Contribution of Rainfall Intensity to Flooding in Ozoro, Delta State, Nigeria

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Abstract:- The frequency and risk of flash floods in Ozoro have increased due to climate change and intense rainfall events. The territory was divided into five pre-existing communities throughout the three-month research period, which ran from July to September 2023. Measurements were made to ascertain the flood's volume, area, length, and depth. Using a regular rain gauge with a moveable geo-referenced device, rainfall data was gathered. The rainfall total for July 2023 dropped to 6732.6 mm, and by September of the same year, it further reduced to 1121.5mm. This resulted in a flood that covered an area of 6435m^2 and had a volume of 14431.4m^3. The neighbourhood that experienced the highest level of flooding was Oruamahdu Quarters, with an average depth of 0.6 metres. The average rainfall rate is 89.7 millimetres per hour, suggesting heavy rainfall. The most return rainfall occurred in July, while the least amount occurred in August. The calculated F value of 77.34 indicates a substantial correlation between the volume of rainfall and the flood volume in Ozoro. Flood flow decreased at a rate of 11.57 m3/day over the study period. In Ozoro, the increasing intensity of rainfall is responsible for 85.6% of floods. To help city planners visualise the combined dangers of floods and drainage, the rainfall intensity-duration-frequency (IDF) curve should be employed as a metric for climate adaptation.

Keywords:- *Rainfall, Flood, Intensity, IDF, Ozoro*.

I. INTRODUCTION

Climate change, sea level rise, and land subsidence are all anticipated to increase the frequency and severity of floods (Wang et al., 2018). Flooding is one of the most frequent and dangerous climate-related natural disasters (Wilby & Keenan, 2012). Different aspects of the climate system, particularly rainfall (intensity, duration, volume, duration, and phase), have an impact on flooding (Westra et al., 2008). The degree of urbanisation, the presence of dams and reservoirs, present river levels, soil qualities and conditions (permeability, soil moisture, and vertical distribution), and drainage conditions all impact flooding. Rainfall, terrain, soil type, land use, and land cover are among the variables that contribute most to floods (Sugianto et al., 2022).

River basins can exhibit intricate interdependencies between precipitation and subsequent inundation. The response of humans to rainfall is shaped by historical factors, while the response to flooding is often determined by the location of the rainfall within the basin. The Niger Delta floods are primarily attributed to or exacerbated by excessive and prolonged rainfall, as indicated by several studies (Aich et al., 2017). Several authors have observed that the duration, intensity, frequency, seasonality, and variability of extreme rainfall characteristics are associated with the frequency of flooding in Nigeria (Ologunorisa & Diagi, 2005; Olanrewaju et al., 2017).

Urban flooding occurs when intense precipitation in urban areas causes a swift flow of water from paved and developed areas, surpassing the capacity of drainage systems. Runoff pond development occurs in low-lying areas of cities due to the accumulation of debris that obstructs drains and sewers (Tran et al., 2024). This obstruction is primarily caused by neglect (Wang et al., 2024). This is in addition to abnormally high levels of precipitation. As the green structures in urban areas decrease and more impermeable areas are created, the poor will be forced to relocate to flood-prone areas such as rivers and low floodplains (Ferreira et al., 2021). This will worsen the situation, as even regular storms will result in increased surface runoff (Wang et al., 2024).

In Nigeria, flash floods are frequent during the rainy season, which runs from May to September. In September 2022, two major floods struck Nigeria: the Ladgo Dam Flood and the Niger-Benue Flood (Lokoja and Benue-Niger). Heavy rains from early July to September 2022 overflowed reservoirs, forcing authorities to open dams (such as the Lagdo Dam in North Cameroon province) to relieve pressure on Cameroon and Niger, which resulted in the coast and devastated infrastructure. Floods in the Niger Delta region cause deaths, damage to buildings, bridges, roads, and other social and economic infrastructure, as well as disease epidemics, contamination of surface and groundwater, and interruption of economic activity (Brown et al., 2015).

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In recent years, flood damage in urban areas has become a major problem in Ozoro. They are mainly related to poorly design urban systems and land use planning. In addition, the lack of early warning systems and systematic flood mitigation measures at the national and local levels exacerbates the severity of the problem. Floods affect transportation services. Some floods even cause accidents. Some of the effects of flooding in Nigeria include disruption of trade and commerce, possible disease outbreaks, and more (Ajiboye & Orebiyi, 2021).

Vehicle traffic in Ozoro has been greatly impacted by the characteristics and regularity of floods. Certain regions of Uruto became inaccessible, resulting in a cessation of socioeconomic activities. Nevertheless, despite the flood policy recommendations and government initiatives aimed at mitigating the risk, flooding has become a recurring occurrence in the majority of Nigerian cities. Undoubtedly, the occurrence rate and magnitude of the event have increased twofold in recent times. With the on-going increase in populations, a larger number of individuals are residing in areas that are susceptible to flooding, such as river beds and floodplains. Consequently, this has led to a rise in the extent of damage caused and an increase in the number of fatalities. Furthermore, climate change is anticipated to worsen the issue of urban flooding as a result of the potential for increased size and frequency of rainstorms.

- *Study Area*

The Ozoro is located between 5˚31'N and 5˚35'N and 6˚13'E and 6˚19'E. Ozoro is the seat of the Isoko North Delta Municipality. In addition, this region features alluvium, coarse grain, and mixed hydrological soil. The rock is sedimentary, with a massive gravel layer up to 17 meters thick and a powdery, clay, and sand top (4-6 meters), standing 6.1m above sea level. The region is characterised by a tropical equatorial climate with an average annual temperature of 28°C and precipitation ranging from 2400 mm to 3504 mm. The time of rainfall varies from January to December, with a minimum of 21.2 mm in January and more than 620.4 mm in September. This area also features a mixed soil and hydrogeological characteristic of coarse-grained, alluvial soil. From December to February bring light harmattan. The natural vegetation is tropical forests and coastal vegetation. Ozoro is the fastest-growing town in the Niger Delta, with a population rapidly growing from 35,716 in 1991 to 43,339 in 2006 and an estimated 69643 in 2023.

II. CONCEPTUAL ISSUES

The capacity of the atmosphere to hold water and the concentration of water vapour, along with the characteristics of the atmosphere and the amount and distribution of rainfall, are the key factors in the climate system that influences the risk of flooding (Liu et al., 2020). Large-scale circular patterns dictate the duration of rainfall. The mechanisms involved in these facts are intricate and overly simplified, which renders them perplexing. Visible factors in the climate include evaporation, precipitation, temperature history (important for snow cover, freezing and thawing in rivers and lakes), and pre-treatment of variables.

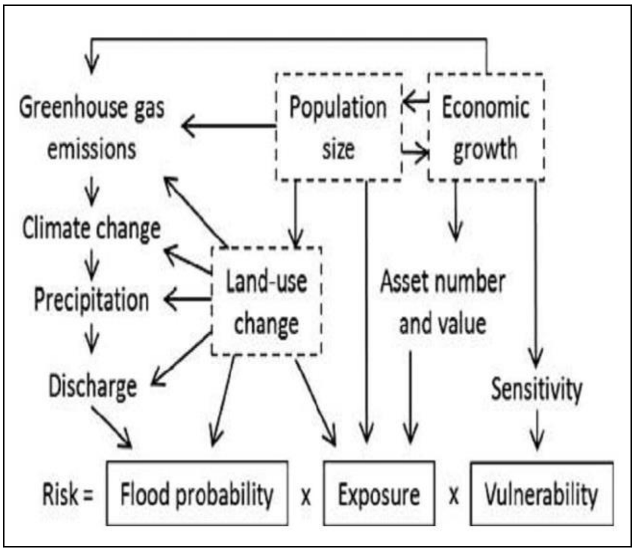

Fig 1: Climate System and Flood Risk Dynamics
Source: Bouwer (2019)

Soil moisture, groundwater, and surface water are important factors that greatly influence surface hydrology. The climate system has an impact on the changes in flood risk (Bouwer, 2019). Climate change is expected to modify numerous factors that influence flooding. Sea level, the condition of glacial lakes, and vegetation can modify flood characteristics (refer to Fig 1).

III. METHODS AND MATERIALS

The study area is divided into five zones, which are determined based on the presence of existing settlements (Etevie, Erovie, Uruto, Urude, Oruamudhu) (refer to Fig 2). Field surveys were conducted after the rains, using this representation, to determine the flood area and type, the percentage of road length that was flooded, and the extent of the inundation.

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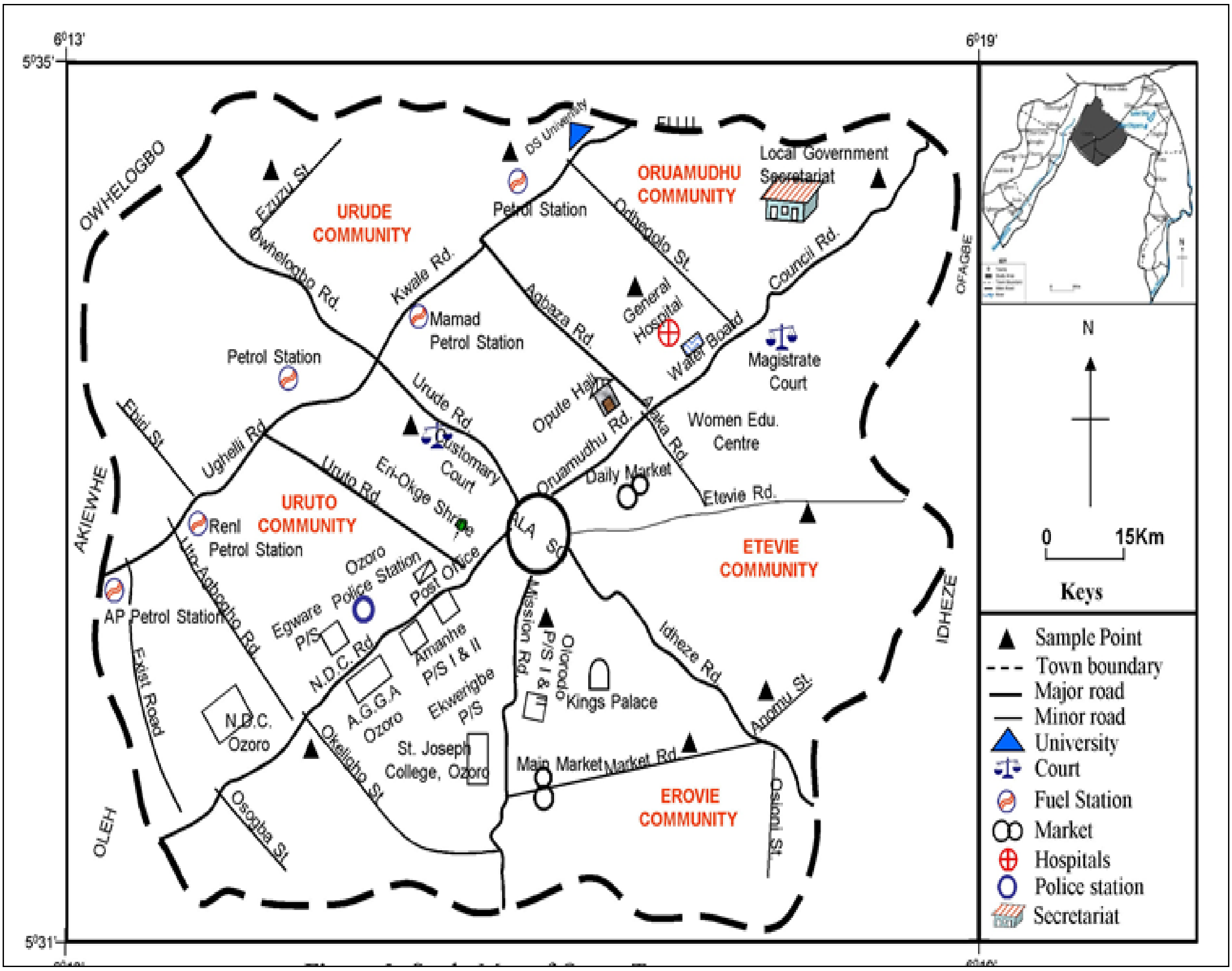

Fig 2: Study Map of Ozoro Town
Source: Ministry of Land, Survey and Urban Development, Asaba

The flood region is measured using a tape measure to ascertain the dimensions of the floodwater, including its height, length, area, and volume. Stacks have been prepared and adjusted based on the depth of the flooding. Following a rainstorm, the stakes are frequently submerged in the floodwater and subsequently examined to determine the watermarks. The research was conducted over three months, spanning from July 2023 to September 2023. Data on flooding was gathered in each of the aforementioned areas. The measurements were made after every rainfall. The weekly measurements have been calculated as an average. The precipitation statistics encompass both the duration and intensity of the rain. Ten homes were selected from five quarters based on their location relative to the dominant wind direction (Fig 2 and Table 1).

Table 1: Rainfall Collection Areas

Quaters	Settlement	Numbers of Gauges
Urude	Ezuzu Street and DST University	2
Uruto	Customary Court and Okeligho Street	2
Oruamudhu	General Hospital and Local Government Secretariat	2
Etevie	Anomu Street and Etevie Road	2
Erovie	Mission road and Main market	2

Fieldwork, 2023

The chosen houses are at least 50 meters apart from one another. Every household is provided with standard rain gauges, and GPS receivers are utilised to accurately determine the geographic coordinates of each gauge's position. It was recommended that families monitor the quantity of precipitation. Precipitation is determined by analysing the gathered data. Each ward in the neighbourhood has two peaks. To determine the

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relationship between the intensity of rainfall and the cycle of rainfall return for the locations under study, two commonly used methods of frequency analysis were employed. The system calculated the precipitation rate per hour. When the values were rated, the value with the highest rating was chosen as the one with the largest magnitude. The return periods (recurrence intervals) are calculated using the Weibulls formula as follows:

$$\text{Equation 1: } T = (n+1)/m$$

where m is the rank value of each rainfall intensity, T is the return duration, and n is the greatest rank. The precipitation characteristics used include daily and monthly precipitation, intensity, frequency, trend, and repetition cycle.

IV. RESULTS AND DISCUSSION

Table 2 displays the flood data of the Ozoro community. According to the spatial distribution of flooding (see Table 2), the Oruamahdu neighbourhoods in the Ozoro community were the most impacted. These neighbourhoods cover an area of 2124 m^2, which represents 33% of the territory, and have an average depth of 0.6 m. Uruto's neighbourhoods cover an area of 646 square metres, which represents 10% of the total territory. These neighbourhoods have an average depth of 1.2 metres, making them the least affected by flooding compared to other areas (see Table 2).

The amount of flooded water due to the rise in rainfall was the greatest in Oruamahdu and the smallest in Uruto (refer to Fig 3). This indicates that Oruamahdu, characterised by its extensive land expanse, suffers from inadequate drainage, resulting in heightened occurrences of flooding. Nevertheless, the areas of Urude, Erovie, and Oruamahdu are susceptible to significant flooding (refer to Fig 4). Furthermore, July exhibits the highest flood volume among all months, with a total of 8310.6 m^3 and an average of 1662.1 m^3. On the other hand, August has the lowest flood volume, with a total of 2675.2 m^3 and an average of 535 m^3, as shown in Table 2. The increase in flooding during July is attributed to the frequent occurrence of intense rainfall, resulting in an elevation in the level of floodwaters. However, the flood decreased in August due to a 2-week holiday known as August break.

Table 2: Monthly Inundation

	Parameters	**July**	**August**	**September**	**Mean**	**Total**	
Quarters	Flood duration	2 weeks	1 week	3 weeks	2 weeks	6 weeks	Ranking
Uruto	Depth (m)	2.2	0.6	0.8	1.2		5
	Length (m)	19	19	19			
	Width (m)	34	34	34			
	Area (m^2)	646	646	646			
	Volume (m^3)	1419.9	387.6	513.4	773.6	2320.9	
Urude	Depth (m)	1.5	0.5	0.5			2
	Length (m)	25	25	25			
	Width (m)	50	50	50			
	Area (m^2)	1250	1250	1250			
	Volume (m^3)	1891.1	584.2	625	1033.4	3100.3	
Etevie	Depth (m)	1.6	0.4	0.5			4
	Length (m)	23	23	23			
	Width (m)	41	41	41			
	Area (m^2)	943	943	943			
	Volume (m^3)	1518.7	371.21	441.5	777.1	2331.4	
Erovie	Depth (m)	1.1	0.4	0.6			3
	Length (m)	32	32	32			
	Width (m)	46	46	46			
	Area (m^2)	1472	1472	1472			
	Volume (m^3)	1588.8	588.8	903.7	1027.1	3081.3	
Oruamadhu	Depth (m)	0.9	0.4	0.5	0.6		1
	Length (m)	36	36	36			
	Width (m)	59	59	59			
	Area (m^2)	2124	2124	2124			
	Volume (m^3)	1892.1	743.4	962	1199.2	3597.5	
Total Volume (m^3)		**8310.6**	**2675.2**	**3445.6**	**14431.4**		
Mean Volume (m^3)		**1662.1**	**535.0**	**689.1**			

Source: Fieldwork, 2023

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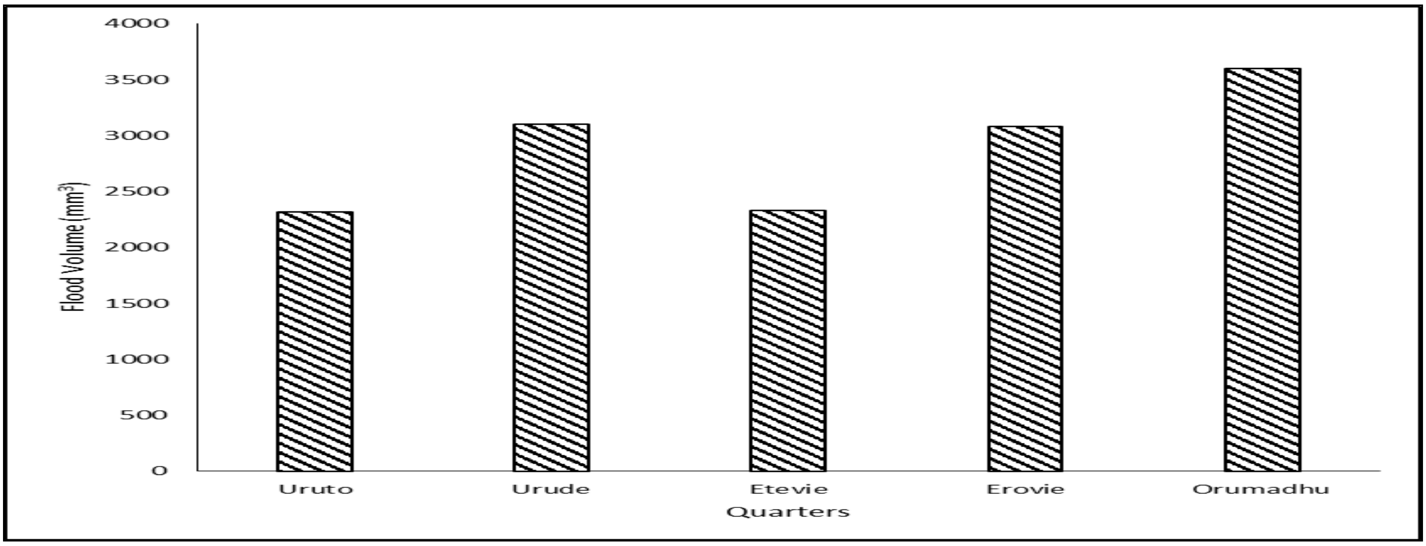

Fig 3: Flood Distribution in Ozoro

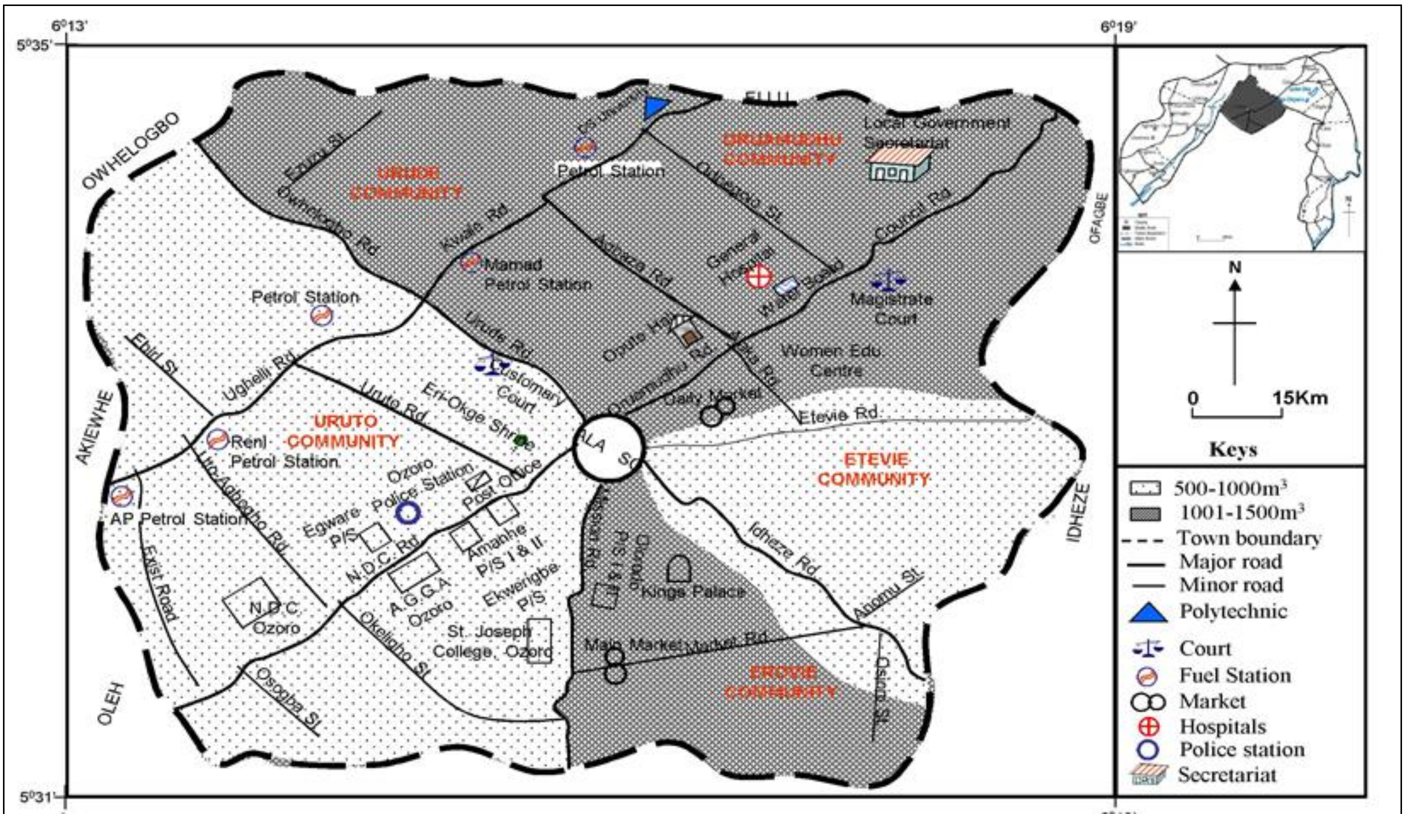

Fig 4: Flood Prone Map of Ozoro Town
Source: Modified after Ministry of Lands, Survey and Urban Development, Asaba

Table 3: Rainfall Depth in Ozoro

Quarters	July Rainfall (mm)	August Rainfall (mm)	September Rainfall (mm)
Uruto	1345	123	223
Urude	1348.2	124.7	224.7
Etevie	1345	122.9	222.9
Erovie	1346.1	125	225
Orumadhu	1348.3	125.9	225.9
Average	1346.5	124.3	224.3
Total	6732.6	621.5	1121.5

Source: Fieldwork, 2023

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Table 3 shows rainfall data for the Ozoro community. The distribution of rainfall indicates that the amount of rainfall in a given month is relatively consistent across the different regions of Ozoro. However, some variations in rainfall depth within the same month may be attributed to the typical rainfall patterns in the community. Additionally, the total rainfall in July is 6732.6 mm, with an average of 1346.5 mm, making it the month with the highest amount of rainfall. In contrast, August has a rainfall of 621.5 mm, with an average of 124.3 mm, making it the month with the lowest amount of rain (refer to Table 3). July is considered the peak of rainfall, as it has the heaviest precipitation (refer to Fig 5).

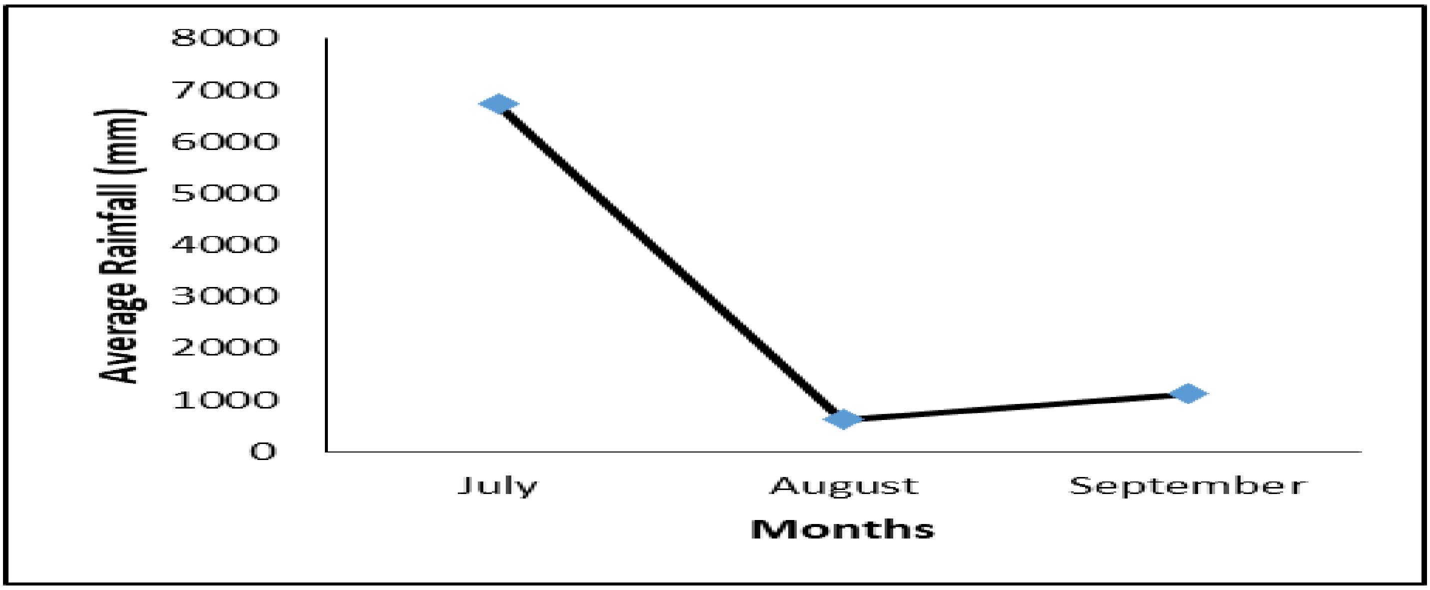

Fig 5: Rainfall Distribution in Ozoro

Table 4: Rainfall Intensity

Months	Date	Depth (mm)	Hrs	Rainfall Intensity (mm/Hr)	Ranking	Return Period (T)	Probability (1/T)
July	06-Jul	729	7	104.1	6	2.7	0.4
	10-Jul	876	8	109.5	5	3.2	0.3
	12-Jul	897.3	8	112.2	4	4.0	0.3
	15-Jul	971	6	161.8	3	5.3	0.2
	19-Jul	835.2	5	167.0	2	8.0	0.1
	21-Jul	732	4	183.0	1	16.0	0.1
	22-Jul	558.1	6	93.0	7	2.3	0.4
	27-Jul	662	8	82.8	8	2.0	0.5
	30-Jul	472	6	78.7	9	1.8	0.6
August	25-Aug	74.3	4	18.6	14	1.1	0.9
	29-Aug	50	4	12.5	15	1.1	0.9
September	02-Sept	357.2	5	71.4	10	1.6	0.6
	07-Sept	221.1	7	31.6	13	1.2	0.8
	20-Sept	324.2	5	64.8	11	1.5	0.7
	30-Sept	219	4	54.8	12	1.3	0.8
	Average	531.9		89.7		3.5	0.5

Source: Fieldwork, 2023

The results of the study showed that July had the highest daily rainfall intensity of 183mm/h, while the lowest daily rainfall intensity was recorded in August at 12.5mm/h (refer to Table 4). The mean precipitation intensity recorded during the study period was 89.7mm/h, surpassing the threshold value for Isesco's water resources as indicated in Table 5. Therefore, in Ozoro, the amount of rain during the study period consisted of intense rainfall, which may have led to a heightened risk of flooding in 2023. On July 21, there was a rainfall intensity of 183 mm/h, resulting in a four-hour torrential downpour in Ozoro. While August typically experiences low rainfall, the precipitation that does occur is characterised by a high level of intensity.

Table 5: Classification of Rainfall Events

Class	Rainfall intensity (mm/hr)
Light	< or = 2.4
Moderate	>= 2.4 - or < 7.8
High	>7.8
Violent	>49.8

Source: Chiadikobi et al. (2011)
(According to Isesco Water Resources)

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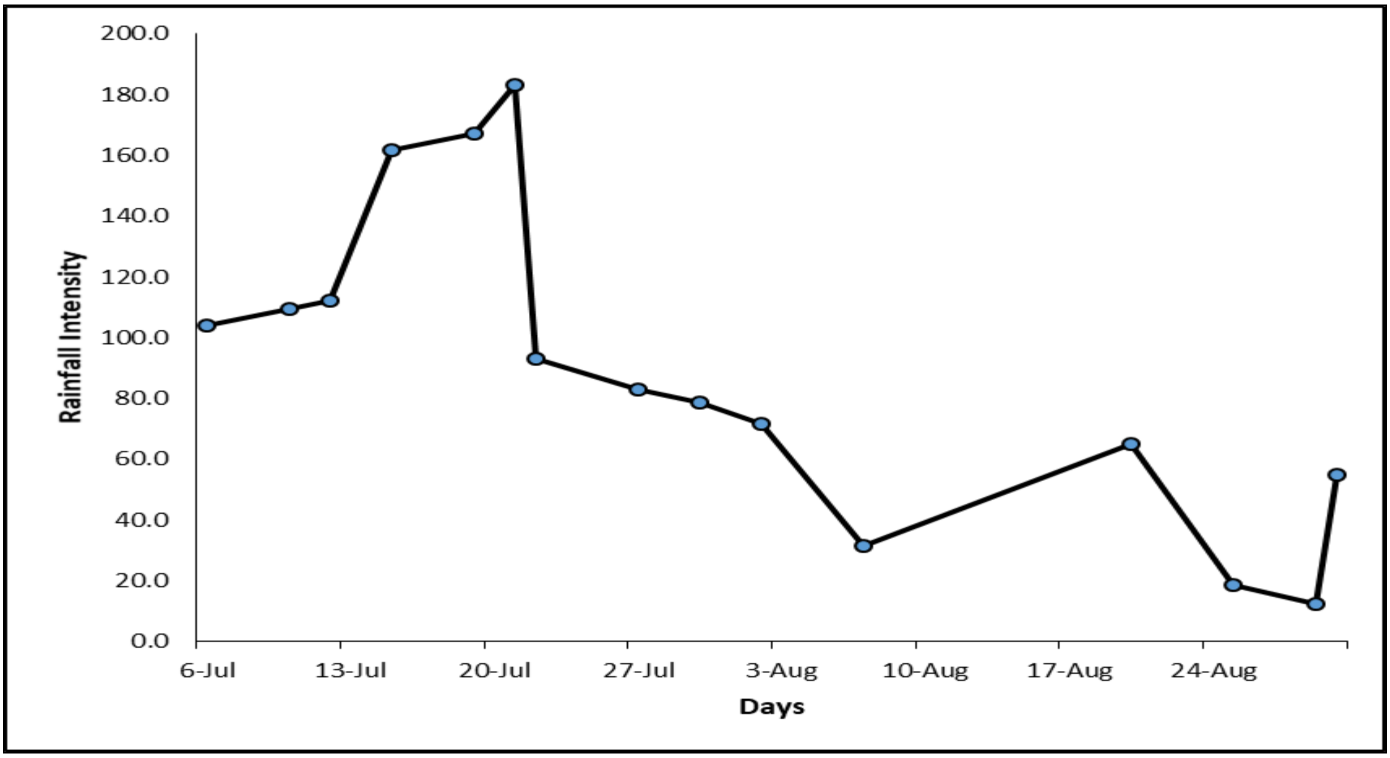

Fig 6: Rainfall Intensity in Ozoro

Based on the Intensity-Duration-Frequency (IDF) curves, there was a rise in the intensity of rainfall between July 6 and July 21, followed by a decline in intensity until August 12. From September 2 to September 30, there were fluctuations in the intensity of rainfall. The intensity of rain diminishes as time progresses, meaning that the intensity of rainfall during shorter periods is greater than that during longer periods (refer to Fig 6). The observed decrease further validated the declining pattern of rainfall intensity in the area over the days. The intensity of rainfall is a key factor in causing flooding, although its potential to cause flooding is contingent upon the timing of the rainfall. High intensity refers to a significant amount of rainfall, but it does not necessarily imply the opposite, which is heavy rainfall. The intense rainfall can lead to the occurrence of floods (Tabari, 2020).

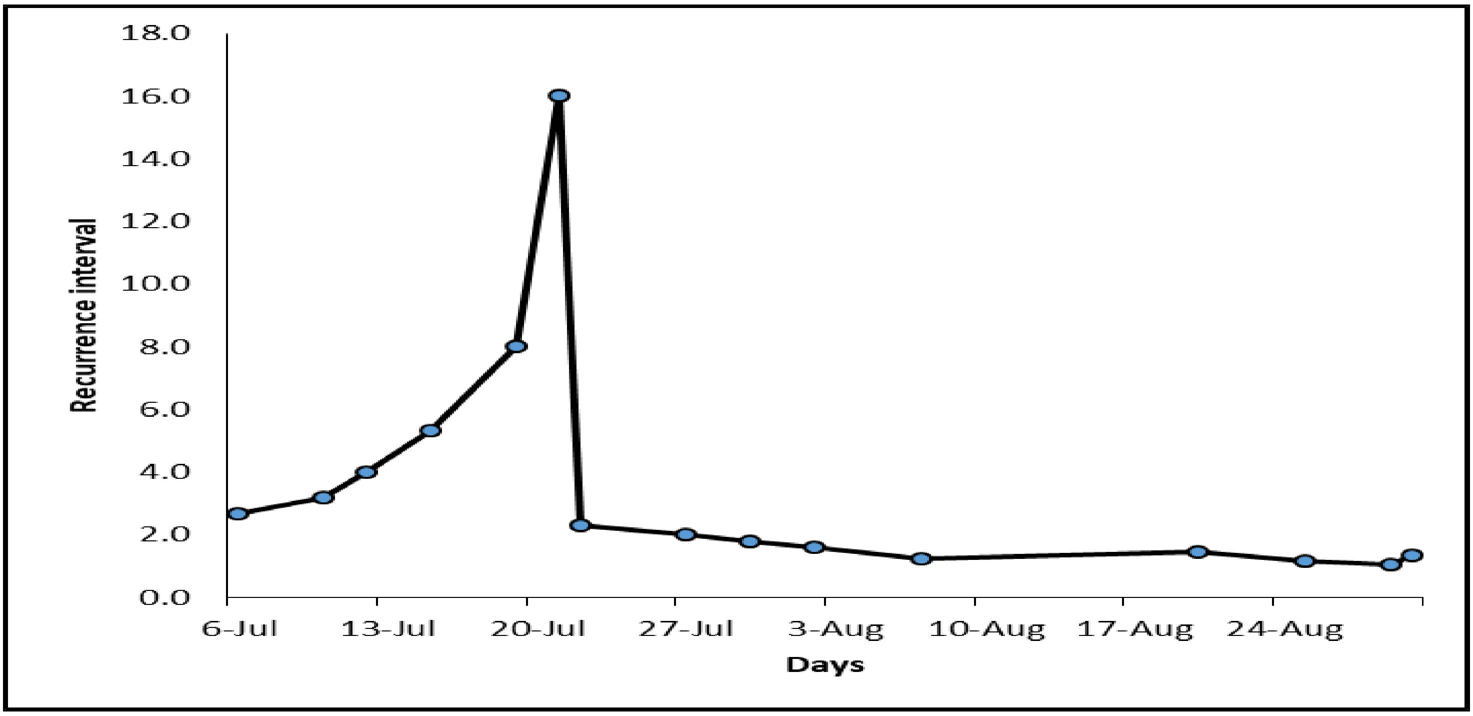

Fig 7: Rainfall Recurrence Interval in Ozoro

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Increased rainfall intensity corresponds to heightened susceptibility to flooding. Fig 7 displays the anticipated recurrence interval (return period) of exceptional daily precipitation. The IDF curve reached its peak during the highest point of the repeat cycle (return period) in July and reached its lowest point in August 2023, indicating a gradual decline in rainfall over the return period. Similarly, the rainfall return periods for the maximum rainfall on July 21 (16.0) and the minimum rainfall on August 25 and 29 (1.1) also confirm the descending order. The amplitude of precipitation events typically increases until a certain point, after which extending the repeat interval does not result in any further increase in amplitude.

Table 6: Rainfall intensity on Flooding in Ozoro

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.925[a]	.856	.845	216.60752	.856	77.341	1	13	.000
a. Predictors: (Constant), Rainfall Intensity									

Source: SPSS output

Table 6 demonstrates a robust correlation with a correlation coefficient (R) of 0.925 between the intensity of rainfall and the occurrence of flooding. The obtained model can be represented as $Y = 66.03 + 11{,}511 + X_1$, where Y represents the intensity of rainfall and X_1 represents the independent variable of flood. The data indicates that the flood volume at Ozoro experienced a decrease of $11.57m^3$ per day for the 3-month study period. Nevertheless, the r^2 value indicates a correlation coefficient of 0.856, suggesting that 85.6% of the flood can be attributed to the intensity of precipitation at Ozoro. Given a significance level of $P<0.05$, the calculated F value is 77.34; whereas the critical value from the table is 4.67. Consequently, the amount of water that floods Ozoro is greatly influenced by the level of rainfall intensity. Moreover, as the precipitation intensity escalates, the level of flooding correspondingly rises. Ologunorisa and Tersoo (2006) concur that intense daily precipitation events, particularly torrential rainfall, have the potential to result in surface runoff.

- *Management Measures of Flood*

Sustainable development necessitates the implementation of a comprehensive mechanism to uphold the ability to withstand and recover from unexpected events and disturbances, such as catastrophic floods. A widely accepted understanding of sustainable development is that it involves ensuring that civilization, wealth (both human and natural capital), and the environment (both man-made and natural) are preserved and handed down to future generations without being depleted or impoverished. Implementing flood protection measures is imperative for the current generation to attain a satisfactory level of immunity against disastrous occurrences.

However, it is crucial to ensure that these measures do not have detrimental consequences for future generations. Sustainability is based on three fundamental aspects: economic, social, and environmental activities that enhance the capacity of current and future generations to live within the earth's limits, while ensuring economic growth, social fairness, and environmental protection (Hajian & Kashani, 2021). Nevertheless, this entails making arrangements for unlikely occurrences and an unexpected moment of influence.

V. CONCLUSION

The study revealed that the districts of Oruamahdu exhibited the most extensive inundated area. Nevertheless, the districts of Urude, Erovie, and Oruamahdu are highly susceptible to significant flooding. Moreover, there has been a rise in flooding during July, which could be attributed to an increase in consistent precipitation. Nevertheless, August experiences numerous rainless days. Nevertheless, Ozoro receives average rainfall, with the most intense daily rainfall occurring in August. The downpours are intense and significantly contribute to the occurrence of floods in Ozoro.

The Intensity-Duration-Frequency (IDF) curves demonstrate that rainfall intensity is greater during shorter periods compared to longer ones, and the anticipated recurrence interval decreases. The magnitude of flooding in Ozoro is directly influenced by the intensity of rainfall, thereby confirming that the occurrence of flooding is a natural consequence of seasonal fluctuations. It is advisable to adhere to climate adaptation methods. For planning purposes, the rain intensity-duration-frequency curve can be modified by incorporating an approximation of the rainfall intensity in a specific area, provided that the duration and frequency of precipitation (repeating cycles) are known. Planners should integrate a comprehensive drainage and flood hazard map into their processes to aid in site inspections and plan approvals.

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