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ASSESSMENT OF URBAN FLOODING CAUSES AND DRAINAGE SYSTEM EFFICIENCY IN BAYELSA STATE, NIGERIA

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ABSTRACT
This study assessed the causes of urban flooding and the efficiency of drainage systems in Bayelsa State, Nigeria. A descriptive survey design was adopted, with 400 respondents selected from Yenagoa, Brass Town, Nembe Town and Amassoma. Data were collected using the Urban Flooding and Drainage Efficiency Questionnaire (UFDEQ) ,which yielded a reliability coefficient of 0.87 using Cronbach's Alpha and analyzed using mean, standard deviation, and independent sample t-test at the 0.05 significance level. Findings revealed that the drainage systems exhibits moderate but insufficient effectiveness in managing flooding, particularly during heavy rainfall. Poor maintenance, waste clogging and urban land-use changes were identified as key factors reducing drainage efficiency. The results further showed no significant difference in the perceptions of residents and urban planners regarding drainage system performance. The study concludes that existing drainage infrastucture is inadequate to cope with increasing flood pressures. It recommends improved maintenance practices, stricter waste management enforcement, and integration of effective drainage planning into urban development.

Keywords: Assessment, Urban Flooding, Causes, Drainage System, Efficiency, Waste clogging ,Land-use change, Bayelsa State.

Introduction
Urban flooding has become a major environmental challenge in rapidly urbanizing regions worldwide, with significant socio-economic and ecological consequences. (UN-Habitat, 2020). In Nigeria's Niger Delta particularly in Bayelsa State,flooding is a recurrent issue driven by intense rainfall patterns, low-lying terrain, and increasing urbanization. (Okeke & Nwankwo, 2023). The state's extensive wetlands and tropical monsoon climate make its urban centers especially vulnerable, as heavy seasonal rainfall frequently exceeds the capacity of existing drainage systems, resulting in widespread flooding and disruption. Bayelsa State, characterized by its low-lying terrain, extensive wetlands, and a tropical monsoon climate, experiences heavy seasonal rains that frequently overwhelm urban drainage systems, leading to widespread flooding and disruption (Adelekan et al., 2021). The state's urban centers, such as Yenagoa and Nembe, are particularly vulnerable due to increasing population density, unplanned urban growth, and limited drainage capacity.

Drainage systems play a critical role in mitigating urban flood risks by channeling stormwater away from built-up areas. However, their efficiency in Bayelsa State is often compromised by poor maintenance, waste clogging, and inadequate consideration of changing land-use patterns (Ezeh et al., 2022). Rapid urban expansion has led to the conversion of permeable surfaces into impermeable structures, increasing surface runoff and placing additional pressure on already limited drainage infrastructure (Ibe et al., 2020). In addition, weak institutional capacity, limited funding, and ineffective waste management practices further reduce the functionality of drainage systems and exacerbate flooding events (Odili & Chukwu, 2023; Nwafor et al., 2021)

Despite the growing body of literature on urban flooding in Nigeria, there remains limited empirical evidence that simultaneously examines the combined effects of heavy rainfall, drainage maintenance, . Furthermore, few studies have compared the perceptions of residents and urban planners regarding the performance of drainage systems. This gap constrains the development of targeted and context-specific flood management strategies (Oladipo & Arogundade, 2024).
This study therefore aims to assess the causes of flooding and evaluate the efficiency of drainage systems in Bayelsa State, Nigeria, with specific focus on rainfall intensity, maintenance practices, waste clogging, and urban land-use changes.

Aim and Objectives of the Study
This study aimed to carry out an assessment of urban flooding causes and drainage system efficiency in Bayelsa State. Specifically, the study aims to:

1. evaluate the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity.
2. assess the efficiency of the drainage system in managing flooding caused by poor drainage maintenance.
3. evaluate the drainage system's effectiveness in handling flooding resulting from waste clogging.
4. examine how well the drainage infrastructure mitigates flooding caused by urban land-use changes.

Research Question

1. What is the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity?
2. What is the efficiency of the drainage system in managing flooding caused by poor drainage maintenance?
3. What is the effectiveness of the drainage system in handling flooding resulting from waste clogging?
4. How well does drainage infrastructure mitigate flooding caused by urban land-use changes?

Hypotheses
H_{O1}: There is no significant difference in the perception of residents and urban planners on the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity.
H_{O2}: There is no significant difference in the perception of residents and urban planners on the efficiency of the drainage system in managing flooding caused by poor drainage maintenance.
H_{O3}: There is no significant difference in the perception of residents and urban planners on the effectiveness of the drainage system in handling flooding resulting from waste clogging.
H_{O4}: There is no significant difference in the perception of residents and urban planners on how well drainage infrastructure mitigates flooding caused by urban land-use changes.

Theoretical Framework
This study is anchored on Systems Theory and the Urban Flood Risk Framework. Systems Theory, associated with Ludwig von Bertalanffy, conceptualizes the urban environment as an interconnected system in which environmental and human factors interact to influence outcomes. Recent studies highlight that urban flooding arises from the interaction of rainfall intensity, infrastructure capacity, and land-use dynamics rather than isolated factors.(Ivanov,V.Y,Tran V.N,Huang W. et al) . Within this system, drainage infrastructure serves as a critical component whose efficiency determines the systems ability to manage excess runoff. The urban Flood Risk

Framework explains flooding as the interaction of hazard, exposure and vulnerability. Heavy rainfall represents the primary hazard, while urban expansion and waste management practices increase exposure and vulnerability. Drainage system efficiency plays a mediating role in determining the system's capacity to manage excess runoff.(Bolarin S.K etal) In addition, recent research highlights that rapid urbanization and climate variability intensify flood risks and frequently overwhelm drainage systems, especially in developing regions.
Together, these perspective provide a basis for understanding how environmental pressures and infrastructural limitations interact to influence drainage system efficiency and urban flooding in Bayelsa State.

Conceptual Framework
This study examines the relationship between key causes of urban flooding and drainage system efficiency in Bayelsa State. Heavy rainfall, poor drainage maintenance, waste clogging, and urban-use changes are treated as independent variables influencing drainage system performance, which is the dependent variable. The efficiency of the drainage system determines the extent to which flooding is mitigated or exacerbated. Institutional factors such as government funding, institutional capacity, and public behavior are considered intervening variables.

[Heavy Rainfall Intensity]
[Poor Drainage Maintenance]
[Drainage System Efficiency]
[Urban Flooding Outcome]
[Waste Clogging]
[Urban Land-Use Changes]
` Intervening Variables'
[Government Funding]
[Institutional Capacity] [Public Awareness]
Conceptual framework showing the relationship between urban flooding causes and drainage system efficiency, with institutional factors as intervening variables.

Methodology
This study was conducted in Bayelsa State, located in Nigeria's Niger Delta region. Bayelsa State comprises eight Local Government Areas (LGAs): Brass, Ekeremor, Kolokuma/Opokuma, Nembe, Ogbia, Sagbama, Southern Ijaw, and Yenagoa. While the state has predominantly rural characteristics, it also includes urban centers where flooding and drainage challenges are most pronounced.
A descriptive survey research design was adopted for this study. This design is appropriate as it allows for systematic collection and analysis of data to describe the causes of urban flooding and assess the efficiency of drainage systems in Bayelsa State without manipulating any variables.
The population comprised 1,704,515 residents and key stakeholders in the study areas across the state who experience or manage urban flooding and drainage issues. The population was based on the 2006 census report. A sample size of 400 respondents was selected, drawn from four strategically chosen urban communities known for their vulnerability to flooding and drainage challenges: Yenagoa (Yenagoa LGA), Brass Town (Brass LGA), Nembe Town (Nembe LGA), and Amassoma (Ogbia LGA).
A purposive sampling technique was used to select these communities based on their ecological relevance, urbanization level, and exposure to flooding. Within each community, respondents were selected through simple random sampling to ensure representativeness. The sample included

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residents and urban planners who possess relevant knowledge and experience regarding urban flooding and drainage efficiency.

Data were collected using a structured questionnaire developed specifically for this study, titled the "Urban Flooding and Drainage Efficiency Questionnaire (UFDEQ)." The questionnaire contained four sections aligned with the study's objectives, addressing flooding caused by heavy rainfall, poor drainage maintenance, waste clogging, and urban land-use changes. Responses were measured on a four-point Likert scale: Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1), with a criterion mean of 2.50 serving as the decision threshold.

The questionnaire underwent rigorous face and content validation by experts in Geography, Environmental Science, and Urban Planning to ensure clarity, relevance, and comprehensiveness. Reliability testing was conducted using Cronbach's Alpha, yielding a coefficient of 0.87, indicating high internal consistency and suitability for the study.

Trained research assistants facilitated data collection by administering questionnaires directly to respondents in the selected urban communities. Assistance was provided when needed to ensure accurate and complete responses. Completed questionnaires were retrieved promptly to maximize response rates.

Data analysis was descriptive in nature, employing measures such as mean scores and standard deviations to summarize respondents' perceptions and assessments. Inferential statistics, like the independent sample t-test was used to test the hypotheses at a 0.05 level of significance.

Results

Research Question One: What is the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity?

Table 1: Mean and SD of the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity

S/N	Items	Respondent (n = 400)		
		$\bar{x}$	SD	Decision
.1	Heavy rainfall frequently leads to water accumulation in the urban areas of Bayelsa State	3.10	0.93	Agree
.2	The current drainage system can handle normal rainfall without causing flooding	3.01	0.92	Agree
.3	During intense rainfall, the drainage system becomes overwhelmed and causes urban flooding	3.25	0.82	Agree
.4	Floodwaters from heavy rainfall take a long time to recede due to inefficient drainage	3.35	0.67	Agree
.5	The drainage channels are regularly cleaned to cope with heavy rainfall	2.03	1.02	Disagree
.6	Flooding from heavy rainfall disrupts daily activities in my community	3.09	0.91	Agree
.7	The drainage system design considers the volume of rainfall typical for Bayelsa State	2.91	1.04	Agree
	Grand Mean	**2.96**		

(Criterion Mean = 2.5, Mean ≥ 2.5, Agree, Mean < 2.5, Disagree)

Table 1 presents respondents' perceptions of the drainage system's effectiveness in handling flooding caused by heavy rainfall intensity in Bayelsa State. The results indicate that most respondents agreed with six of the seven items, with mean scores equal to or above the criterion mean of 2.5, except for the item on regular cleaning of drainage channels, which scored below the benchmark. With a grand mean of 2.96, the findings imply that while the drainage system is

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moderately effective in managing normal rainfall, it faces significant challenges during heavy rainfall, particularly due to insufficient maintenance.

Research Question Two: What is the efficiency of the drainage system in managing flooding caused by poor drainage maintenance?

Table 2: Mean and SD of the efficiency of the drainage system in managing flooding caused by poor drainage maintenance

S/N	Items	Respondent (n = 400)		
		$\bar{x}$	SD	Decision
.8	Poor maintenance of drainage channels contributes significantly to urban flooding	3.26	0.79	Agree
.9	Blocked drains due to a lack of maintenance cause water to overflow onto roads and homes	3.09	0.87	Agree
.10	There is regular inspection and maintenance of the drainage infrastructure in my area	1.51	0.58	Disagree
.11	Maintenance activities are often carried out to prevent flooding	2.00	1.03	Disagree
.12	Residents are involved in reporting drainage problems to the relevant authorities	3.01	0.92	Agree
.13	Lack of funding limits proper drainage maintenance in urban areas	3.17	0.88	Agree
.14	Poorly maintained drainage systems are a major cause of flooding in my community	3.20	0.78	Agree
	Grand Mean	**2.75**		

(Criterion Mean = 2.5, Mean ≥ 2.5, Agree, Mean < 2.5, Disagree)

Table 2 presents respondents' perceptions of the efficiency of the drainage system in managing flooding caused by poor drainage maintenance in Bayelsa State. The results indicate that most respondents agreed with five of the seven items, with mean scores equal to or above the criterion mean of 2.5, while two items related to regular inspection and maintenance scored below the benchmark. With a grand mean of 2.75, the findings suggest that poor maintenance significantly contributes to urban flooding and that the drainage system's efficiency is hindered by inadequate upkeep and limited funding.

Research Question Three: What is the effectiveness of the drainage system in handling flooding resulting from waste clogging?

Table 3: Mean and SD of the effectiveness of the drainage system in handling flooding resulting from waste clogging

S/N	Items	Respondent (n = 400)		
		$\bar{x}$	SD	Decision
.15	Waste disposal into drains frequently causes blockages, leading to flooding	2.99	0.92	Agree
.16	There are adequate waste management measures to prevent drain clogging	2.10	1.05	Disagree
.17	Residents commonly dump solid waste into drainage channels	3.21	0.86	Agree
.18	Waste clogging significantly reduces the drainage system's capacity to manage floodwaters	3.25	0.75	Agree

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.19	Authorities enforce regulations against dumping waste into drainage channels	1.77	0.90	Disagree
.20	Flooding incidents increase during periods of heavy waste accumulation in drains	3.03	0.92	Agree
.21	Public awareness campaigns exist about the impact of waste clogging on flooding	3.06	0.89	Agree
	Grand Mean	**2.77**		

(Criterion Mean = 2.5, Mean ≥ 2.5, Agree, Mean < 2.5, Disagree)

Table 3 presents respondents' perceptions of the effectiveness of the drainage system in handling flooding caused by waste clogging in Bayelsa State. Most respondents agreed with five of the seven items, with mean scores at or above the criterion mean of 2.5, while two items concerning waste management measures and enforcement of regulations scored below the benchmark. With a grand mean of 2.77, the findings indicate that waste clogging significantly impairs the drainage system's capacity to manage floodwaters, exacerbating urban flooding in the area.

Research Question Four: How well does drainage infrastructure mitigate flooding caused by urban land-use changes?

Table 4: Mean and SD of how well drainage infrastructure mitigates flooding caused by urban land-use changes

S/N	Items	Respondent (n = 400)		
		$\bar{x}$	SD	Decision
.22	Conversion of wetlands and green spaces to urban development increases flood risk	2.99	0.92	Agree
.23	Urban expansion has reduced natural water absorption areas, leading to more surface runoff	3.10	0.92	Agree
.24	The drainage system has been upgraded to accommodate changes in land use	1.84	0.98	Disagree
.25	Poor urban planning contributes to inadequate drainage capacity in growing towns	3.16	0.83	Agree
.26	Flooding occurs more frequently in newly developed urban areas	2.18	1.08	Disagree
.27	Land-use changes are properly considered in flood risk management plans	3.07	0.86	Agree
.28	Urban development projects include provisions for effective drainage solutions	3.13	0.86	Agree
	Grand Mean	**2.78**		

(Criterion Mean = 2.5, Mean ≥ 2.5, Agree, Mean < 2.5, Disagree)

Table 4 presents respondents' perceptions of how well drainage infrastructure mitigates flooding caused by urban land-use changes in Bayelsa State. Most respondents agreed with five of the seven items, with mean scores at or above the criterion mean of 2.5, while two items related to drainage system upgrades and frequency of flooding in new developments scored below the benchmark. With a grand mean of 2.78, the findings suggest that although urban expansion and poor planning increase flood risks, drainage infrastructure efforts to mitigate these impacts are only partially effective.

Hypothesis One: There is no significant difference in the perception of residents and urban planners on the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity.

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Table 5: Summary of the independent sample t-test on the difference in the perception of residents and urban planners on the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity

Respondents	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision
Residents	264	20.81	2.60	398	0.69	1.96	0.49	Retain: H_{01}
Urban Planner	136	20.62	2.61					

Table 5 indicates that t_{cal} = 0.69, df = 398, and t_{tab} = 1.96. Since $t_{cal} < t_{tab}$ and P > 0.05, there is no noteworthy disparity in the perception of residents and urban planners on the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity. Hence, the null hypothesis is retained at the 0.05 alpha level.

Hypothesis Two: There is no significant difference in the perception of residents and urban planners on the efficiency of the drainage system in managing flooding caused by poor drainage maintenance.

Table 6: Summary of the independent sample t-test on the difference in the perception of residents and urban planners on the efficiency of the drainage system in managing flooding caused by poor drainage maintenance

Respondents	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision
Residents	264	19.16	2.48	398	1.01	1.96	0.31	Retain: H_{02}
Urban Planner	136	19.42	2.37					

Table 6 indicates that t_{cal} = 1.01, df = 398, and t_{tab} = 1.96. Since $t_{cal} < t_{tab}$ and P > 0.05, there is no noteworthy disparity in the perception of residents and urban planners on the efficiency of the drainage system in managing flooding caused by poor drainage maintenance. Hence, the null hypothesis is retained at the 0.05 alpha level.

Hypothesis Three: There is no significant difference in the perception of residents and urban planners on the effectiveness of the drainage system in handling flooding resulting from waste clogging.

Table 7: Summary of the independent sample t-test on the difference in the perception of residents and urban planners on the effectiveness of the drainage system in handling flooding resulting from waste clogging

Education Level	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision
Residents	264	19.37	3.18	398	0.40	1.96	0.69	Retain: H_{03}
Urban Planner	136	19.50	3.01					

Table 7 indicates that t_{cal} = 0.40, df = 398, and t_{tab} = 1.96. Since $t_{cal} < t_{tab}$ and P > 0.05, there is no noteworthy disparity in the perception of residents and urban planners on the effectiveness of

the drainage system in handling flooding resulting from waste clogging. Hence, the null hypothesis is retained at the 0.05 alpha level.

Hypothesis Four: There is no significant difference in the perception of residents and urban planners on how well drainage infrastructure mitigates flooding caused by urban land-use changes.

Table 8: Summary of the independent sample t-test on the disparity in the difference in the perception of residents and urban planners on how well drainage infrastructure mitigates flooding caused by urban land-use changes

Education Level	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision
Residents	264	19.67	2.81	398	1.95	1.96	0.05	Retain: H_{04}
Urban Planner	136	19.10	2.78					

Table 8 indicates that t_{cal} = 1.95, df = 398, and t_{tab} = 1.96. Since $t_{cal} < t_{tab}$ and P > 0.05, there is no noteworthy disparity in the perception of residents and urban planners on how well drainage infrastructure mitigates flooding caused by urban land-use changes. Hence, the null hypothesis is retained at the 0.05 alpha level.

Discussion of Findings

The findings for research question one show that while the drainage system is moderately effective in managing normal rainfall, it faces significant challenges during heavy rainfall, particularly due to insufficient maintenance. The corresponding hypothesis, which revealed no noteworthy disparity in the perception of residents and urban planners on the drainage system's effectiveness in handling flooding resulting from heavy rainfall intensity. This aligns with the findings of Adebayo and Adeoye (2020), who reported that urban drainage systems in Nigerian cities often fail during intense rainfall events due to inadequate maintenance and outdated infrastructure. Similarly, Akintola et al. (2019) found that heavy rainfall overwhelms drainage capacities in rapidly urbanizing areas, resulting in frequent urban flooding. These studies corroborate the perception that maintenance deficiencies critically limit drainage effectiveness during heavy rainfall.

The result of research question two revealed that poor maintenance significantly contributes to urban flooding and that the drainage system's efficiency is hindered by inadequate upkeep and limited funding. The corresponding hypothesis shows no noteworthy disparity in the perception of residents and urban planners on the efficiency of the drainage system in managing flooding caused by poor drainage maintenance. This is consistent with the work of Abdulraheem and Oladipo (2021), who identified funding shortages and irregular maintenance as primary causes of drainage failure in Nigerian urban centers. Likewise, Oloruntoba and Ogunleye (2018) emphasized that insufficient maintenance and blocked drainage channels exacerbate flooding in metropolitan areas. Together, these studies reinforce the conclusion that maintenance lapses are a key factor undermining drainage efficiency.

The result of research question three revealed that waste clogging significantly impairs the drainage system's capacity to manage floodwaters, exacerbating urban flooding in the area. The corresponding hypothesis, which showed no noteworthy disparity in the perception of residents and urban planners on the effectiveness of the drainage system in handling flooding resulting from waste clogging. This concurs with the research of Nwankwo and Eze (2020), who documented that indiscriminate dumping of solid waste into drains is a major cause of urban flooding in Nigerian cities. Additionally, Emeka and Chinedu (2017) reported that poor waste management practices lead

to blocked drainage channels, reducing their flood mitigation capability. These findings highlight the critical role of waste management in maintaining drainage effectiveness.

The result of research question four revealed that although urban expansion and poor planning increase flood risks, drainage infrastructure efforts to mitigate these impacts are only partially effective. The hypothesis indicated no noteworthy disparity in the perception of residents and urban planners on how well drainage infrastructure mitigates flooding caused by urban land-use changes. This finding is in agreement with Eze and Okereke (2021), who found that rapid urbanization without adequate drainage planning exacerbates flood vulnerability in Nigerian urban areas. Similarly, Bello et al. (2019) reported that urban land-use changes reduce natural water absorption, increasing surface runoff and flooding risks, while drainage infrastructure upgrades often lag behind urban growth. These studies underscore the need for integrated urban planning and drainage development to effectively manage flood risks related to land-use changes.

Conclusion

This study reveals that urban flooding in Bayelsa State is influenced by multiple interrelated factors, including heavy rainfall, poor drainage maintenance, waste clogging, and urban land-use changes. Thus, the study concludes that, while the existing drainage system demonstrates moderate effectiveness in managing normal rainfall, it struggles significantly during intense rainfall events due to insufficient maintenance and inadequate infrastructure. Poor upkeep and limited funding further compromise the system's efficiency, exacerbating flooding risks. Additionally, improper waste disposal practices severely impair drainage capacity, highlighting the need for improved waste management. Urban expansion and inadequate planning also increase flood vulnerability, with drainage infrastructure upgrades failing to keep pace with rapid land-use changes.

Recommendations

1. The Bayelsa State urban water and drainage agency should enhance routine maintenance schedules and upgrade drainage infrastructure to better manage the volume of heavy rainfall typical of the region, thereby reducing flood incidence during intense rain events.
2. Local government authorities should increase budget allocations and establish transparent maintenance programs specifically targeting drainage system upkeep to address blockages and prevent flooding caused by poor maintenance.
3. Environmental protection agencies should implement and enforce stricter waste management regulations and public education campaigns to reduce waste dumping into drainage channels and minimize clogging-related flooding.
4. Urban planning and development authorities should integrate flood risk assessments and effective drainage solutions into urban land-use planning and development approvals to mitigate flooding risks associated with rapid urban expansion and land-use changes.

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