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Spatial analysis of the probability and severity of flood events in Rivers and Bayelsa States, Niger Delta Region, Nigeria

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Abstract

The present study examined the spatial analysis of the probability and severity of flood events in Rivers and Bayelsa States, Niger Delta Region, Nigeria. Archive data of flood events from NEMA were made use from 2012 to 2018 with a view to computing the trend surface of flood event within this period in the study area. Also, 400 copies of questionnaire were administered to the residents of the study area to elicit information on the flood events in the study locations. Descriptive statistics were applied in the data analysis. Findings showed that that flood height events of 2012 was the highest among the years and the least was in 2018. The trend surface analysis of flood height from 2012 to 2018 revealed that the flood height was reducing at a rate of 0.4714 ft over the period considered for this study and 39.75% of the variation in the flood height could be explained by the different years. However, Kolokuma/Opokuma and Yenagoa LGAs showed the highest prominence in the flood height and the least was found in Sagbama LGA. The probability of flood across the LGA sampled, findings revealed that a very high percentage of respondents in the LGA affirmed that their communities has been flooded each accounting for 100% of the responses obtained from the survey except for 20%, 10%, and 10% of respondents from Abua/Odual, Ahoada, and Ogbia. The study concluded that flood probability and severity in Rivers and Bayelsa States are increasing and there is variation in the prominence of flood height It is thus recommended that should be adequate flood preparedness for the vulnerable and risky public facilities especially educational and health facilities to prevent much loss of facilities and lives; and majority of the residents should be given more orientation programmes on flood preparedness and mitigation measures to always reduce the impact of flooding on the livelihood of individuals and corporate establishments.

Keywords: Probability; Severity; Flood events; Trend surface; Flood preparedness

1. Introduction

Flooding is excess water flowing onto land which is usually dry (Djimesah et al., 2018), e.g. when rainfall exceeds absorption capacity of the soil, which in turn causes significant environmental consequences (Nwachukwu et al., 2018). In addition, flooding is a general temporal state of partial or fully submersed inundation from overflows of inland or tidal waters or from infrequent and rapid accumulation of runoff (Onuigbo et al, 2017). A natural calamity or natural disaster is said to have occurred when a sudden unwanted variation on the stable natural processes occurs and causes floods, storm etc. resulting in wide spread destruction and loss of life. Flooding is the most common cause of disaster declaration in the United States, Federal Emergency Management Agency (FEMA) tracking statistic since 1953 shows that 62% of all major disaster declarations have been flood related. (Brusenter, 2017).This makes flooding the most prevalent natural disaster in Nigeria since 2012. However, flooding is expected to intensify, given increasing urbanization and climate change (Gilroy & McCuen, 2011). Humans and the environment will continue to suffer the calamitous effect of frequent flooding. Most civilization on earth is settled in flood prone areas such as wetlands, riverbanks, coastal areas and areas close to other water bodies and several factors such as poor building structures, lack

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of evacuation and flood management measures, over-dependence of households on agriculture, lack of diversification of economic activities, and weak household economic capacity were identified as causes (Oyedele et al., 2022). Floods take a heavy toll on society, costing lives, damaging buildings and property, disrupting livelihoods, and sometimes necessitating national disaster relief, which has risen to record levels in recent years (National Research Council, 2015). Despite the rapid economic growth and urbanization witnessed in many developing nations, flooding is the major development challenge facing many of their cities. Urban flooding is more intensified by dramatic changes in the impervious area, in addition to heavy rainfall and extreme climatic events (Birhanu, *et al*., 2016). High incidence of flooding could be attributed to climate change, reduction in percolation, poor environmental and infrastructure planning, poor governance, population explosion as well as rapid urbanization. The persistent migration of people from deprived areas, coupled with poor governance has put unprecedented pressure on cities' resources and infrastructure (Odufuwa, *et al*., 2012).

The ever-increasing population and the combination of properties in built-up areas also increased flooding potential. In the future, the impact of flooding will increase as the population increases (Walker and Burningham, 2011). By 2030, the effect on individuals living within 100 km of the coast is projected to be much more significant (Abbas et al. 2009). Increased population growth is also expected to rise in flood incidence (Adger, 2006). Due to population increase, the valuable surface was turned into a water-resistant area, resulting in erosion, natural rushing, and flood rise. In recent years, the average loss of flooding has risen to around fifty billion USD dollars on average. Analysis has found that between 2010, 2013, 2014, 2015, 2017, 2018, and 2019 increased cases of flood catastrophes (Adger et al., 2005).

Flood disasters struck numerous people in 2000, 2007, 2014, and 2015. Between 2010 and 2020, almost 3.6 billion inhabitants were inundated, comprising 56 percent of the world's total population. During 2010–2020, about 820,000 people in South and North America alone suffered from flood hazards (Rehman et al., 2019). In the least developed countries, flood disasters created dreadful conditions that caused major human trauma, massive losses to the substructure, life threats, and commercial development.

Over the past decade, Bangladesh, Mozambique, Germany, India, China, Malaysia, and the United States have caused disastrous circumstances and tremendous damage to lives and property (Alias et al., 2020). The tragedy is limited to developed countries and significantly impacts the world's most urbanised and developed nations. In 1988–2000 significant damage and economic losses of USD 3.64 trillion were caused in Central America and Asia due to natural and manmade disasters (Andrade and Szlafsztein, 2018). Andrew Hurricane in America has caused losses of around $ 27 billion Aroca-Jimenez at al., 2020). In Nigeria, many studies have carried out various hazard and vulnerability assessment towards flood events using various model and analysis (Wizor & Week, 2014; Komolafe *et al*., 2015; Nkwunonwo et al., 2016). The continent of Africa has suffered several devastating effects of floods in the years from 1996 to 2005 (Satterthwaite et al, 2007). There were approximately 290 cases of flood-disasters recorded within that period. Over 8,183 deaths were recorded as a result, and about 23 million people were consequently affected in diverse ways. The resultant huge economic losses were estimated at $1.9 billion (Satterthwaite et al, 2007). Through the application of advanced technology and massive investment of capital, treat to human life as a result of flooding events has decreased reasonably in most developed countries within recent decades (Smith, 2018). Despite many of these studies in this regards, the aspect of probability and severity has received little attention which seems to have contributed to various degree of loss recorded over the years, hence, the need for the analysis that not only consider the hazard and vulnerability but as well as the probability and severity of flood. There is therefore need to analyse the probability and severity of flood events the in wetlands of Rivers and Bayelsa States, Niger Delta Region of Nigeria.

2. Material and methods

The study was carried out in both Bayelsa and Rivers States, Niger Delta Region of Nigeria. Bayelsa State lies along latitudes between 4° 48' 00'' North and 5° 24' 10''East; and longitudes between 6° 12' 00''E and 6° 39' 30''E (Figure 1). It is bounded by Rivers State on the North and Delta State by the East and has a population of 1,704,515 by 1996. Yenagoa is the capital city of Bayelsa State. It has a population size of 24,335 people, according to 2006 population census estimates. Rivers State is one of the 36 states of Nigeria. The climate of the region is an equatorial type of climate. There are two distinct seasons in the region in a year, they are called rainy and dry seasons. The rainy season begins from the month of February and gradually rises to its peak in the month of July. The major vegetation in the study area comprises of mangrove and freshwater swamp. The region is located within the lower Delta Plain believed to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. Generally, region is lowland with mean elevation of between 3m and 7m above mean sea level and characterized by flood plains. Umeuduji and Aisebeogun (1999) identified that the area is within the belt of beach ridge barrier complexes generally trending in an east-west direction with height which vary between 10-25m above sea level. The net features such as lagoons are dominant relief features in the study area and are drained by many rivers and creeks among which are Epie Creek, Nun

River, Orashi River, and Ekole Creek. Abam and Fubara (2022) also reported that the River Niger follows a relatively straight southwesterly trajectory after Onitsha. The flood plain is a homo-climate geomorphic structure whose trends west ward and southwards' are broken in many places by small hogback ridges and shallow swamps basic. The soil of the sandy ridges are mostly sandy or sandy barns and supports crops like Coconut, oil palm, raffia palm and cocoyam. The major geological characteristic of the state is sedimentary alluvium. The region lies on the recent coastal plain of the eastern Niger Delta.

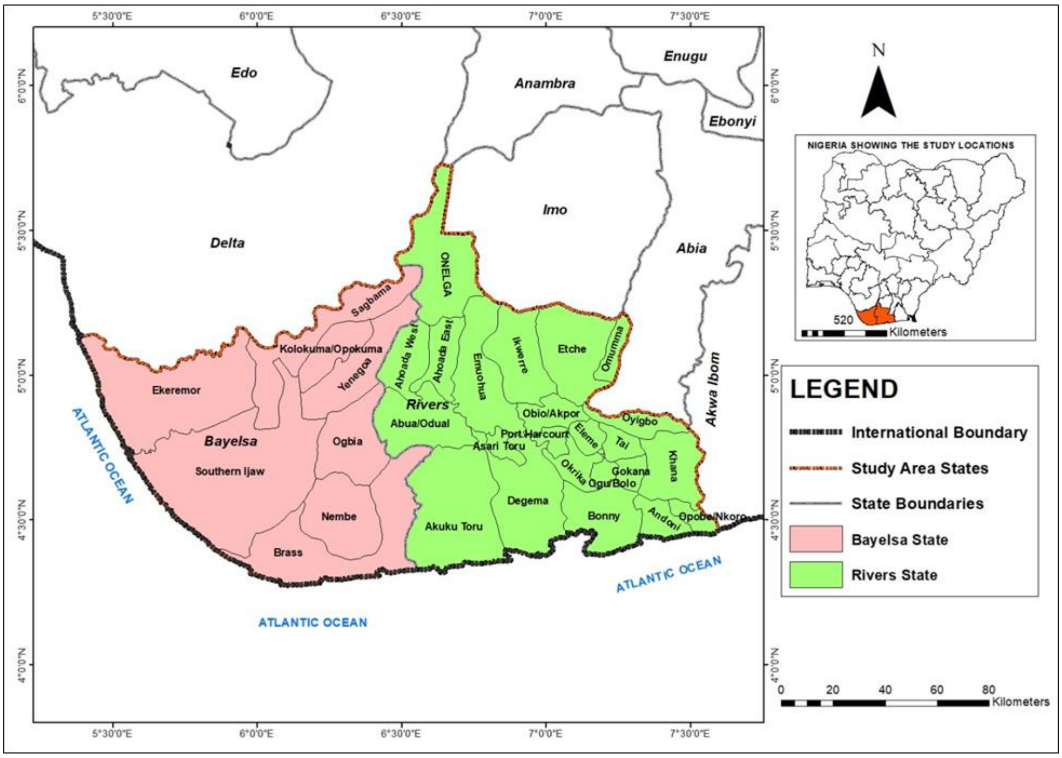

Figure 1 Rivers and Bayelsa States showing the Local Government Areas

Table 1 Wetland Local Government Areas/Communities in the Study Area

S/N	States	Local Government Area	2006 Population	2010 Population	2020 Projected population	Household Size	Sample size
1.	Bayelsa State	Sagbama	186869	209853	235669	39278	29
		Yenagoa	352285	395615	444283	74047	55
		Ogbia	179606	201697	226509	37751	28
		Kolokuma Opokuma	79266	89015	99965	16660	12
		Southern Ijaw	321808	361389	405846	67641	51
		Ekeremor	269588	302746	339989	56664	42
		Nembe	130966	147074	165166	27527	20
Total						**319,568**	
	Rivers State	Ahoada East	166324	190554	213995	35665	26
		Ahoada West	249238	285541	320668	53444	40
		Ogba/Egbema/Ndoni	283294	324565	364492	60748	45
		Abua - Odual	282410	323552	363355	60559	45
Total						**210,416**	**400**

Source: Researcher's preliminary studies (2018); Nigeria Population Commission (NPC) 2006)

The flood height data were collected through the archive data from NEMA from 2012 to 2018.. Descriptive analysis was applied for the data analysis while maps and tables were used for the data presentation. In a related development, Taro Yamane sampling methods was used to compute the 400 population sample required in this study for questionnaire administration as displayed in Table 1 to elicit information about the flood experiences and height in the study locations.

3. Results and discussion

Table 2 presents the flood height recorded by respondents from 2012 to 2018 flood events in the study area. From the analysis, it is shown that the mean flood height in 2012 was 7.4ft, 4 ft in 2013, 3.4 ft in 2014, 2.9 ft in 2015, 2.8 ft in 2016, 4.3 ft in 2017 and 3 ft in 2018. This shows that flood height events of 2012 was the highest among the years and the least was in 2018. The known fact here is that flood was reoccurring every year at different magnitude. The trend surface analysis of flood height from 2012 to 2018 displayed in Figure 2 revealed that the flood height was reducing at a rate of 0.4714 ft over the period considered for this study and 39.75% of the variation in the flood height could be explained by the different years. Similarly, the mean flood height experienced per Local Government Area in the study area is depicted and displayed in Figure 3 whereby Kolokuma/Opokuma and Yenagoa LGAs showed the highest prominence in the flood height and the least was found in Sagbama LGA.

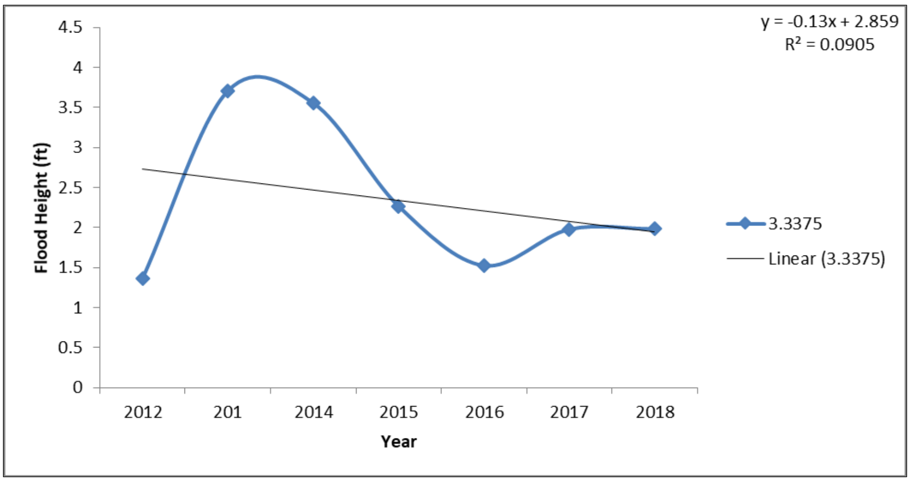

Figure 2 Trend Surface Analysis of Flood Height from 2012 to 2018

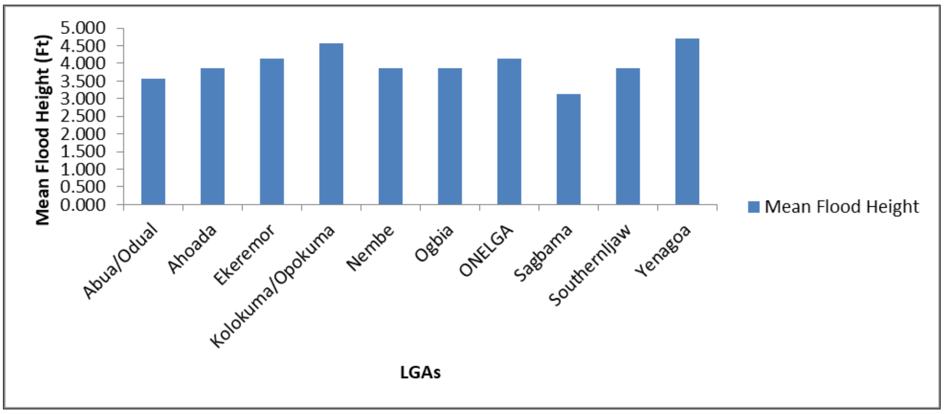

Figure 3 Mean Flood Height across the selected LGAs

In examining the rank of flood height, probability of flooding and flood occurrence and reoccurrence intervals (RI) in the study area based on the years, it is displayed in Table 3 whereby the flood height in 2012 was found the highest and ranked number 1. The 2nd, 3rd, 4th , 5th , 6th and 7th rank included 2017, 2013, 2014, 2018,2015 and 2016 respectively. Based on the probability of flooding and flood occurrence, 2016 had the highest probability level which was 87.5. This is followed by 2015 which had 75, 2018 had 62.5 while 2014 had 50. The minimum was experienced in 2017.

Concerning the reoccurrence intervals, of flood within 2012 and 2018, it is arranged in a descending order as follows: 2012>2017>2013>2014>2018>2015>2016. In examining the probability of flood across the LGA sampled, findings from the questionnaire survey revealed that a very high percentage of respondents in the LGA affirmed that their communities has been flooded each accounting for 100% of the responses obtained from the survey except for 20%, 10%, and 10% of respondents from Abua/Odual, Ahoada, and Ogbia LGA respectively who were of the opinion that their communities has never been flooded as shown in the Table 4.

Table 3 Flood height recorded by respondents (2012 – 2018 Flood events)

LGA/Year	2012 Flood Height (Ft)	2013 Flood Height (Ft)	2014 Flood Height (Ft)	2015 Flood Height (Ft)	2016 Flood Height (Ft)	2017 Flood Height (Ft)	2018 Flood Height (Ft)	Mean Flood Height (Ft) across LGAs
Abua/Odual	9	4	2	2	2	4	2	3.571
Ahoada	7	5	3	3	4	2	3	3.857
Ekeremor	7	4	3	3	2	5	5	4.143
Kolokuma/Opokuma	7	5	4	2	3	6	5	4.571
Nembe	7	4	2	4	3	5	2	3.857
Ogbia	7	3	3	4	3	5	2	3.857
Ogba/Egbema/Ndoni	7	3	3	3	4	6	3	4.143
Sagbama	7	4	3	2	2	2	2	3.143
SouthernIjaw	7	4	4	2	2	4	4	3.857
Yenagoa	9	4	7	4	3	4	2	4.714
Mean Flood Height (Ft)	7.4	4	3.4	2.9	2.8	4.3	3	

Table 4 Probability of flooding/flood occurrence

Flood Year	Height	Rank	Probability	Reoccurrence Intervals (RI)
2012	7.4	1	12.5	8
2013	4	3	37.5	2.6
2014	3.4	4	50	2
2015	2.9	6	75	1.3
2016	2.8	7	87.5	1.1
2017	4.3	2	25	4
2018	3	5	62.5	1.6

From the results of the questionnaire survey, it was observed in Table 6 that 66.7% of respondents in Ogba/Egbema/Ndoni LGA and 55.6% of respondents from Ogbia LGA which had the peak percentages of responses obtained indicated that communities in these LGA have experienced flooding and mostly in the month of September through October while a minor percentage of respondents in Abua/Odual recorded as 28.8% mentioned that they experienced flood in the year 2020 and mostly in the month of June which was affirmed by 16.7% of the respondents. Meanwhile, for the month of October which cuts across all the LGAs selected for this study, it is revealed that 28.6% of total respondents attested to it in Abua/Odual LGA, 33.3% agreed to it in Ahoada, 50% agreed to it in Ekeremor LGA, 100% in Kolokuma/Opokuma LGA, 80% in Nembe LGA, 55.6% in Ogbia LGA, 33.3% in Ogba/Egbema/Ndoni, 50% of respondents in Sagbama LGA and 90% in Yenagoa LGA.

Table 5 Flood occurrence and experiences among residents across the study area

Names of LGA		Yes	No	Total count & percentages
Abua/Odual	Count	32	8	40
	% of total	80	20	100
Ahoada	Count	36	4	40
	% of total	90	10	100
Ekeremor	Count	40		40
	% of total	100		100
Kolokuma	Count	16		16
	% of total	100		100
Nembe	Count	40		40
	% of total	100		100
Ogbia	Count	36	4	40
	% of total	90	10	100
Ogba/Egbema/Ndoni	Count	36		36
	% of total	100		100
Sagbama	Count	40		40
	% of total	100		100
Southern Ijaw	Count	36		36
	% of total	100		100
Yenagoa	Count	40		40
	% of total	100		100

Table 6 Month and year of last flood occurrence

Names of LGA		June	July	September	October	November	2018	2020	Total count & percentages
Abua/Odual	Count			8	8		8	4	28
	% of total			28.6	28.6		28.8	14.2	100
Ahoada	Count	4		12	8				24
	% of total	16.7		50	33.3				100
Ekeremor	Count				20	20			40
	% of total				50	50			100
Kolokuma	Count				16				16
	% of total				100				100
Nembe	Count			8	32				40
	% of total			20	80				100

Ogbia	Count		8	8	20				36
	% of total		22.2	22.2	55.6				100
Ogba/Egbema/Ndoni	Count			24	12				36
	% of total			66.7	33.3				100
Sagbama	Count			20	20				40
	% of total			50	50				100
Southern Ijaw	Count					36			36
	% of total					100			100
Yenagoa	Count			4	36				40
	% of total			10	90				100

Table 7 Extent/Height of flood water within the premises

Names of LGA		**Ground level**	**Came into the rooms through doors**	**Above windows**	**Total count & percentages**
Abua/Odual	Count	16	16	8	40
	% of total	40	40	20	100
Ahoada	Count	30	12		42
	% of total	71.4	28.6		100
Ekeremor	Count	24	20		44
	% of total	54.5	45.5		100
Kolokuma	Count		8		8
	% of total		100		100
Nembe	Count	30	20		50
	% of total	60	40		100
Ogbia	Cou	4	32		36
	% of total	11.1	88.9		100
Ogba/Egbema/Ndoni	Count	30	12		42
	% of total	71.4	28.6		100
Sagbama	Count	16	24		40
	% of total	40	60		100
SouthernIjaw	Count	20	20		40
	% of total	50	50		100
Yenagoa	Count	16	20	12	48
	% of total	33.3	41.7	25	100

Flood inundation, extent, depths and duration are important factors in hazards evaluation in evaluating the extent of flood in the LGA sampled. Measures used include the depth of flood water which was categorized into ground level as measured as 1 to 4 feet, door level as measured as above 5 feet to 7 feet and above window level measures as above 8 feet. The results obtained from the survey revealed that 71.4% of respondents from Ahoada and Ogba/Egbema/Ndoni experienced water depth at ground level followed by 60% from Nembe amongst others while the extent of flood depth that gets to the window level was at peak in Kolokuma/Opokuma LGA (100%) followed by Ogbia (88.9%) and lastly 20%and 25% of respondents from Abua/Odual LGA and Yenagoa LGA respectively recorded depth of above window level as presented in the Table 7.

4. Conclusion

The study is concluded that the flood height, vulnerability and risk varied in the entire study area with significantly highest record in 2012 and 2016 recording the highest probability level. Flood occurrence was established in more than 90% of the spatial extent of the entire study area with October as the month with the highest flood occurrences, the major cause of flood occurrences was heavy rainfall and frequency of flood occurrence was annually. It is thus recommended that there should be adequate flood preparedness for the vulnerable and risky public facilities especially educational and health facilities to prevent much loss of facilities and lives; and majority of the residents should be given more orientation programmes on flood preparedness and mitigation measures to always reduce the impact of flooding on the livelihood of individuals and corporate establishments.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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