Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2019, 6(4):194-200

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Impact of Climate Change on the Development of Infrastructure in the Niger Delta

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Abstract Engineering infrastructure has been designed based on time invariant probability distribution, and can no longer perform accurately under climate change conditions. Climate change will intensify the frequency of natural hazards, corrosion of reinforcement in bridges, buildings, wharves and other concrete infrastructure, coastal flooding, urban storm systems, degradation of ecosystems, etc. The performance of existing infrastructure will be threatened when subjected to extreme climate –related hazards and will perform below their design levels. Furthermore, it will accelerate the deterioration process in concrete structure, cause corrosion-induced cracking and spalling, which will result in more costly and disruptive repairs, as well as strength loss of concrete structures. Also coastal flooding induced by extreme water level events in low-lying, high populated coastlines due to sea level rise. The challenges before engineers is how can we plan, design and deliver climate change resilient infrastructure. The results of the two quantitative studies in this paper indicate that the rainfall intensity magnitude will be different in the future and the potential change of IDF magnitudes is in the range of 28%. An economic analysis should be performed to justify the necessary investment that this change will require. While the second study indicates that 42.6% the Niger Delta is highly vulnerable to sea level rise (SLR), particularly Rivers State Coastal area will experience a sea level rise of 3.5m by 2100. There is urgent need to adopt climate adaptation engineering to existing and new infrastructure. Also, research cooperation with climate scientists to quantify impact change on load bearing structures.

Keywords Climate Change, Infrastructure

1. Introduction

Climate change is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods [1].

Climate change has become the most important environmental threat that mankind currently faces due to upsurge in the number of extreme events. Some of the documental impacts of climate change includes; The European heat wave of the 2003, which likely was the hottest summer at least since the year 1500, caused at least 35,000 deaths – more than all traffic accidents in Europe during the entire year. Decrease in electricity production potential at existing hydropower stations by more than 25% by the 2070s [2]. Increase of pathogen load due to more heavy precipitation events in areas without good water supply and sanitation infrastructure. The impacts on the coastal zone increase the risk of flooding, loss of coastal ecosystem such as salt marshes, mangroves and the degradation of fisheries and freshwater resources (due to salt intrusion). It was estimated that over 120 million people are exposed each year to hazards from tropical cyclone, and these storms caused 250,000 deaths between 1980 and 2000 [3]. These storms are becoming more hazardous as the sea level rises, and the intensity of the storms is increasing. The "Hot Spots" of greatest risk are the deltaic areas. The impact of climate change on Infrastructure performance is a temporal and spatial process, the most existing models of infrastructure design are based on stationary climate. The assumption of stationarity is clearly questionable under climate change conditions. Thus, there is urgent need to revise the current design standards and provisions and incorporate the predicted effects of climate change. This paper is divided into sections; section 2 contains understanding the characteristics of the climate with commendation to the 18th and 19th century science. The anatomy of climate change is discussed in section 3. Section 4 presents a brief description of current approach in modelling climate variables, while sub – section 4.3 highlights climate change hazards to infrastructure. The vulnerability of the Niger Delta region to climate change with of two quantitative examples are presented in section 5. Finally the main conclusion and recommendations are presented in section 6.

2. Understanding Climate

Global warming (Climate Change) occurs when short-wavelength radiation from the sun enters our atmosphere and heats the Earth, but the re-radiation long-wavelength heat is partially prevented from escaping back into space by “greenhouse” gases.

The so-called “greenhouse” gases act the same way that a garden greenhouse maintains a higher temperature inside than outside. The “greenhouses gases” such as Carbon dioxide, Nitrous oxide, Chlorofluorocarbons (CFCs) and methane. Possible impact includes higher sea levels, altered patterns of rainfall and air temperatures, and increased frequency and intensity of severe storms.

Scientific understanding of the basic physics of the greenhouse effect, and the potential for global warming as a result of Carbon dioxide emission, has been building for over two centuries. We must commend the 18th and 19th Century scientists for laying a sound foundation in understanding the climate system. Some notable scientific contributors are presented in Table 2.1 for better understanding.

Table 2.1: Some contributors to science of climate change

S/No	Name	Date	Scientific Contributions
1.	Joseph Fourier	1827	Introduced the idea of greenhouse effect/ invented the greenhouse
2.	Sir. William Herschel	1800	Discovered that energy can be transported by invisible infrared radiation
3.	John Tyndal	1859	Identified carbon dioxide, methane and water vapour as greenhouse gases
4.	Svante Arrhenius	1896	Proved that doubling carbon dioxide in the atmosphere would increase the temperature of the Earth by an average 4-6^{o}C. Despite uncertainties due to crude data, he provided the answer to CO_2 emission correctly
5.	Guy Steward Calendar	1938	Estimated the climate sensitivity due to equilibrium warming from doubting CO_2.
6.	Stewart-Boltzmann Equation		Discovered that an ordinary object emits light all the time as long as its temperature is greater than absolute zero (-459^{o}F or -273^{o}C). This law makes it easier to calculate other aspects of the climate.
7.	Clausius-Clapeyron Equation		Discovered that the amount of water vapour that fits into a given volume increases by 7% for each ^{o}C warming. This law shows that accumulated heat energy in the atmosphere causes greater evaporation, which results in more storms and increased storm intensity
	In Conclusion	Thanks to the science of the 18th and 19thcentury which laid the foundation for theories and models that are currently used to explain the phenomenon of climate change.	

3. Anatomy of Change

Stationarity is the scientific foundation for most engineering design (including civil engineering structures).In a broad sense, it means statistical parameters such as mean and variance are independent of time. It is necessary to distinguish between climate variability and climate change. Climate variability is random variation from a long-run distribution, whereas climate change is a trend or a shift in the long-run distribution.

Climate variability can be confused for climate change (trend) when records are short, which will disappear when more data are collected. So the detection of changes in longtime series is an important and difficult issue of increasing interest under climate change. Change can occur in numerous ways, for example long-term trend (progressive increase or decrease on the average), step –change (abrupt change) or long-tern cyclical variation.

The Change, therefore must be detected as a trend, step-change or cyclical behaviour, otherwise it is Never a Change. Thus, the occurrence of one or more tropical storms, like hurricane Katrina cannot tell us much about long-term trends or about the important question of whether those trends are influenced by global warming. Some of the widely used change detection tests are (i) Wilcoxon-Mann-Whitney test (ii) Pettit's test for step change, Spearman's rho, Mann-Kendall with Thiel-Sen's test. In conclusion there must be a substantial trend (upward or downward); step-change or cyclical variation for a change to occur. There must be a change, for climate change to occur.

4. Climate Modelling

The current approaches to modelling weather variables and extreme weather events under climate change are described under global circulation and weather generating models.

4.1. Global Circulation Models (GCMs)

The global circulation models discretize the planet and its atmosphere into a large number of three dimensional cells, to which equations describing the conservation of mass, Momentum, heat, perfect gas laws, and conservation (and phase changes) of water, are supplied. Future climate is projected by defining carbon emission scenarios in relation to changes in population, economy, technology, energy, land use and agriculture. A total of four scenario families, i.e. – A1, A2, B1, and B2. Based on various overall scenarios storylines are developed that each describes a possible path.

- The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1F1), non-fossil energy sources (A1T), or a balance use of all sources (A1B).
- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities.
- The B1 storyline and scenario family places emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
- The B2 storyline and scenario family describes a world continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 story lines.

The application of GCMs involves two uncertainties; temporal scales and spatial scales. The uncertainties associated with GCMs are resolved through the use of weather generating models.

4.2. Weather Generating Models

Weather generating models offer one way of addressing deficiencies of global climate modeling for use at local scales. They are stochastic simulation tools that synthetically create climate information for an area by combining both, local and global weather data.

The weather generator takes as input historical climate information, as well as inputs from the global circulation models, and generates climate information for an arbitrary long period of time for the local weather station. The relationships between various models and methodologies used to interpret likely changes in hydrological models under a future climate is shown in Figure 1.

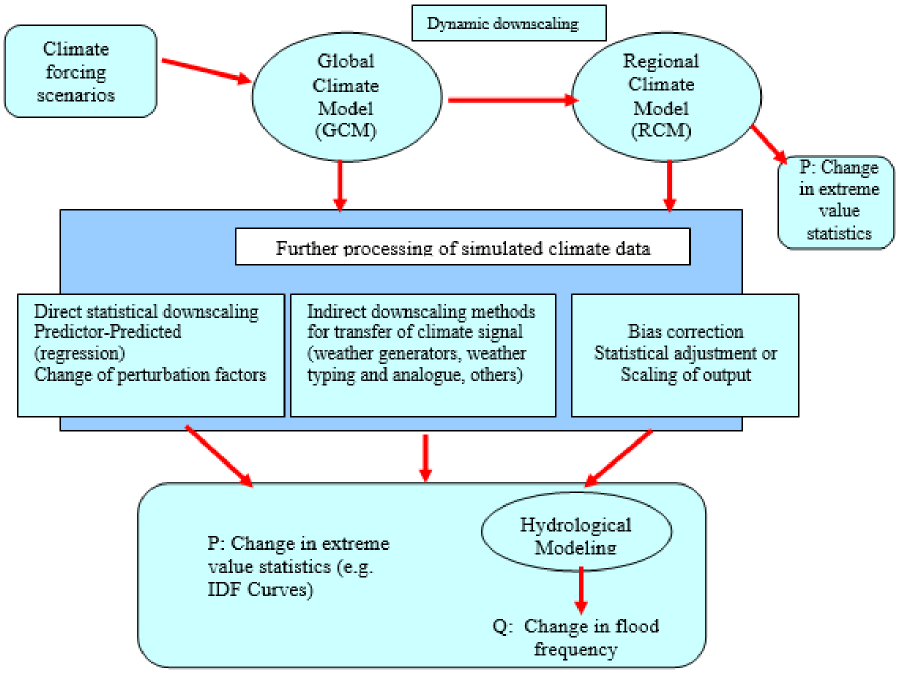

Figure 1: Model Relationships in Climate Change Predictions

4.3. Climate Change Hazards and Infrastructure

Climate change hazards on infrastructure may be evaluated in terms of future increase in temperatures, precipitation, and sea level rise. Infrastructure is a key component of human settlement that promotes economic activities through buildings, transport, energy, water and communication. Table 2 shows examples of infrastructure and assets that are likely to be affected by climate change.

Table 2. Overview of Climate Change Hazards on Development of Infrastructure

Infrastructure Sector and Component	**Climate risk factor**	**Potential infrastructure impacts**
Energy		
Production	Temperature	- Increased user demand for and consumption of energy - Potential for more frequent power outage - Overuse and strain on equipment and materials, increasing Maintenance - Equipment damage
	Precipitation	- Equipment damage from flooding
	Sea level rise	- Equipment damage from flooding and corrosive effect of Seawater
Transmission and Distribution overhead and	Temperature	- Increase sag of overhead lines - Increase in number of underground fires, manhole Expositions
Underground	Precipitation	- Increase in outage frequency, extents (customers, lost), and Duration
	Sea level rise	- Increase in number and duration of local outage from corroded equipment

Transportation		
Roadways	Temperature	- Increased road material degradation, resulting in increased road maintenance
	Precipitation	- Declining level of service from flooded roadways - Increase hours of delay from increased congestion during street flooding - Insufficient pumping capacity and associated increased energy use for additional pumping to remove excess water prevent flooding
	Sea level rise	- Declining level of service from flooded roadways - Increased hours of delay from increased congestion during street flooding episodes - Insufficient pumping capacity and associated increased energy use for additional pumping to remove excess water to prevent flooding.
Transit	Temperature	- Increased use of cooling equipment - Increased rail degradation and equipment deterioration, resulting in increased maintenance - For commuter rail, increase in transit accident from train collisions with overhead line sagging
	Precipitation	- Insufficient pumping capacity and associated increased use of energy use to remove excess water for prevention of flooding - Mean distance between failure (MDBF) decreases producing delays - Increase in number of stops due to emergencies - Increase in number of emergency evacuations
	Sea level rise	- Increased rail degradation and equipment deterioration from saltwater inundation. - Potential increase in infiltration into the distribution system
Waste (wastewater) Quality	Temperature	- Treatment capacity of wastewater treatment plants improved up to a point due to increase heat affecting biological processes but then decline of temperatures and extreme tolerance limits - Increase loading of equipment corrosion from salt water - If substantial evaporation or drought occurs, quantity of wastewater becomes insufficient to sustain treatment process.
	Precipitation	- Hydraulic capacity of sewers and wastewater treatment plants exceeded owing to increased flows - Treatment capacity of treatment plants exceeded from dilution from increased flows - Decline in water reflected in Lean Water Act standard variances
	Sea level rise	- Reduced function of wastewater treatment plants if sea level overwhelms plant facilities

		- Sawer backups from excess and accumulated water
Waste (solid waste)		
Closed landfills	Temperature	- Alteration of chemical composition of contaminant below the surface, changing evaporation rates
	Precipitation	- Unexpected leaching of contaminants where precipitation penetrates the surface of closed landfills
	Sea level rise	- Release of contaminants from unexpected inundation of landfills increasing public health concerns
Marine transfer stations	Temperature	- Increased evaporation of contaminants and decay of refuse, thereby increasing public health concerns from vermin
	Precipitation	- Increased damages to curbside refuse containment and releasing refuse, increasing public health concerns
	Sea level rise	- Inundation of refuse from water release contaminants to streets and waterways, increasing public health concerns
Contamination		
Supplies: electric power	Temperature	- Power disruption/outage frequency and severity affects communication equipment
	Precipitation	- Equipment flooded and stored materials damaged
	Sea level rise	- Increased flooding of equipment and corrosion from salt water
Equipment: fiber-optic cable; cell towers; internet	Temperature	- Destruction of equipment and increased maintenance
	Precipitation	- Excessive precipitation flooding equipment - Line congestion, tower destruction, or lost of function - Call carrying capacity reduced, lost, or blocked - Internet traffic increases and accessibility declines
	Sea level rise	- Increased flooding of equipment and corrosion from salt water from increased sea level rise

5. Vulnerability of the Niger Delta to Climate Change

Despite the looming threat to humanity, there is a dearth of quantitative assessment/studies particularly in the Niger Delta dealing with impact of climate change. The results of two quantitative studies were presented. They are;

i. Development of Intensity-Duration-Frequency Equation under climate change, and
ii. Modelling the effects of sea level rise on flooding in the Lower Niger Delta.

The result of the first study indicates that the rainfall intensity magnitude will be different in the future and the potential change of IDF magnitudes is in the range of 28% [4]. An economic analyses should be performed to justify the necessary investment that this change will require. While the second study indicates that 42.6% the Niger Delta is highly vulnerable to sea level rise (SLR), particularly Rivers State Coastal area will experience a sea level rise of 3.5m by 2100 [5].

This claims are not mere speculations to frighten the audience, they are simply telling us, we cannot escape the hazardous impacts of climate change. Therefore, there is urgent need to plan for Adaptation and Mitigation measures.

6. Conclusion and Recommendations

Responding to climate change is in two main aspects; Adaptation and Mitigation. Mitigation of climate change requires a political will and cooperation unprecedented in the history of mankind. The main culprits of CO_2 emission may not accept the blame.

Even the most ambitious reductions in greenhouse gas emissions, such as those discussed at the 2009 global treaty-making conference in Copenhagen, (including a substantial shift to 20% renewable energy, a 20% improvement in energy efficiency and a 30% cut in greenhouse gases by 2020) will not be enough to head off temperature increases that threaten to drown small island nations, chase vast numbers of people from their homes in the river deltas of Africa, Asia and Latin America and cause public health problems far more dire than the 2010 earthquake in Haiti.

I therefore recommend that the way forward is adaptation; that is acoastal defense (e.g. dyke) taking climate change and the associated sea level rise (SLR) explicitly into account during design.

There is need for cooperation between climate scientist and engineers. Standards and design provisions are the main instruments of engineering practice, therefore we the research responsibility to address these challenges for the survival of our region.

In terms of quantitative studies, most of the work of IPCC is done by thousands of research scientists at universities and national laboratories around the world. We need local capacity building to develop our manpower in all areas influence by climate change. Mathematical modelling studies should be commissioned (PhD degree Research) to quantify the impact of sea level rise on coastal flooding. One of such studies is being concluded for Rivers State Coast in the Netherlands.

We need Early planning with proper Foresight, which is cheaper, than a “wait - and – see” approach, which is Costly and Unsafe in terms of dykes and other long – term infrastructure in response to climate change .

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