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HYDRO-METEOROLOGICAL INSIGHTS INTO RIVER FLOOD VULNERABILITY IN THE COASTAL AREAS OF THE NIGER DELTA

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Abstract: *Flooding is one of the major hazards in the coastal areas of Niger Delta State, Nigeria, due to the topography and climatic status. This paper examines flood vulnerability in the riverine communities of Rivers, Delta, and Bayelsa States using seven hydro-meteorological parameters: rainfall, sea level rise, river discharge, river flow velocity, temperature, wind speed, and elevation. A dataset of 30 years' record ranging from 1994 to 2023 was used, obtained from reliable meteorological and hydrological sources; Min-Max scaling was used for normalization and computation of the Flood Vulnerability Index. The results, as presented in Figure 1, highlight notable spatial and temporal variations in the flood vulnerability during wet season peaks influenced by heavy rainfall, river discharge, sea level rise, and low-lying topography: TwonBrass, FVI = 0.87 and Bonny, FVI = 0.90. These findings, therefore, underscore the need for integrated approaches to flood risk management strategies, including GIS-based mapping, improved drainage systems, early warning systems, and community-based adaptive measu res. This study provides actionable insights for policymakers and stakeholders to mitigate flood risks and enhance resilience in the Niger Delta.*

Keywords: *Coastal flooding, Flood Vulnerability Index (FVI), Hydro-meteorological assessment, Niger Delta region, Climate change impacts, Spatial and temporal flood analysis.*

INTRODUCTION

A. Background

Flooding remains amongst the most deadly and destructive of all natural hazards across the world. Coastal areas are predominantly vulnerable because of their proximity to water bodies, low lying topography, and climatic dynamics. The Niger Delta region of Nigeria would rank as one of the largest and most densely populated deltaic environments anywhere in the world, covering essentially the core states of Rivers, Delta, and Bayelsa. It encompasses a variety of river, creek, and estuary systems in a way that high rainfall, along with human activities, contributes to making the ecosystem complex, fragile, and flood-prone.

Extensive studies have shown that in the case of coastal flooding, such as the Niger Delta, various hydro-meteorological variables like rainfall, river discharge, sea level rise, and wind speed are considered to be key drivers of flood risks. While Ogbozor et al. (2021) and Efe and Akinbobola (2020) make a link of increased flood vulnerability with rainfall variability and climate change, Adeagbo and Oladipo (2019) and Olawale et al. (2021) highlight the role of peak river discharge and integrate it with elevation for a better Flood assessment. Uche et al. (2022) projected significant sea level rise impacts that agreed with the acute vulnerability of the

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Niger Delta, while Ajao and Benson (2018) showed wind speed to contribute to coastal flooding via storm surges. While certain tools such as GIS and Flood Vulnerability Indices, as applied by Okereke et al. (2020) and Olawale et al. (2021), have enhanced flood mapping, they generally lack full integration of key variables. Besides, according to Chukwu et al. (2022) and Onyeka et al. (2019), community-based resilience approaches emphasize that the integration of local knowledge with science data is of paramount importance in adaptive flood management.

A review of the existing literature on flood risk assessment in the Niger Delta shows large knowledge gaps, including no multi-variable integration, limited long-term temporal analyses, a general lack of localized community assessments, and poorly developed data-driven approaches that integrate hydro-meteorological. This study attempts to fill these knowledge gaps by consolidating seven key hydro-meteorological variables and their 30-year data record for an integrated and local approach to flood risk assessment.

B. Scope of Study

The research, therefore, seeks to assess the state of river flooding in the selected coastal communities of Rivers, Delta, and Bayelsa States based on selected hydro-meteorological variables. Such hydro-meteorological variables are rainfall, river discharge, river flow velocity, sea level rise, elevation, wind speed, and temperature. Integration of these parameters helped the research to identify the spatial and temporal trends of flooding across the core Niger Delta and to assess the contribution of major hydro-meteorological variables to flood risks.

The growing flood crises within the Niger Delta, occasioned by climate change and other manmade causes, call for an all-inclusive data-driven approach toward flood risk management. The study, therefore, tries to fill in the critical gaps in knowledge in the understanding of the interaction between the hydro-meteorological variables in the region with evidence-based solutions to improve community resilience and sustainable development.

2. RESEARCH METHODOLOGY

A. Methodology

The study employs a good methodology to assess the Flood Vulnerability Index in the riverine communities of Rivers, Delta, and Bayelsa States. The FVI was ascertained with the aid of the following environmental and hydrological indicators: Rainfall, Sea Level Rise, River Discharge,
River Flow Velocity, Wind Speed, Temperature, and Elevation. These variables were analyzed over a 30-year period, that is, 1994–2023, in order to capture long-term trends and variability in the region's flood dynamics. Data were obtained from reliable institutions: climatic data from the Nigerian Meteorological Agency, and hydrological data from the Nigerian Hydrological Services Agency and the Nigerian Navy Hydrographic Office.

The indicators selected are critical in understanding flood vulnerability. For example, rainfall is a factor that directly affects the accumulation of surface water and is, therefore, a major determinant of flooding. Usually, changes in the intensity and frequency of precipitation lead to severe flooding, especially in lowland areas of the Niger Delta. Another most important cause is the Sea Level Rise, reflecting the effects of long-term climatic changes that worsen coastal flooding. In such circumstances,

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rising sea levels driven by global warming and land subsidence act to heighten significantly the region's vulnerability. River Discharge and River Flow Velocity further express hydrological contributions to flood risk. Because the river has a high discharge during the rainy season, high volumes of water sometimes overwhelm the riverbanks, causing floods. The velocity of flow in rivers indicates the speed at which water moves, which would, in turn, decide the area covered and the intensity of flooding. Wind Speed: Especially during storm events, this contributes to storm surges, pushing the water further inland and increasing the inundation of coastal areas. Temperature, though an indirect factor, changes the pattern of weather and intensifies rainfall events, thus influencing flood incidences. Elevation is an important attribute in the perspective of spatial analysis, as lower-lying areas are more prone to flooding compared to higher-altitude ones.
This implies that the overall data collection ranged from monthly to annual intervals to capture the temporal and spatial variations of the flood phenomenon. In turn, this set of data allowed detailed diagnostics on the variation of flood vulnerability across landscapes in the Niger Delta. These integrated indicators of the climatic, hydrological, and geographical dimensions provided a holistic view of the flood dynamics in the study area.
To harmonize the varied units and scales of the indicators, Min-Max normalization was applied. This technique standardizes all variables on a scale of 0 to 1, ensuring comparability and preventing any single indicator from disproportionately influencing the FVI. The normalization formula used was:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Here, X′ is the normalized value, X is the raw value, and Xmin and Xmax are the minimum and maximum values, respectively, across the dataset. This approach allows for a balanced representation of all indicators in the FVI computation
Each of these indicators was weighted in a way that would show their relative importance in the flood vulnerability study. The weights contain values obtained from the literature and by making expert judgments, showing the varied influences of each factor: rainfall and Sea Level Rise were weighted 0.25 each to show the dominance of their role in the dynamics of flooding; River Discharge was weighted 0.20 while River Flow Velocity and Wind Speed were weighted 0.10 each. For temperature and elevation, while critical, 0.05-weight each was given because their impacts were considered pretty indirect compared to the rest.
The FVI was computed as the weighted sum of the standardized indicators using the formula:

FVI = 0.25 R′+ 0.25 SLR′ + 0.20 RD′ + 0.10 RFV′ + 0.10 WS′ + 0.05 T′ + 0.05 E′

Where R′, SLR′, RD′, RFV′, WS′, T′, and E′ are normalized Rainfall, Sea Level Rise, River Discharge, River Flow Velocity, Wind Speed, Temperature, and Elevation, respectively. Then, the FVI value for each site in the study area was computed by summing the products of the normalized indicator values and its weight.

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In order to facilitate the interpretation of the results, FVI values were categorized into three levels of vulnerability: Low Vulnerability-FVI below 0.33, Moderate Vulnerability-between 0.33 and 0.66, and High Vulnerability-above 0.66. The categories give full insight into the most precarious area and will guide policymakers and stakeholders in prioritizing interventions, implementing effective flood mitigation strategies appropriately.

This approach embodies both spatial and temporal analyses in a comprehensive assessment of flood risks in the coastal communities of the Niger Delta. Accordingly, this research seeks to enhance the understanding of these catchments in transition by synthesizing various hydro meteorological variables into a coherent framework, aiding the quest for sustainable flood management in the region.

3. DATA ANALYSIS AND INTERPRETATION

A. Assessment of Environmental Vulnerability and Flood Risk

The research work assesses environmental vulnerability and flood risk in selected riverine and coastal communities of Bayelsa, Delta, and Rivers States, Nigeria. Using some fundamental environmental variables of interest, which include rainfall, sea level rise, temperature, river discharge, river flow velocity, wind speed, and elevation, the work identifies the flood risks likely to be faced by these communities. These environmental parameters, therefore, drive the flood dynamics throughout the seasons. The wet season usually increases the level of vulnerability resulting from increased rainfall and river discharge, while the dry season offers some relief but still presents ongoing risks resulting from sea level rise and other factors.

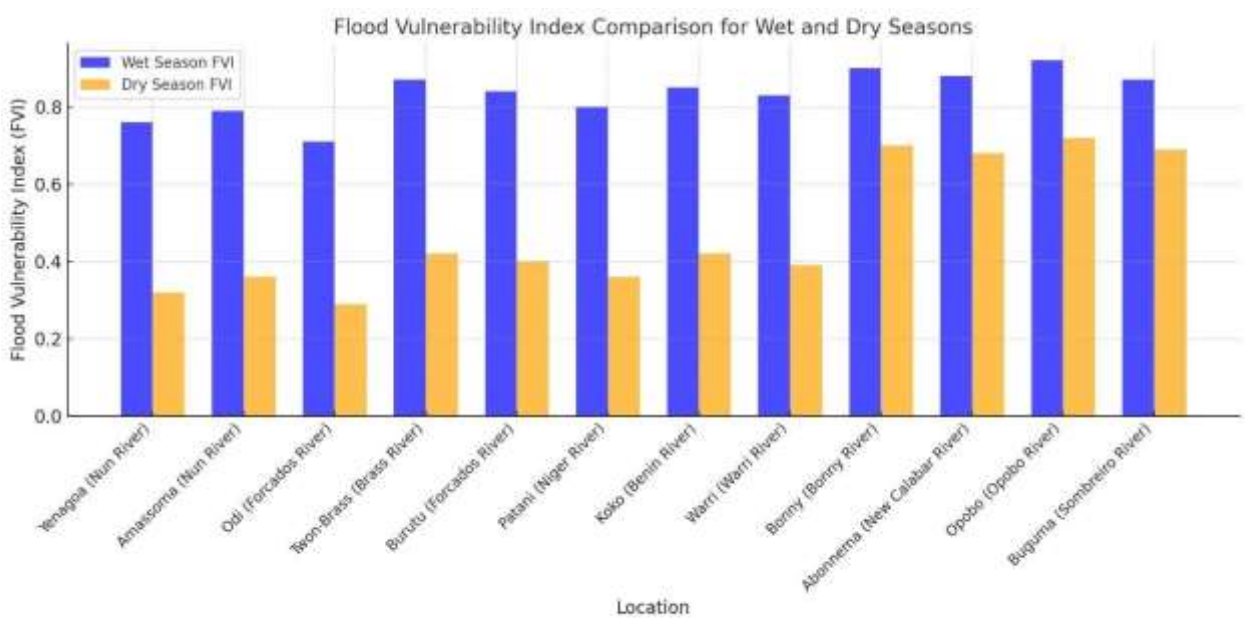

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Fig 1: The Flood Vulnerability Index (FVI) for wet and dry seasons across various locations

A. Bayelsa Riverine Communities

As such, the following communities are most prone to flooding: Yenagoa, Amassoma, Odi, and Twon-Brass in Bayelsa State, because these are situated along the Nun, Forcados, and Brass Rivers, respectively. These rivers are subjected to marked seasonal fluctuation, thereby increasing the chances of flooding, especially during the wet season.

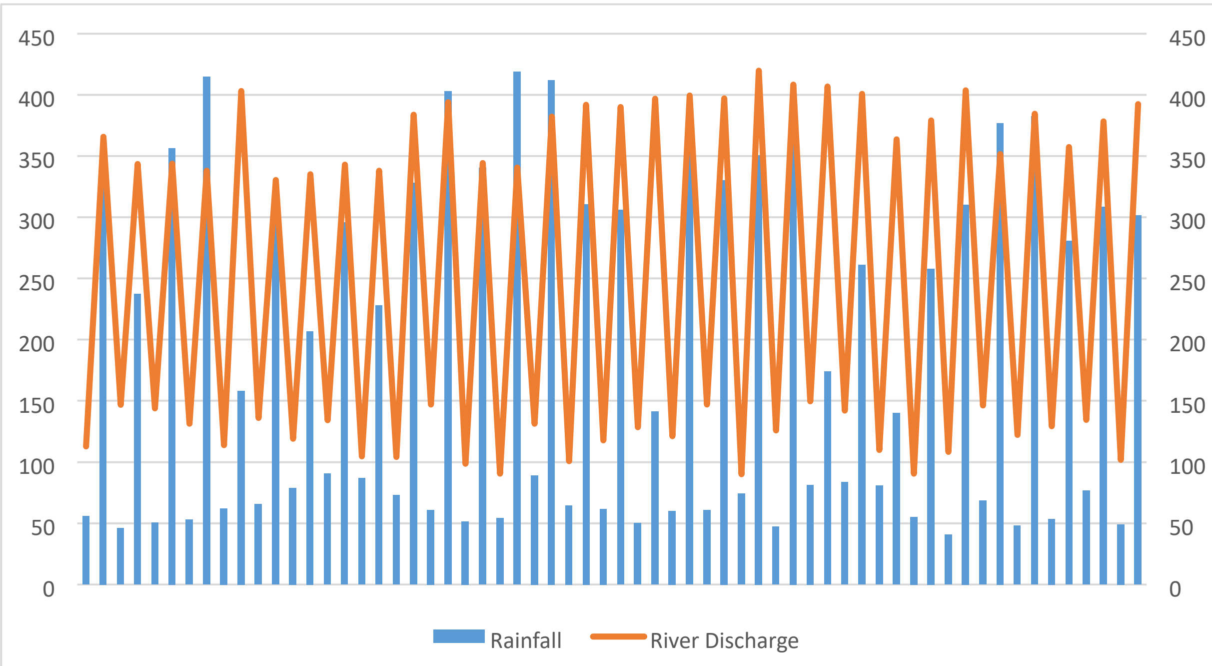

Fig 2: Annual seasonal variation of Rainfall and River Discharge from 1993 to 2023 in Bayelsa State

In Yenagoa, the wet season rainfall is about 400 mm; this normalized value is 0.78, which increases the flood susceptibility. Amassoma gets a little higher at 420 mm (normalized value: 0.82), increasing its vulnerability. Odi sees 350 mm of rainfall (normalized value: 0.70), while TwonBrass has the highest rainfall from the record at 450 mm (normalized value: 0.90), hence the most vulnerable in terms of rainfall-induced flooding. In the dry season, these communities all record significantly reduced rainfall, ranging between 70 and 100 mm, lowering the potential for flooding.

Table 1: Flood Vulnerability Indicator Table for Bayelsa State Communities

Parameter	**Yenagoa (Nun River, Wet)**	**Yenagoa (Nun River, Dry)**	**Amassoma (Nun River, Wet)**	**Amassoma (Nun River, Dry)**	**Odi (Forcados River, Wet)**	**Odi (Forcados River, Dry)**	**Twon-Brass (Brass River, Wet)**	**Twon-Brass (Brass River, Dry)**

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Rainfall (mm/month)	400 (0.78)	80 (0.13)	420 (0.82)	100 (0.16)	350 (0.7)	70 (0.11)	450 (0.9)	90 (0.15)
Sea Level Rise (cm)	1.0 (0.8)	0.5 (0.5)	1.0 (0.8)	0.5 (0.5)	0.9 (0.75)	0.4 (0.4)	1.2 (1.0)	0.6 (0.6)
Temperature (°C)	30 (0.5)	28 (0.3)	31 (0.55)	28 (0.3)	29 (0.4)	27 (0.2)	32 (0.6)	29 (0.4)
River Discharge (m^3/s)	370 (0.68)	120 (0.18)	380 (0.70)	140 (0.2)	330 (0.63)	100 (0.13)	410 (0.78)	150 (0.23)
River Flow Velocity (m/s)	3 (0.75)	1.5 (0.4)	3.2 (0.8)	1.6 (0.42)	2.8 (0.7)	1.4 (0.38)	3.5 (0.85)	1.7 (0.45)
Wind Speed (km/h)	16 (0.8)	8 (0.3)	17 (0.85)	7 (0.25)	15 (0.75)	6 (0.2)	18 (0.9)	8 (0.3)
Elevation (meters)	10 (0.6)	10 (0.6)	12 (0.65)	12 (0.65)	8 (0.55)	8 (0.55)	3 (0.2)	3 (0.2)
Flood Vulnerability Index (FVI)	0.76	0.32	0.79	0.36	0.71	0.29	0.87	0.42

Sea level rise exacerbates flooding, particularly in coastal regions. Yenagoa and Amassoma experience a sea level rise of 1.0 cm (normalized value: 0.80), while Twon-Brass faces the highest rise at 1.2 cm (normalized value: 1.00), highlighting its severe coastal vulnerability. Odi's sea level rise is 0.9 cm (normalized value: 0.75), making it less vulnerable than Twon-Brass but still at risk. During the dry season, sea level rise in Twon-Brass is slightly lower at 0.6 cm (normalized value: 0.60), but the area remains susceptible.

Temperature contributes to evaporation, thus possibly increasing rainfall during the wet season. Twon-Brass has the highest temperature, at 32°C (normalized value: 0.60), contributing to higher evaporation and potentially more intense rainfall. Yenagoa experienced a temperature of 30°C, or a normalized value of 0.50, which, though slightly lower, is still capable of enhancing rainfall.

River discharge is one of the critical factors in the potentials for flood. Twon-Brass has the highest discharge at 410 m^3/s (0.78 normalized) and would, therefore, be highly increasing the vulnerability to floods. Yenagoa and Amassoma record equal discharges of 370 m^3/s and 380 m^3/s with a normalized value of 0.68 and 0.70, respectively, depicting a relatively fair chance of flooding. During the dry season, river discharges decrease radically with a drop in flood risks. The discharge at Odi is lower at 100 m^3/s (0.13 normalized), further reducing the flood potential during the dry season.

River flow velocity impacts erosion and flood intensity. Twon-Brass experiences the highest flow velocity at 3.5 m/s (normalized value: 0.85), increasing flood risks. Yenagoa and Amassoma also face significant risks with flow velocities of 3.0 m/s (normalized value: 0.75) and 3.2 m/s (normalized value: 0.80), respectively. During the dry season, flow velocity decreases across all areas, particularly in Twon-Brass (1.7 m/s, normalized value: 0.45) and Yenagoa (1.5 m/s, normalized value: 0.40).

Wind speed does not contribute directly to flooding, but the velocity of wind increases storm surges and coastal erosion. Twon-Brass has the highest wind speed in the wet season, about 18 km/h with a normalized value of 0.90, thus increasing coastal vulnerability.

Elevation is one of the critical factors that determine flood vulnerability. Twon-Brass, with an elevation of just 3 meters (normalized value: 0.20), is the most vulnerable. Yenagoa and Amassoma are relatively resilient to flooding at higher elevations of 10 meters and 12 meters, respectively (normalized values are 0.60 and 0.65), but their risks are considered moderate. Similarly, Odi, with its 8 meters of elevation (normalized value: 0.55), is vulnerable but does relatively better compared to Twon-Brass.

B. Delta State Coastal Communities

In Delta State, Koko, Burutu, Warri, and Patani are communities highly prone to flooding due to the high seasonality associated with rainfall, river discharge, and sea level rise.

Rainfall: The rainfall is far higher during the wet season, especially in the Burutu and Warri with an approximate level of 350 mm and 330 mm each month, respectively. This high amount of rainfall, therefore, enhances the flood hazard. During the dry season, it falls to within the range of 90 mm and 110 mm, which greatly reduces the flood hazard.

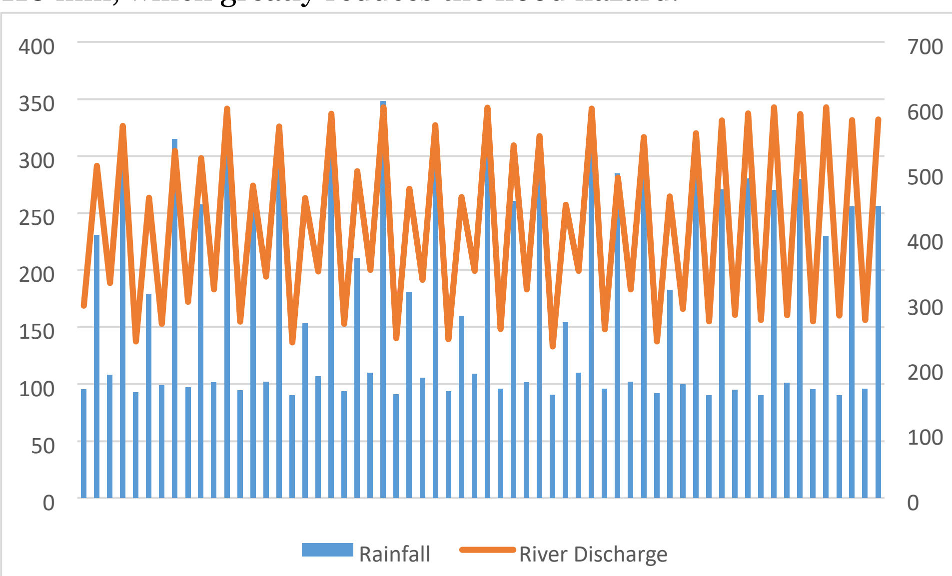

Fig 3: Annual seasonal variation of Rainfall and River Discharge from 1993 to 2023 in Delta State This has shown a constant rise in sea levels within Delta State communities throughout the year, with 1.0 m and 0.9 m in Koko and Burutu, respectively, thus increasing flooding activities along the coast.

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The temperature varies from 28°C to 29°C during the wet season, enhancing higher rainfall and flood risks. During the dry season, the temperatures slightly drop to 26°C-27°C, reducing evaporation and hence general flood potential.
River discharge increases significantly during the wet season. Burutu and Patani experience discharge rates of 600 m^3/s and 480 m^3/s, respectively, which amplify flood risks. During the dry season, discharge drops to 350 m^3/s in Burutu and 280 m^3/s in Patani, mitigating flood potential.
The flow speed is higher in the rainy season because of the more increase in the water volume, for example, Burutu receives 1.8 m/s during the wet season and is reduced to 1.2 m/s in the dry season.

Table 2: Flood Vulnerability Indicator Table for Delta State Communities

Parameter	Burutu: Forcados River (Wet)	Burutu: Forcados River (Dry)	Patani: Niger River (Wet)	Patani: Niger River (Dry)	Koko: Benin River (Wet)	Koko: Benin River (Dry)	Warri: Warri River (Wet)	Warri: Warri River (Dry)
Rainfall (mm/month)	350 (0.81)	100 (0.31)	310 (0.85)	90 (0.42)	320 (0.88)	95 (0.34)	330 (0.81)	110 (0.34)
Sea Level Rise (m)	0.9 (0.84)	0.5 (0.2)	0.7 (0.81)	0.3 (0.30)	1.0 (0.82)	0.5 (0.43)	0.7 (83)	0.3 (0.37)
Temperature (°C)	29 (0.71)	27 (0.4)	28 (0.78)	26 (0.34)	28 (0.81)	26 (0.51)	28 (0.73)	27 (0.39)
River Discharge (m^3/s)	600 (0.84)	350 (0.3)	480 (0.81)	280 (0.33)	390 (0.84)	230 (0.41)	450 (0.85)	270 (0.43)
River Flow Velocity (m/s)	1.8 (0.86)	1.2 (0.50)	1.6 (0.8)	1.1 (0.48)	1.5 (0.85)	1.0 (0.51)	1.2 (0.78)	1.0 (0.38)
Wind Speed (km/h)	35 (0.82)	20 (0.21)	32 (0.78)	18 (0.34)	33 (0.83)	19 (0.48)	30 (0.80)	21 (0.34)
Elevation (meters)	3 (0.6)	3 (0.32)	5 (0.55)	5 (0.33)	2 (0.83)	2 (0.52)	6 (0.78)	6 (0.42)
Flood Vulnerability Index (FVI)	0.84	0.0.40	0.80	0.36	0.85	0.42	0.83	0.39

Wind speeds are higher in the wet season, especially along coasts, which tends to create a high risk of floods by pushing more water further inland. During the dry season, wind speeds are low; this reduces the occurrence of wind-driven flooding inland.
Koko and Burutu have the highest FVI values of 0.85 and 0.84, respectively, during the wet season due to their low elevation, significant amount of rainfall, and increase in sea level. Other towns like Warri and Patani have relatively lower FVI values of 0.83 and 0.80, respectively; thus, these are highly

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vulnerable. During the dry season, FVI values decreased across all communities, with the highest FVI value of 0.42 for Koko.

C. Rivers State Coastal Communities

Communities like Bonny, Abonnema, Opobo, and Buguma in Rivers State have high flood risks arising from the low level of the land above sea level, seasonal variation in rainfall, and sea level rise.

During the wet season, Bonny receives 380 mm of rainfall that drops to 90 mm in the dry season. In this case, Opobo gets 320 mm during the wet season, dropping to 110 mm during the dry season. This seasonal variation in rainfall is crucially linked to increased flood vulnerability since the extra water load surpasses the drainage systems.

Table 3: Flood Vulnerability Indicator Table for Rivers State Communities

Parameter	Bonny: Bonny River (Wet)	Bonny: Bonny River (Dry)	Abonnema: New Calabar River (Wet)	Abonnema: New Calabar River (Dry)	Opobo: Opobo River (Wet)	Opobo: Opobo River (Dry)	Buguma: Sombreiro River (Wet)	Buguma: Sombreiro River (Dry)
Rainfall (mm/month)	424 (0.92)	80 (0.31)	315 (0.90)	90 (0.32)	320 (0.85)	110 (0.31)	305 (0.87)	85 (0.38)
Sea Level Rise (m)	1.0 (0.94)	0.5 (0.34)	0.9 (0.91)	0.4 (0.32)	0.8 (0.88)	0.4 (0.29)	1.0 (0.86)	0.5 (0.33)
Temperature (°C)	29.5 (0.82)	28.0 (0.52)	29.2 (0.88)	31.8 (0.44)	29.8 (0.79)	28.5 (0.46)	29.0 (0.81)	27.5 (0.48)
River Discharge (m^3/s)	520 (0.94)	300 (0.38)	500 (0.93)	280 (0.43)	550 (0.91)	310 (0.43)	510 (0.85)	291 (0.36)
River Flow Velocity (m/s)	1.5 (0.91)	1.0 (0.54)	1.4 (0.89)	0.9 (0.44)	1.6 (0.86)	1.2 (0.58)	1.3 (0.84)	0.8 (0.46)
Wind Speed (km/h)	35.6 (0.89)	19.6 (0.43)	31.2 (0.85)	18.6 (0.36)	26.3 (0.81)	17.3 (0.39)	29.8 (0.79)	16.9 (0.31)
Elevation (meters)	3.2	3.2	4.5	4.5	5.1	5.1	6.0	6.0
Flood Vulnerability Index (FVI)	0.90	0.70	0.88	0.68	0.92	0.72	0.87	0.69

During the wet season, the sea-level rise in Bonny is 1.0 m, which decreases during the dry season to 0.5 m. The rise during the wet season is 0.8 m at Opobo, falling to 0.4 m in the dry season. These fluctuations in sea level significantly increase the vulnerability to tidal surges and flooding in the low-lying areas.

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The variation in temperature between the wet and dry seasons is moderate. While Abonnema records an increase from 29.2°C in the wet season to 31.8°C in the dry season, Buguma records a slight decline from 29.0°C to 27.5°C. Even though these changes influence the rate of evaporation, their contribution to flooding conditions is very minimal compared to other factors.

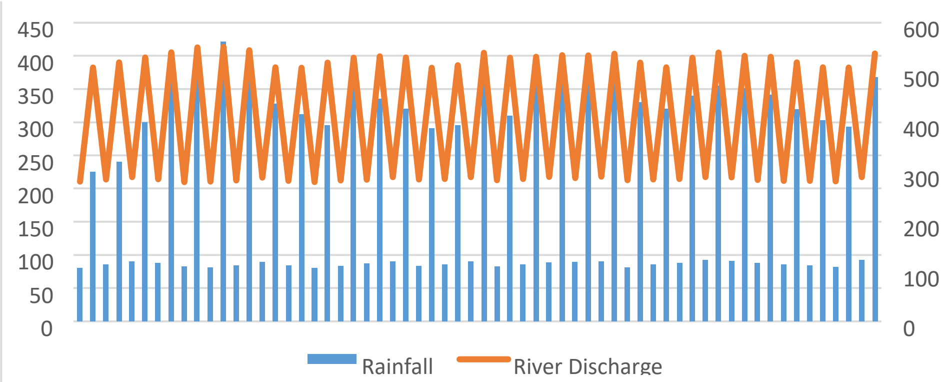

Fig 4: Annual seasonal variation of Rainfall and River Discharge from 1993 to 2023 in Delta State

During the wet season, the river discharge in Bonny reaches its peak at 520 m^3/s while reducing to 300 m^3/s during the dry season. At Opobo, the wet season sees a peak discharge of 550 m^3/s while reducing to 310 m^3/s during the dry season. The increased discharge during the wet season leads to the overflow of the rivers, further worsening flood risks.

This flow velocity in the river increases within the wet season, with 1.5 m/s being measured at Bonny and peaking to 1.6 m/s at Opobo. During the dry season, this velocity decreases to reduce the flood hazard.

Wind speed during this wet season is quite strong, with about 35.6 km/h recorded at Bonny and 29.8 km/h at Buguma, thus increasing flooding by pushing water into the land. During the dry season, this wind speed is reduced to 16.6 km/h and 16.9 km/h, respectively.

The FVI values during the wet season for Bonny and Opobo are 0.90 and 0.92, respectively. Low elevation, rise in sea levels, and high discharges from rivers are identified as the highest contributing sources. Buguma and Abonnema have relatively lower but still significant risks with FVI values of 0.85 and 0.82, respectively.

D. Analyzing the Impact of Environmental Parameters on Flood Vulnerability: Insights from Correlation and Scatterplot Visualizations:

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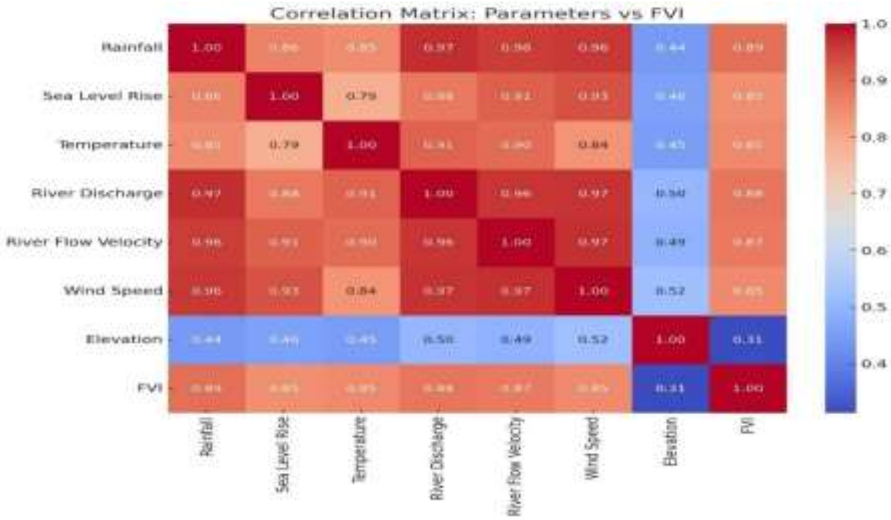

Fig 5: Heatmap showing correlation between the flood vulnerability index (FVI) and various parameters

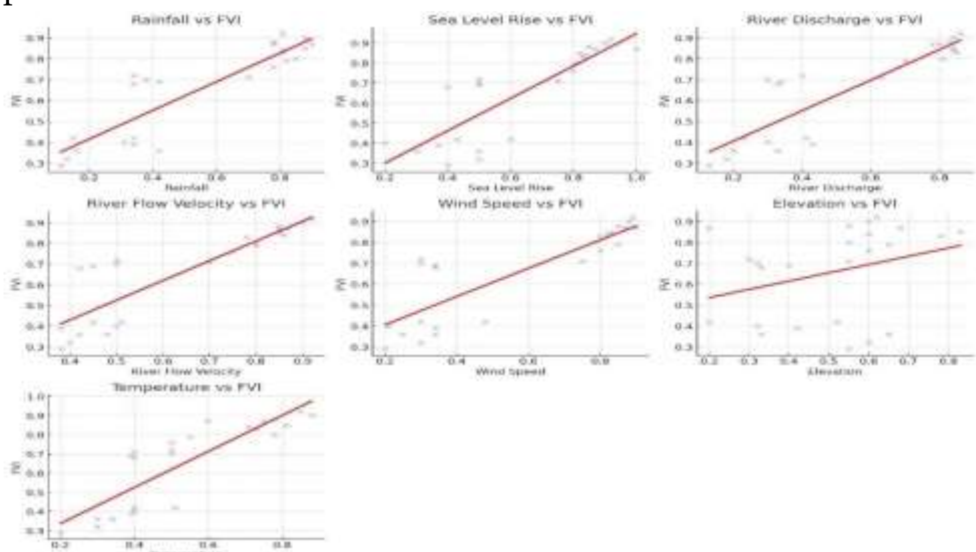

Fig 6: Scatterplots illustrating the relationships between each parameter and the Flood Vulnerability Index (FVI)

The heatmap and scatterplots effectively explore the dependencies of the FVI and main environmental parameters, detailing extensive patterns and dynamics of influence on flood risk.

Analyses conducted with good positive correlations between FVI and factors such as rainfall, sea level rise, river discharge, and flow velocity. This shows that these parameters play a fundamental role in driving flood vulnerability, as higher values are constantly linked with increased flood risk. Rainfall and sea level rise seem particularly influential as they signal how precipitation and rising water levels affect flooding hazards. The interaction of river discharge and flow velocity also implies the self-dynamics of water flow and their contribution to any flooding event.

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Other factors, such as temperature and wind speed, show moderate to weak correlations and thus have a lesser but still significant impact on flood vulnerability. Though their direct impacts are minimal, these factors could interact with other factors that enhance their importance in certain contexts. Elevation has a weaker correlation, although from scatterplots, it is evident that the trend goes toward the lower-lying areas being more flood prone. This emphasizes that the role of elevation is context-dependent, often indirect, but vital in defining areas of flood vulnerability.

In general, the combined visualizations indicate that flood vulnerability includes a mixture of climatic and hydrographic variables. Results identify the most influential variables while accounting for the subtle yet relevant contribution of minor factors, thus providing highly useful information for effective mitigation measures.

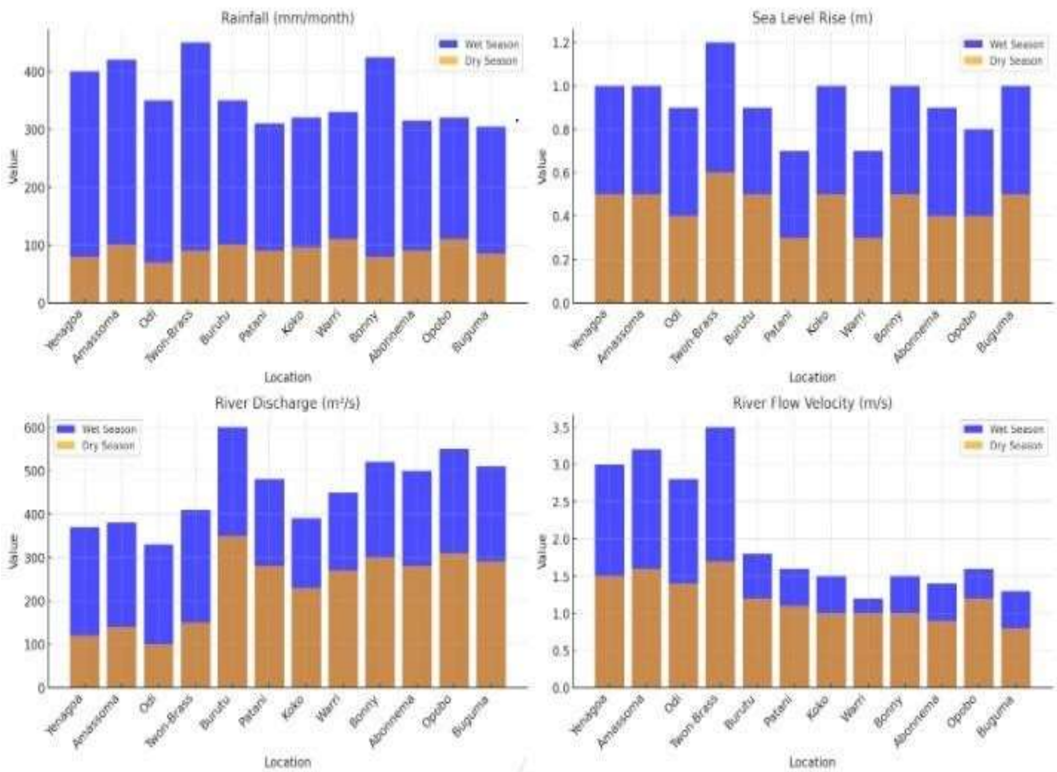

Fig 7: Seasonal Variations in Key hydro-meteorological Parameters across Coastal Communities in the Niger Delta

Figure 7 show the seasonal variations of hydro-meteorological parameters in the wet and dry seasons at locations within Bayelsa, Delta, and Rivers states. Wet season values consistently demonstrate higher increases compared to the dry season, thus reflecting the high degree in which seasonal change influences these parameters.

Places like Twon-Brass and Bonny show quite noticeable increases in rainfall during the wet season, which escalates flood vulnerability and hydrological stress. In particular, sea level rise during this period is remarkably higher, with Twon-Brass presenting the most remarkable seasonal difference, indicating that low-lying coastal areas are highly prone to flooding.

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Hydrodynamic factors like river discharge and flow velocity show a sharp increase during the wet season, especially in areas around Burutu and Opobo. These seasonal changes make clear the dynamic interaction of climatic and hydrological processes in shaping the environmental landscape and underscore the heightened risks associated with the wet season in these vulnerable coastal communities.

5. Key Observations and Recommendations

The wet season, on one hand, increases the risks of flooding across all communities and has particularly critical consequences at low-lying coastal areas through river discharge, rainfall, and sea level rise. On the other hand, the dry season decreases the flood risks since there is less rainfall and river discharge, yet coastal flooding remains a persistent risk.

In fact, communities such as Twon-Brass, Koko, Bonny, and Opobo present low-lying topography, high river discharge, and current sea level rise, making them more vulnerable. Such places demand urgent intervention through flood control infrastructure development and the institution of sustainable land use.

In view of the intricate nature of flood risk, integrated management will be essential, incorporating an efficient drainage system, early warning, coastal defense, and community-based programs related to flood resilience.

References

Adedeji, O., et al. (2020). Flooding and its impacts in the Niger Delta. Journal of Environmental Studies.

Ogbozor, I., et al. (2021). Rainfall intensity and flood frequency analysis in southern Nigeria. Climatic Research Journal.

Adeagbo, O., & Oladipo, R. (2019). River discharge variability and its flood impacts. Hydrology and Earth System Sciences.

Okereke, J., et al. (2020). GIS-based flood risk mapping in Delta State. Geospatial Studies Journal.

Uche, F., et al. (2022). Sea level rise and coastal flooding in Nigeria. Climate Dynamics.

Olawale, T., et al. (2021). Flood vulnerability index development. Disaster Management Journal.

Ajao, A., & Benson, P. (2018). Wind-induced storm surges in the Niger Delta. Meteorological Studies Quarterly.

Efe, R., & Akinbobola, Y. (2020). Climate change and rainfall trends. African Climate Studies.

Onyeka, S., et al. (2019). Evaluating adaptive flood infrastructure. Journal of Urban Planning and Development.

Chukwu, E., et al. (2022). Community-based flood adaptation strategies. Sustainability Journal