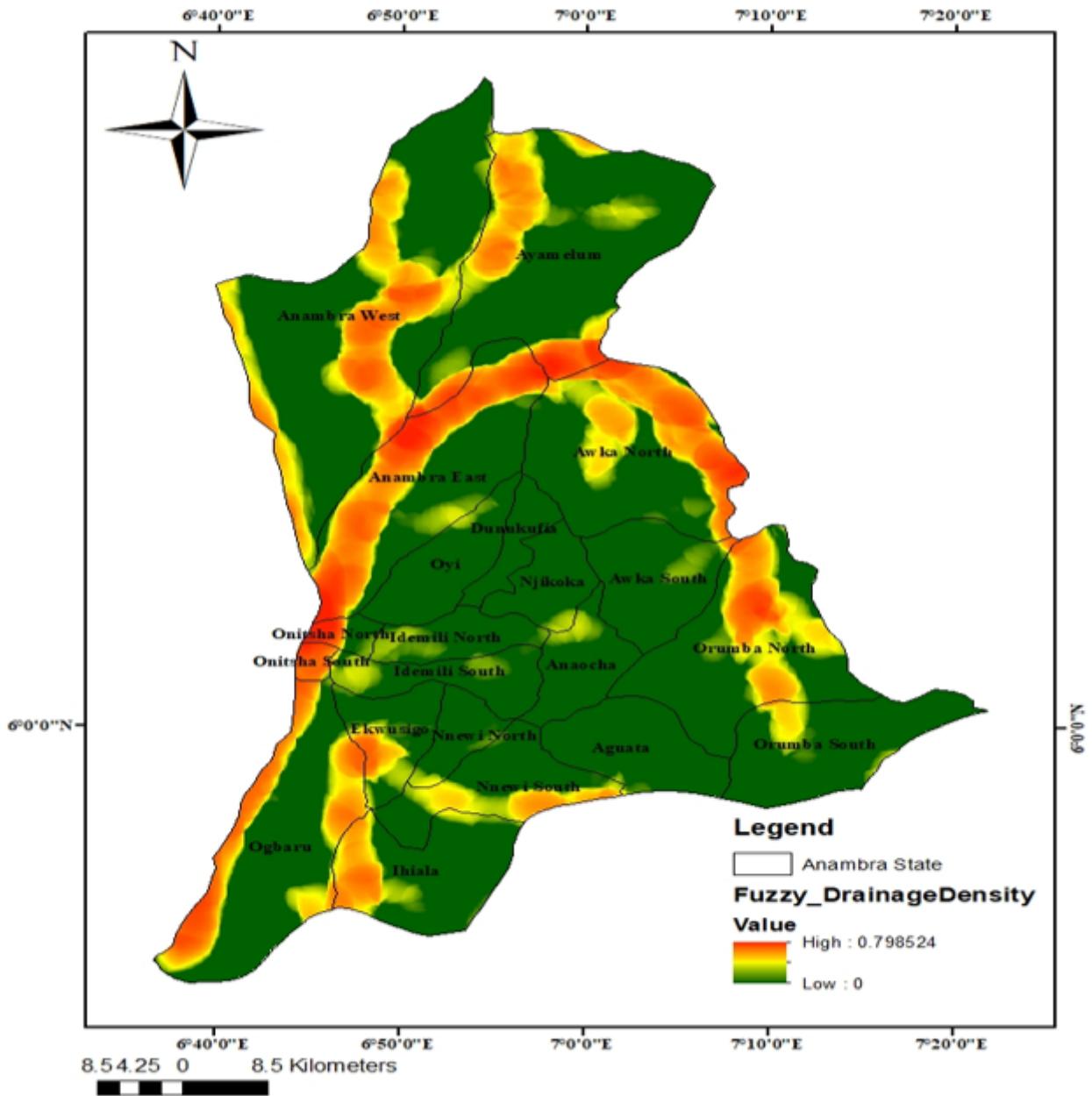
**Figure 4**

Fuzzified Plastic Waste Density Geospatial Variable Map



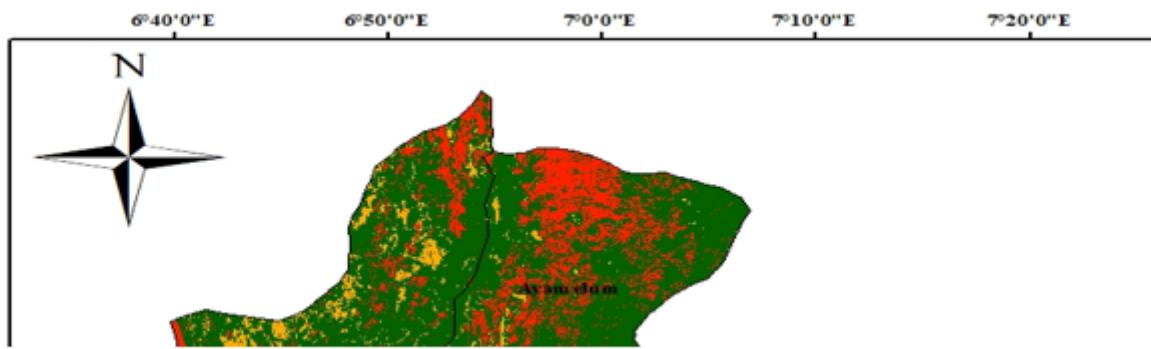
**Figure 5**

Fuzzified Slope Geospatial Variable Map



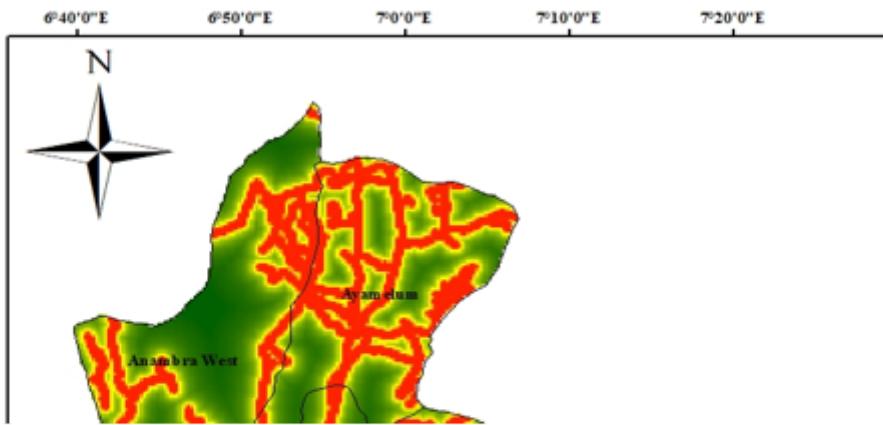
**Figure 6**

Fuzzified Drainage Density Geospatial Variable Map



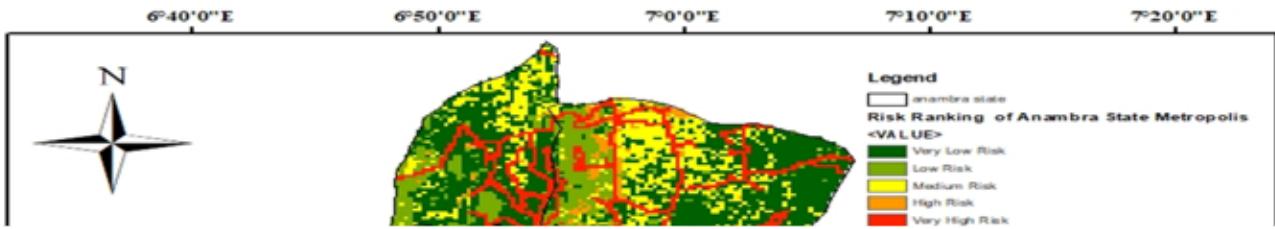
**Figure 7**

Fuzzified Landuse Geospatial Variable Map



**Figure 8**

Fuzzified Distance to Drainage Network Geospatial Variable Map



**Figure 9**

Final Risk Map of the Study Area