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MITIGATING CLIMATE CHANGE: A SUSTAINABLE CITY PLANNING MECHANISM IN LAGOS METROPOLIS

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ABSTRACT
Over the past couple of years, Nigeria has been experiencing freak weather patterns ranging from longer-than-usual rainy seasons to severe dryness in the country's northern parts and seemingly drought phenomena across the country. This study examined a sustainable city planning mechanism for mitigating climate change in the Lagos Metropolis. Empirical studies on the analogies of climate change in urban areas in Nigeria were discussed to explain the vagaries of the study. Several flood parameters in selected locations of the Lagos metropolis were leveraged to demonstrate the incidence and consequences of flooding in the area. Width in meters, height ever recorded in meters, frequency per annum and most extended duration experienced in days were used to analyze the consequences of flooding in Lagos metropolis. The means for the flood parameters for the entire metropolis are 137.35 meters, 2.43 meters, 6.12 times per annum and 22.87 days. An array of possible causes of floods identified mainly torrential rains (94.10%), filled/silted/dirty drainage channels (87.15%), blocked canals (97.55%), inadequate drainage channels (94.30%), and encroachment (90.90%) in Lagos metropolis. Therefore, This study recommends a sustainable city planning mechanism for mitigating climate change.

Keywords: Climate Change, Sustainability, Planning, Mechanism and Weather Regions.

INTRODUCTION
Recent variations in the weather patterns across the globe are creating grave concerns among researchers, planners, policymakers and ordinary citizens as to what may be responsible for these. Climate projections have foreseen both global warming, sea level rise and an increase in the frequency and intensity of extreme events, such as heavy rain and storm events (hurricanes, monsoons and floods), heat waves, desertification and giant forest fires. The change in the earth's climate is now seen as the result of increased heat-trapping greenhouse gases (GHGs) caused by human activities. People are not only worried about these variations, though these apparent changes are enough for people to be disturbed by what is happening to the weather. Much more severe arise from what these variations and changes in the weather pattern portend over time if these continue, how to handle and manage the consequences arising from these and the fact that cities and towns face particularly significant risks as primary centers of national economic and industrial development.

Over the past couple of years, Nigeria has been experiencing freak weather patterns ranging from longer than usual rainy seasons, severe dryness in the northern parts of the country and seemingly drought phenomena across the country (Odiana and Ibrahim, 2015). Drought and devastating wildfires in Russia (between July and September 2010), the floods in Pakistan (July 2010), which affected an estimated 20 million people and the floods in North West Nigeria (September 2010) in Sokoto and Kebbi states affecting about 2 million people and prompting the Federal Government of Nigeria to provide more than ₦ 2 billion for these states in emergency assistance, again increased the consciousness of scientists, policymakers and indeed people living in the affected areas on the issues surrounding changing weather patterns (Egbu, 2018).

A typical urban area is a concentration of people and capital stock (housing, economic production, water supply, transportation and infrastructure) comprising social, economic and environmental components. Each is closely linked with the other; people, for example, will choose their housing according to their preferences, provision of local amenities, budget, and distance to their places of work. Urban areas are also responsible for greenhouse gas (GHG) emissions and climate change. They are also impacted by the consequences of climate change, such as disruption to urban economic activities, disruptions to urban infrastructure, and flooding arising from sea rise affecting low-lying cities and towns (Egbu, 2018).

With the risks and vulnerabilities of the urban areas occasioned by weather patterns and climate change variations, urban planners need to up their game in coping with its consequences on our cities and towns (Ojeh, Balogun, and Okjimamhe, 2016).

To address the corollaries of climate change in urban areas in Nigeria as ascertained from empirical studies, this study leveraged a sustainable mechanism to mitigate them in vulnerable areas such as the study area (Lagos metropolis).

Corollaries of Climate Change on Urban Areas of Nigeria

Cities are the critical engines of economic growth because they economize on the transportation costs of goods, workers, and ideas. Cities also facilitate learning and the generation and diffusion of new ideas. Cities raise per capita income by encouraging specialization and facilitating trade (Egbu, 2018). Thus, more affluent individuals and consumers spend more on goods and energy, and a by-product of this activity is more greenhouse gases (GHGs). Emitted greenhouse gases (GHGs) are Carbon Dioxide (CO_2), Chlorofluorocarbons (CFCs), Methane (CH_4) and Nitrous Oxide (N_2O), among others. However, Carbon Dioxide (CO_2) currently contributes the highest rate of greenhouse gases (GHGs) (Ojeh et al., 2016). The emission of these gases is now considered responsible for the variation in global climatic patterns and thus responsible for climate change phenomenon. Evidence from some significant urban areas of Nigeria suggests that there are observable changes in the climatic patterns of these urban areas over several years of observation.

In his study, Egbu (2018) observed that the meteorological data on surface air temperatures for Kano, Calabar and Lagos show increasing surface air temperatures since 1920. The data analysis indicates that the surface air temperature is 0.25^0C for Calabar and Kano and

0.25^0C-0.50^0C for Lagos. Furthermore, the author observed that those other climatic variables, especially rainfall, have declined in magnitude and distribution since 1911 (Egbu, 2018).

In his study of Lokoja, the confluence town (confluence of Rivers Niger and Benue), Egbu (2018) used Pearson Moment Correlation Coefficient to measure the relationship between the rate of increase of the built-up area of the town and three (3) main elements of climate that are directly related to urban growth; these are rainfall, humidity and temperature. Akbari, Cartalis, Kolokotsa, Muscio, Pisselo, Rossi, Santamouris, Synnefa, Wong and Zinzin (2016) observed a positive correlation between built-up area and high temperature at 0.05 confidence level. The implication is that as the urban area expands, the urban temperature also increases, requiring more energy for cooling and emitting greenhouse gases (GHGs).

Urban heat island seriously impacts the quality of life of urban residents. It increases energy consumption for cooling purposes, increases peak electricity demand during the hot season, deteriorates indoor and outdoor thermal comfort, increases the concentration of harmful pollutants like tropospheric ozone, and seriously impacts the health condition of vulnerable urban populations (Odiana and Ibrahim, 2015).

In their study on the impacts on coastal urban settlements in Nigeria, Komolafe, Adegboyega, Anifowose, Akinluyi, and Awoniran (2014) they are projected that coastal cities in the country are to experience an increase in average surface temperature by 1.1^0C-2.8^0C by the year 2099. These would likely lead to several potentially severe consequences in the affected areas, namely, increased mortality rates due to heat stress and potential transmission of infectious diseases. In addition, rising sea levels would increase the number of people whose lives and properties may be at risk from severe flooding or permanent inundation.

Flooding is a significant consequence of climate variability and climate change globally for coastal and low-lying cities. Lagos, with its vast coastline, low-lying topography and dense population, is particularly vulnerable to flooding from rising sea levels, more intense rainfall and increasing storms, which pose severe risks to the city, causing loss of life and property as well as devastating infrastructure (Egbu, 2018). In their study of incidences of flooding in the Lagos metropolis, Nkwunonwo, Whitworth and Baily (2016) they used several flood parameters in selected locations of the Lagos metropolis to demonstrate the incidence and consequences of flooding in the area. Width in meters, height ever recorded in meters, frequency per annum and most extended duration experienced in days were used to analyze the consequences of flooding in Lagos metropolis. Table 1 shows the analysis results of data derived from the selected flood parameters from different locations in the Lagos metropolis. The means for the flood parameters for the entire metropolis are 137.35 meters, 2.43 meters, 6.12 times per annum and 22.87 days, respectively (Nkwunonwo et al., 2016). The authors noted that all forms of urban transport are negatively affected by flooding each time it occurs, and weather-related disasters are becoming increasingly common in the Lagos metropolis. The floods lasted longest at Ebute Meta (Oko Baba), where it was 132 days. It has apparently become a permanent feature of some localities: Oko Baba, Ajegunle, Idi Araba, Lekki, Victoria Garden City (VGC) and Apapa. Table 2 provides an array of possible causes of floods, mostly torrential rains (94.10%), Filled/Silted/Dirty drainage

channels (87.15%), Blocked Canals (97.55%), Inadequate Drainage channels (94.30%), Encroachment (90.90%), etc. (Sojobi, Balogun and Salami, 2016).

Table 1: Selected Flood Parameters in Different Locations of Lagos Metropolis

Location	**Mean Width(Meters)**	**Highest Experienced Height (Meters)**	**Frequency (Per Annum)**	**Longest Durations Ever Lasted (Days)**
Victoria Island (Ajose)	138.00	0.98	6	5
Iyana Ipaja (Ie Street)	109.00	3.80	4	4
Agege (Oke Odo)	116.00	3.88	5	4
Alapere (Origun)	135.00	3.40	6	5
Surulere (Adeniran Oguneanya	107.00	2.25	7	5
Akoka (Afolabi-Brown)	161.00	2.16	6	5
Alagbado (Cassio Bus Stop)	111.00	2.10	6	3
Isheri (Riverview Estete)	109.00	3.40	6	3
Apapa (Mile 2)	210.00	2.37	5	71
Egbeda (Akin-Olugbade)	102.00	2.25	2	5
Lekki (Phase II)	148.00	2.26	3	105
Lagos Island (Obalende)	118.00	1.68	3	11
Bariga (Abule)	122.00	2.35	4	13
Mushin (Idi-Oro)	161.00	2.18	8	10
Ojuelegba	128.00	1.92	3	86
Ebute Meta (Oko Baba)	128.00	2.40	6	132
Oworonshoki	108.00	2.18	3	12
Victoria Garden City (VGC)	111.00	1.73	8	13
Maryland (Aworojobe)	118.00	3.15	4	4
Oshodi (NITEL)	113.00	2.03	8	5
Idi-Araba (LUTH)	183.00	2.22	8	11
Iju-Agege Road	107.00	3.20	8	7
Ijora	135.00	2.21	8	7
Apapa (Ajegunlle)	191.00	2.26	10	20
Mean	**137.35**	**2.43**	**6.13**	**22.87**

Source: Nkwunonwo et al., (2016)

Table 2: Causes of Flooding in Lagos Metropolis

Causes	Number of Respondents	% Proportion
Torrential Rain	1882	94.10
Base Water Flow	116	5.80
Spring Water Flow	110	5.50
Car-Wash Operations	88	4.40
Watering Flowers	68	3.40
Filted/Silted/Dirty Drainage Channels	1643	87.15
Social Cultural Activities	1012	50.60
Ocean/Lagoon Surge	1185	59.25
Illegal Channelization of Drains	1211	60.55
Construction and Reconstructions	1075	53.75
Blockage of Canals	1941	97.55
Inadequate Drainage Channel	1886	94.30
Non-compliance with regulations	1629	81.45
Illegal Structure on Drainage Channels	1779	88.95
Encroachment	1818	90.90
Negligence	1177	56.85
Collapsed Bridges/Culverts	75	3.75
Farming along Flood Plains	81	4.50
Nature of Terrain	785	34.25
Others (Specified)	66	3.30

Source: Sojobi, et al., (2016)

In their study of Calabar, a coastal town of about 60km from the Atlantic Ocean in the South-South zone of Nigeria, Okon, Ogba, Idoko, Eni, and Sule (2015) they were observed that the town suffers from high flood risks because of the population trends, diversity in and changing land use, obsolete drainage infrastructure and most significantly climate change effects. The Authors noted that all the areas in Calabar are liable to flooding due mainly to defective drainage infrastructure and high rainfall intensity. Table 3 reveals high rainfall amounts in 2011, unusual from other years, which could be explained by sudden changes in the weather and climatic elements of the town. Table 3 further reveals a maximum rainfall of 828.2mm in July 2005. Rainfall amounts for November 2011 totaled 325.2mm, the highest for November since 2011 (Okon et al., 2015). This violent storm's human, socio-economic and material loss amounted to several millions of Naira (Okon et al., 2015).

Table 3: Monthly Rainfall Data for Calabar (2001-2011) (mm)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2001	0.0	11.6	151.7	371.8	419.4	390.5	268.5	457.0	455.7	381.0	217.1	5.7
2002	0.0	13.5	154.6	383.3	301.3	344.6	274.1	623.5	284.3	285.8	126.0	6.8
2003	26.7	103.2	226.6	283.0	315.3	202.2	327.4	398.6	399.2	224.1	148.5	2.9
2004	9.9	19.9	73.5	278.4	270.2	308.0	303.5	391.9	335.5	196.4	168.3	0.6
2005	33.8	35.5	295.7	299.9	263.9	615.6	828.2	634.4	230.4	279.8	182.3	71.5
2006	84.7	57.1	323.0	166.1	430.8	227.7	484.9	273.4	536.0	175.3	134.4	0.1
2007	0.0	51.1	181.0	265.9	384.2	583.2	492.7	415.5	561.7	197.4	262.1	33.1
2008	15.1	1.0	108.1	216.9	286.6	437.0	597.7	509.2	217.9	315.0	105.1	77.1
2009	89.7	38.5	87.5	150.5	308.9	218.4	577.4	507.3	273.9	148.1	126.9	0.0
2010	31.8	88.2	63.6	130.4	306.5	611.3	384.0	406.7	451.3	269.6	272.1	56.2
2011	TR	153.4	123.1	208.8	340.9	388.6	648.6	573.7	251.8	519.9	325.2	23.5

Source: Okon, et al., (2015)

CONCLUSION

Climate change has remained a challenge to the city centers in the developing parts of the world. Its impacts in the areas cited in this study are very conspicuous. Consequently, it is paramount that urban planners no longer hold tenaciously to the conventional systems but instead leverage the sustainable mechanisms, as has been accentuated and explained in this study.

RECOMMENDATIONS

This section provides the four (4) main interrelated concepts and their components for the sustainable city planning mechanism, critical and significant for resilient city and urban areas of Nigeria for their contribution to managing the consequences of climate variations and climate change. These are:

1. **Urban Susceptibility Grid Analysis:** Table 1 depicts the susceptibility of different locations of the Lagos metropolis to flooding. This necessitates the need for urban planners to determine the uncertainties, informality, demography and spatiality of flooding in city land use planning. They should anticipate and integrate risks and possible ways to cope with them.
2. **Incertitude-Driven Planning:** From Table 2, myriads of respondents enumerated the natural and anthropogenic flooding causes in the Lagos metropolis. This accentuates the necessity of adaptation, planning and sustainability in the mechanism. Hence, it is paramount that urban planners scrutinize the adaptation measures, planning methods and characteristics of the existing and planned urban form typologies.

3. **Urban Administration:** To mitigate climate change from the vantage point of sustainable city planning, it is pertinent to leverage an urban administration encompassing equity, integration, and eco-economics. This bolsters the kind of participants in decision-making and planning regarding environmental and uncertainty issues, urban administration's blueprint, and the nature of the existing and planned ecological economy.
4. **Mitigation:** Having established the dynamic nature of climate from this study (as shown in Table 3), planners must determine the mitigation measures to reduce risks and prepare the city for future environmental hazards. Correspondingly, this should integrate planned spatial, physical, and economic restructuring policies that aim to face the environmental hazards and uncertainties. Furthermore, the city should address the energy sector by proposing strategies to reduce energy consumption and leverage innovative and cleaner energy sources.

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