

Climate Change: Vulnerability of the Niger Delta Region, in Nigeria

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Climate change is not just a global threat, but an unprecedented public health emergency. Climate change has been characterized by global warming, increased frequency and intensity of precipitation, catastrophic wind events, and extreme weather events, associated with heat waves, flooding disasters, and prolonged droughts. The United Nations Framework Convention on Climate Change (UNFCCC) attributes climate change to anthropogenic or human activities. Globally, the most vulnerable regions, to hazardous impacts of climate change, are the mega-deltas of Africa and Asia, due to high exposure to sea level rise, storm surges, coastal erosion, and river flooding, compounded by increasing human-induced pressures on coastal areas. The vulnerability of the Niger Delta region, is exacerbated by oil spillages, gas flaring, and environmental degradation. This review article highlights, the urgent implementation of mitigation and adaptation as opportunities for full transformation of economies, of the Niger delta region, in line with sustainable developmental goals (SDGs).

Keywords: *Impacts of climate change; vulnerability to climate change; economic transformation of Niger Delta Region; transition to renewable energy.*

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1. INTRODUCTION

1.1 Climate Change

Climate change is one of the most threatening global challenges of the 21st century. The Earth's climate has changed significantly, compared to the pre-industrial era, in both global and regional scales. The UN's Framework for Convention on Climate Change (UNFCCC) defines Climate Change (CC) as 'a change in 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]. Intergovernmental Panel on Climate Change (IPCC) refers to climate change as 'a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. The IPCC usage differs from that of UNFCCC, where climate change is attributed to human activity. There is new and strong evidence that most of the global warming observed over the last 50 years is attributable to human activities [2, 3]. Climate change has been associated with Global warming and shifting weather patterns that threaten food production, and cause rising sea levels that increase the risk of catastrophic flooding. The impacts of climate change are global in scope and unprecedented in scale.

Climate change signifies that, today, we are altering the Earth's biophysical and ecological systems, at the planetary scale – as is also evidenced by stratospheric ozone depletion, accelerating biodiversity losses, stresses on terrestrial and marine food-producing systems, depletion of fresh water supplies, and the global dissemination of persistent organic pollutants.

International agreements on global environmental issues of climate change consider the principles of sustainable development proposed in Agenda 21 and the UNFCCC. These include the "precautionary principle", the principle of "costs and responsibility" (the cost of pollution or environmental damage should be borne by those responsible), and equity – both within and between countries and over time (between generations) [1,2,4,5].

1.2 Global Climate Variability

The World Meteorological Organization (WMO) defines climate variability as "variation in the mean state and other statistics of the climate (temperature, rain and wind) on all temporal and special scales, beyond individual weather events" [6]. Character of climate variability is determined by exposure to climate related hazards e.g. increased. Precipitation and flooding. The magnitude of Climate Variation is measured by risks of life threatening climate related events such as excess morbidity and mortality from malaria and diarrhoea, and risks of internal displacement. The Rate of climate variation is increased by frequency of variation in climatic elements namely: temperature, precipitation, wind, humidity, atmospheric pressure, cloudiness and solar radiation. Sensitivity of Population or System to Climate Variation describes the responsiveness to climate variability and severely extreme weather events. Determinants of sensitivity include: poverty, inequality, marginalization, food entitlements, access to insurance and housing quality. Appropriate response to climate change include: meteorological services, political will, level of awareness of climate change, cause, effects, mitigation and adaptation, including building adaptive capacity through community mobilization [1,3,7].

Changes in global and regional climate patterns were apparent from the mid- to the late 20th century onwards. Extremes of regional climatic cycles, with severe weather-related events, such as the El Nino Southern Oscillation (ENSO) cycle, associated with flash floods and widespread flooding, in large parts of Asia and parts of Central Europe; heatwave and drought in the Russian Federation, mudslides in China and severe droughts in sub-Saharan Africa. The sequence of current weather-related events matches IPCC projections of more frequent and more intense extreme weather events: increased precipitation, increased weather variability, with increased intensity and frequency of Extreme weather events and disasters, due to global warming. A combination of increased precipitation and melting of glaciers have resulted in rising sea levels [8,9].

1.3 Greenhouse Gases

The greenhouse gases (GHGs) are the atmospheric gases responsible for causing global warming and climate change. The major

GHGs are Water vapour, Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O), Halocarbons and Ozone (O₃). Less prevalent, often man-made, but very powerful GHGs, are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulphur hexafluoride (SF₆). CFCs are used for refrigeration, air conditioning, packaging, insulation, solvents, or aerosol propellants. They drift into the upper atmosphere where, given suitable conditions, they break down ozone. CFCs are to be replaced by safer options, including hydro-chlorofluorocarbons, in compliance with the Kyoto protocol [3,4,10, 11].

Carbon dioxide, produced mostly from fossil fuel combustion and forest burning, is the major problem and growing greenhouse gas (GHG). Methane is produced from irrigated agriculture, animal husbandry and oil extraction [4].

Global emissions are reaching record levels, and show no sign of peaking [12]. Global GHGs emissions have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (24% between 1990 and 2004). It is projected that with the implementations of the United nations' legal instruments (The Kyoto Protocol and Paris Agreement), and related sustainable development goals, GHG emissions will continue to grow over the next few decades.

There is growing and strong scientific evidence that if we act now, by complying with the UN legal instruments, we can reduce carbon emissions within 12 years and hold the increase in the global average temperature to 1.5°C (well below 2°C) above the pre-industrial levels, as recommended by latest science, to stop climate disruption and reverse the impact. The Paris Agreement plans to achieve a 45% global reduction in GHG emissions by 2030, and to dramatically reduce GHG emissions to reach net-zero emissions by 2050 [12].

In Nigeria, the total GHGs emissions was 518.84 million metric tons between 1990 and 2009. This was equivalent to 0.26% of global GHGs. Between 2000 and 2009, the yearly average increase of CO₂ (the most significant GHG) emission was 4.7% which was 2.8% higher than the average global rate of 1.9%¹. Gas flaring in Nigeria contributes significantly to GHGs emission in Nigeria. However, gas flaring has been reduced to 8% as more gas is being utilized to generate electricity [13,14,15].

According to World Meteorological Organization (WMO), the build-up of GHGs in the atmosphere in the 20th century, resulting from the growing use of fossil-based energy and the expansion of the global economy, has altered the radiative balance of the atmosphere [6]. GHGs absorb some of the Earth's out-going heat radiation and re-radiate it back towards the surface. The net effect is to warm the Earth's surface and the lower atmosphere (Fig. 1).

Natural GHGs (Water vapour, Carbon dioxide CO₂, methane CH₄ and Nitrous oxide) absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds to produce the natural 'greenhouse effect' that makes the Earth habitable. Humankind's or Anthropogenic activities are increasing the atmospheric concentrations of energy-trapping GHGs, thereby amplifying the natural "greenhouse effect" that makes the Earth habitable. The resultant Global warming challenges the sustainability of the biosphere and the ecosystems (Fig. 2) [3,11].

1.4 Global Warming

The last four years were the four hottest years on record, and winter temperatures in the Arctic have risen by 3°C since 1990 [12].

During the twentieth century, world average surface temperature increased by approximately 0.6°C, and approximately two-thirds of that warming has occurred since 1975. Climatologists forecast further warming, during the coming century and beyond. The UN's Intergovernmental Panel on Climate Change (IPCC) stated: "that there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" [3]. The IPCC's Third Assessment Report projected that, as we continue to change atmospheric composition, global surface temperature will rise by 1.4°C to 5.8°C in this century, along with changes in precipitation and other climatic variables.

Global temperature on earth is directly linked to the concentration of Greenhouse gases (GHGs), in the earth's atmosphere. Carbon dioxide (CO₂) is the most abundant of the GHGs, accounting for about two-thirds of GHGs. CO₂ is the major product of burning fossil fuels. The concentration of GHGs, in the earth's atmosphere, has been rising steadily, and the mean global temperatures along with it, since the time of the industrial

revolution. From 1880 to 2012, the average global temperature increased by 0.85°C. The 100-year linear warming trend (1906 - 2005) was 0.74°C, with most of the warming occurring in the past 50 years. The warming for the next 20 years is projected to be 0.2°C per decade [1].

Global warming has caused the expansion of oceans due to warming of the oceans and melted ice. Between 1901 and 2010, the global sea level rose by 19 cm. There is evidence that Global warming and some impacts of climate change could persist for centuries, with risks of irreversible changes in major ecosystems and planetary climate system, even if emissions of GHGs are stopped. A special report by the IPCC, in 2018, suggests that a rise of global warming by 2°C would be associated with dangerous global damage. Limiting global warming to 1.5°C, will ensure a more sustainable and equitable society. It will require ‘a rapid and far-reaching’ unprecedented changes in all aspects of society, including: transitions in land, energy, industry, building, transport, and cities. Global net human-caused emissions of CO₂ would need to fall by about 45% from 2010 levels by 2030, reaching ‘net zero’ around 2050. It is expected that remaining emissions would be balanced by removing CO₂ from the atmosphere. The ‘Kyoto Protocol’ and the ‘Paris Agreement’ are the United Nations legal instruments, ratified by 192 and 184 Parties, respectively, brings all nations to undertake ambitious efforts to combat climate

change, accelerate and intensify the global actions and investments needed for a sustainable low carbon future; adapt to the public health impacts of climate change, with enhanced support to assist developing countries to do so [16].

1.5 Dangerous Climate Change

Dangerous Climate Change consists of Changes that are “irreversible” in human time, including:

- i. Sea level rise. Partial melting of Greenland and West Antarctic are expected from temperatures rises 1-4°C, above the 1990 global temperature level resulting in 4-6 metres rise in ocean levels. Total melting is possible within centuries, leading to 15 metres rise in ocean levels.
- ii. Species extinctions. It is estimate that 20-30% of plant and animal species is at risk of extinction with > 1.5-2.5°C average rise in Temperature. Massive extinctions are likely with 4-5°C rise in global temperature. [17].

The World Health Organization, in a global response to climate change, warns the committee of nations to avoid “Dangerous climate change” and limit temperature rise to 1-2°C this century to reduce the extent of global warming, dramatic sea level rise with risks of massive extinctions of aquatic biodiversity, and other impacts.

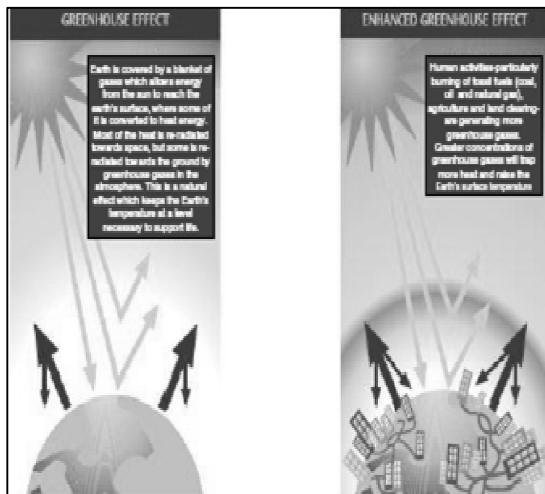


Fig. 1. Greenhouse gases and global warming

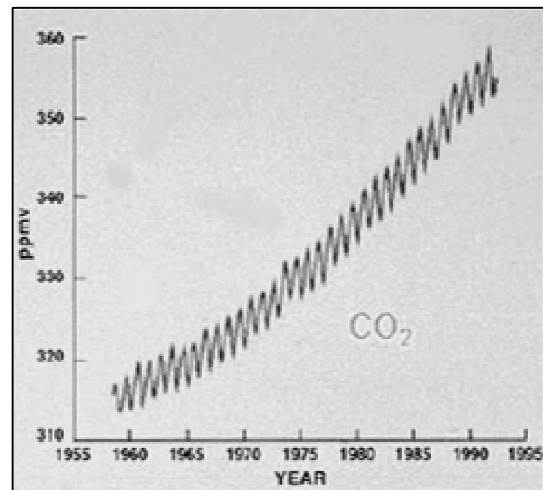


Fig. 2. Indisputable increases in greenhouse gases

Source: WHO. Global Climate Change & Child Health. Children’s Health and the Environment. WHO Training Package for the Health Sector. WHO (2009)

WHO advocates the pursuit of equitable solutions to global warming, that first protects the most vulnerable populations, groups and local conditions, be they defined by demographics, income, or location. The WHO strongly recommends mobilization of individual and collective compliance with Primary intervention (MITIGATION) measures to reduce production of greenhouse gases (GHGs) and Secondary intervention (ADAPTATION) to climate change [5, 18].

WHO, WMO and UNEP collaborate on issues related to climate change and health, addressing capacity building, information exchange and research promotion [6].

2. IMPACTS OF CLIMATE CHANGE

Impacts consist of effects of climate change on natural systems (biophysical and ecological systems) and human health. Impacts of climate change include potential and residual impacts. Potential impacts are all impacts, actual or projected, that may occur, given a projected change in climate, with no consideration of adaptation. Residual impacts are the impacts of climate change that can occur after adaptation. Impacts are more extreme when the adaptive capacity is weak.

The severity, frequency and variability of the unfamiliar impacts of climate change, pose a major challenge to sustainable development, on Earth. The consequences of climate change are global warming, extreme weather events, increased variability and intensity, including: fatal heat waves; droughts; heavier and more frequent storms with disastrous floods; increase in frequency and intensity of El Nino Southern Oscillation.

The UNFCCC has warned that continued emissions of GHGs at or above current rates would cause further global warming and induce many changes in the global climate system in the 21st century that would very likely be larger than those observed during the 20th century [1]. There are actual and expected or projected impacts of climate change.

Actual and expected life-threatening impacts of climate change vary according to locality and region. The most vulnerable regions are the Arctic and Africa, due to high risks of projected warming on the ecosystems and human communities in the Arctic; Africa has a low adaptive capacity and a high risk of projected

climate change impacts. Impacts have been associated with disruption of global, regional and national economies, due to increased morbidity and mortality, air pollution, heat-waves, and risks to food security and food safety [12].

2.1 Actual impacts of Climate Change

Nigeria's climate is already changing. The Nigerian Meteorological Agency (NIMET 2008) assessed the Nigerian climate over the period 1941 to 2000 and demonstrated the following changes:

Rainfall: Compared to previous periods, during the period from 1971 to 2000, the combination of late onset and early cessation shortened the length of the rainy season in most parts of the country. Between 1941 and 2000, annual rainfall decreased by 2-8 mm across most of the country, but increased by 2-4 mm in a few places (e.g. Port Harcourt).

Temperature: From 1941 to 2000, there was evidence of long-term temperature increase in most parts of the country. The main exception was in the Jos area, where a slight cooling was recorded. The most significant increases were recorded in the extreme northeast, extreme northwest and extreme southwest, where average temperatures rose by 1.4-1.9°C [19,20,21].

- i. Increasing global warming with increasing acidification of the oceans, with an average decrease in pH of 0.1 units;
- ii. Contraction of Snow cover with widespread increases in thaw depth over most permafrost regions;
- iii. Shrinking of Sea ice in both Arctic and Antarctic regions, with risks of disappearance of most of the Arctic late summer sea ice, by the later part of the 21st century;
- iv. More frequent, more intense extreme weather variability, with hot extremes, heat-waves, heavy precipitation, catastrophic flooding, and disastrous wind cyclones. Increased precipitations very likely in high latitudes, while decreases are likely in most sub-tropical regions;
- v. Trends towards earlier 'greening' of vegetation and longer thermal growing season
- vi. Changes in marine and freshwater biological systems associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen

- levels and circulation, can impact on fisheries and aquaculture.
- vii. Increasingly negative impacts on local crop production, in all regions, especially in subsistence sectors, at low latitudes, due to increases in the frequency of droughts and floods. Even slight warming decreases yields in seasonally dry and tropical regions. However, moderate warming benefits cereal crops and pasture yields in mid- to high latitude regions.

2.2 Projected Future Impacts

- i. Continued anthropogenic global warming and sea-level rise, for centuries, due to the time scales associated with climate processes and feedbacks, even if greenhouse gas were to be stabilized.
 - ii. Increased water stress, due to increase in frequency and intensity of precipitation events with flood risks; and increase in drought affected areas;
 - iii. Species extinctions and major biome changes, due to multiple stresses, in vulnerable ecosystems, including: continental tundra, boreal forest, mountain and Mediterranean-type ecosystems; coastal mangroves and salt marshes; and oceanic coral reefs and the sea-ice biomes. Progressive acidification of the oceans, has a negative impact on marine shell-forming organisms such as corals and their dependent species.
 - iv. Intensification and expansion of wildfires globally, as temperatures increase and dry spells become more frequent and more persistent.
 - v. The net carbon intake by terrestrial ecosystems is likely to peak before the middle of the 21st century, and then weaken or even reverse, thus amplifying climate change.
 - vi. Changes in the distribution and production of particular fish species are expected, due to continued warming, with adverse effects for aquaculture and fisheries [5,22].
- increasing human-induced pressures on coastal areas, especially oil spillages and gas flaring.
- ii. Small islands would be especially vulnerable due to exposure of population and infrastructure to projected climate change impacts.
 - iii. Increased risks of extreme weather events, e.g. flooding. Millions of people are projected to experience severe flooding every year due to sea level rise by 2080s. Densely populated low-lying areas, where adaptive capacity is relatively low, and which already face other challenges, such as tropical storms, or local coastal subsistence, are especially at risk.
 - iv. Ocean acidification and warming have the potential to impact negatively on the aquaculture and fisheries.
 - v. The poor, dwelling in often rapidly expanding communities, located near rivers and coasts, and who use or depend on climate sensitive resources, are vulnerable to extreme weather events.
 - vi. Increase in the economic and social costs of disruptive events, due to more intense and/or more frequent, extreme weather events [1,3,11,23,24,25].

2.4 Negative (mostly) Impact

Negative impacts include, impacts on ecosystems (loss of biodiversity, aquifers, soil fertility); morbid health outcomes increased worldwide, e. g. diarrhoea (2.4%), malaria (6%) in 2002; warmer average temperatures, combined with increased climatic variability, would alter the pattern of exposure to thermal extremes, heat waves very cold winters, with resultant health impacts, in both equatorial and temperate climatic regions [26].

2.5 Positive Impacts

Climate change is associated with reduction of viability of disease-transmitting mosquito populations, due to global warming. Global warming could also be associated with milder winters and reduction in seasonal deaths.

2.3 Impacts in Coastal Areas and Low-lying Areas

- i. The most at risk populations would be the mega-deltas of the Africa and Asia, due to large populations and high exposure to sea level rise, storm surges, coastal erosion, and river flooding, exacerbated by
- Adaptation is the global strategy for adjustment in natural or human systems, in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities [4, 5].

Table 1. A summary of the projected trends in the key climate change parameters for Nigeria is presented in the following table, by ecological zone

Climate variables	Mangrove zone	Rain forest	Tall grass (savanna)	Short grass (Sahel)
Temperature	↑	↑	↑	↑
Rainfall amount	↑	↑	↓	↓
Rainfall variability	↑	↑	↑	↑
Extreme rainfall events -droughts	Likely	Likely	↑	↑
Extreme rainfall events –storms and floods	↑	↑	Likely	Likely
Sea level rise	↑	NA	NA	NA

Legend: ↑ likely increase or increase; ↓ likely decrease or decrease; NA not applicable

Source: Federal Ministry of Environment Special Climate Change Unit. National Adaptation Strategy and Plan Of Action On Climate Change For Nigeria (NASPA-CCN). November 2011 Federal Ministry of Environment Special Climate Change Unit. November 2011 Electronic version: ISBN 978-0-9878656-5-6. Book version: ISBN 978-0-9878656-4-9

2.6 Cost Implications of Climate Change

- i. Direct costs of climate change consists of costs of mitigation (relief) action and costs of adaptation to climate change. Direct costs of Adaptation include costs of severe and more frequent flooding events due to rising sea-levels; population displacement, for reasons of physical hazards, land loss, economic disruption and civil strife and protein-Calorie Malnutrition due to disturbance of natural and managed food-producing ecosystems, especially ocean fisheries.
- ii. Indirect Costs of CC, include loss of access to international market as a result of association of adverse impacts of products on CC.

2.7 Inequity

The greenhouse gases that cause climate change (CC) originate mainly from developed countries but the health risks are concentrated in the poorest nations, which contributed least to the problem; 88% of the disease burden attributable to climate change afflicts children under the age of five (5) (an innocent and non-consenting segment of the population – a health inequity) [5,18].

There is wide distributional inequity effect of anthropogenic forces within and among nations, between regions and across generations. Countries most responsible for global environmental degradation have benefited in the short term, but the harms will be felt most acutely in the poorest countries that had less of a role in causing the degradation.

Children inherit societies created today: unequal burden of disease; loss of food and water security; loss of biological capital; forced migration due to sea level rise, redistribution of crops, desertification, and drought; reduced economic capacity; depression, mental illness; violence and terrorism. Generations in the future will be left to cope with the results of excess resource extraction, pollution and degradation (damage or worsening) of ecosystems (all living creatures in relation to their physical environments) caused by those living now [27].

3. HEALTH IMPACTS OF CLIMATE CHANGE

Climate change is expected to lead mainly to changes in existing health issues rather than to the emergence of new and unfamiliar diseases. Climate sensitive diseases, associated with changing patterns, include: Malaria, Diarrhoea and Protein-Energy-Malnutrition (PEM), infectious disease such as tick-borne encephalitis and cholera [28].

Climate change is not just a global threat, but an unprecedented public health emergency. Protecting health from impacts is central to mitigation and adaptation strategies. Threat to health is often cited to justify actions to mitigate or adapt to climate change [29]. Climate change is expected to increase threats to human health, particularly in lower income populations, predominantly, within tropical and subtropical countries. Potential (actual or projected) public health consequences of climate change include: Climate change impacts on the biophysical and ecosystems, with risks of loss of biodiversity, aquifers, and soil fertility; the disturbance of

natural and managed food-producing ecosystems (ocean fisheries); flooding due to rising sea-levels; population displacement for reasons of physical hazards; land loss, economic disruption and civil strife [30,31,32].

The actual health impacts will be influenced by local environmental conditions and socio-economic circumstances, and by the range of social, institutional, technological, and behavioural adaptations taken to reduce the full range of threats to health” [33].

Eighty-eight percent (88%) of the disease burden attributable to climate change afflicts children under five [5].

3.1 Categories of Health Impacts

According to the World Health Organization (WHO) health impacts of climate change can be categorized as ‘direct impacts’, ‘indirect impacts’, or ‘diverse health impacts’.

Direct impacts are caused by weather extremes, e.g. impacts of thermal stress, deaths/injury in floods and storms. Indirect impacts, are due to health consequences of various environmental changes and ecological disruptions, that occur in response to climate change, including: changes in the ranges of disease vectors (e.g. mosquitoes), water-borne pathogens, water quality, and food availability and air quality. Diverse health impacts include, traumatic, infectious, nutritional, psychological disorders that occur in demoralized and displaced populations, in the wake of climate-induced economic dislocation, environmental decline, and conflict situations.

Determinants of health impacts include, ecological processes, social conditions, adaptive policies and concurrent global environmental changes. Concurrent global environmental changes can simultaneously affect human health – often interactively*, include vector-borne infectious diseases which is jointly affected by climatic conditions, population movement, forest clearance and land-use patterns, biodiversity losses (e.g., natural predators of mosquitoes), freshwater surface configurations, and human population density [34].

Hazardous Impacts associated with climate change include: Injury, death and illness from extreme weather events; air pollution related illness; water borne diseases; vector borne

illness; heat related illness and deaths; and cold related deaths; and human exposure to chemicals; disturbance of natural and managed food-producing ecosystems, especially ocean fisheries; population displacement due to physical hazards, land loss, economic disruption, and civil strife, with excess morbidity and mortality. Health risk of climate change is the product of exposures to hazard and local vulnerability [5].

3.2 Extreme Weather Conditions

Extreme climate events are expected to become more frequent with climate change. The pacific-based El Nino Southern Oscillation, an approximately semi-decadal cycle, influences much of the world’s regional weather patterns. Climate change is likely to increase the frequency and/or amplitude of El Nino. Categories of climate extremes consists of simple extremes of climatic statistical ranges, such as very low or very high temperatures and Complex events including droughts and fires, extreme precipitation, storms and floods and hurricanes [35].

- i. Storms and Floods cause death and Injury, displacement and disruption of health and education infrastructure, exposure to mycotoxins, with psychological sequelae (e.g. mental depression, suicide).
- ii. Thermal extremes (Heat waves and cold spells). Generally, Extremes of temperature can kill. Global climate change will be accompanied by an increased frequency and intensity of heat waves, as well as warmer summers and milder winters. Most deaths associated with thermal extremes are in persons with pre-existing disease, especially cardiovascular and respiratory disease. The very old and the very young and frail, are most susceptible. It varies between populations.

Deaths, from cold spells, during winter season, are 10-25% higher than those in the summer. The proportion of winter-related mortality, directly attributable to stressful weather, is not easy to determine. When the reduction in winter deaths appear to outnumber the increase in summer deaths, the net impact on annual mortality is difficult to estimate, without additional data. It varies between populations in temperate countries.

Fatal heat waves, are due to severe dehydration, and exposure to extremely high temperatures, especially in the poor and vulnerable poor, children, elderly, the chronically ill, persons on medication, with lack of access to meteorological services. Warmer average temperatures, combined with increased climatic variability, can alter the pattern of exposure to thermal extremes, and resultant health impacts, in both equatorial and temperate climatic regions [11,26]. Heat waves are associated with higher heat-related deaths and excess emergency admissions.

By 2050, the annual excess summer-time mortality attributable to climate change, is estimated to increase several-fold, assuming acclimatization (physiological, infrastructural, and behavioural). Without acclimatization the impacts would be higher. The actual mortality impact of an acute event such as a heat wave is uncertain because an unknown proportion of the casualties are in susceptible persons who would have died in the very near future [36].

- iii. Long term droughts and fires, in many regions, can lead to death, injury, displacement, and poor air quality.
- iv. Extreme precipitation correlates with outbreaks of waterborne illness, due to flooding, with associated contamination of surface and ground water with sewage and sillage. Waterborne diseases represent 15% of deaths of under-five (U-5), in developing countries. Pregnant women, infants, young children, are among the most vulnerable to diarrhoea, from unsafe water. Incidence of diarrhoeal disease correlates with increased temperature. Higher ambient temperatures and associated changes in eating behaviour, favour faster growth of food borne microbiological pathogens, especially Bacteria, Entamoeba Protozoa. Diarrhoeal diseases increased worldwide by 2.4% in 2004 Children [5].
- v. Hospitalizations for diarrhoea/dehydration, have been found to increase by up to 8% increase, per °C above normal average, during El Nino weather event. Extended geographic range (latitude and altitude) and seasonality of certain infectious diseases – including vector-borne infections such as malaria and dengue, and food-borne infections (e.g. Salmonellosis) which peak in the warmer months [5,8,9,37].

Extreme climate events are expected to become more frequent with climate change. The pacific-based El Nino Southern Oscillation (ENSO), an approximately semi-decadal cycle, influences much of the world's regional weather patterns. Climate change is likely to increase the frequency and/or amplitude of El Nino, which has been associated with increase in transmission of malaria [35,38].

Malaria seems likely to be the vector-borne disease most sensitive to climate change. Excessive rainfall and high humidity enhance mosquito breeding and survival. There is evidence that malaria epidemic risk increases around five-fold in the year after an El Nino event [39].

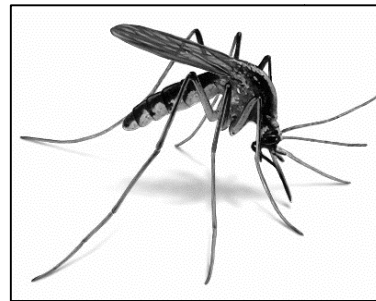


Fig. 3. A Vector

3.3 Enhanced Infection Prevalence of Vector Borne Diseases

Vectors especially mosquito species, which spread malaria, and viral diseases, such as dengue and yellow fever, need access to stagnant water in order to breed. Warmer temperatures enhance vector breeding by reducing the pathogen's maturation period within the vector organism. Adult mosquitoes need humid conditions for viability, very hot and dry conditions can reduce mosquito survival.

Malaria today is mostly confined to tropical and sub-tropical regions. Disease's sensitivity is illustrated by desert and highland fringe areas where higher temperatures and/or rainfall associated with El Nino, may increase transmission of malaria. In these areas of unstable malaria, especially in developing countries, populations lack protective immunity and are prone to epidemics when weather conditions facilitate transmission [40].

In high altitudes and latitudes, global warming is associated with enhanced vector breeding and prolonged transmission season of vectors

(Fig. 3) and vector borne diseases such as malaria. According to the WHO, the morbidity and mortality from climate sensitive diseases e.g. malaria increased by 6%, in 2002 [5,26].

IPCC has concluded, with high confidence, that climate change would cause increased heat-related mortality and morbidity, decreased cold-related mortality in temperate countries, greater frequency of infectious disease epidemics following floods and storms, and substantial health effects following population displacement from sea level rise and increased storm activity [41].

3.4 Salinization of Coastal and Low-lying Areas

Sea level rise, is largely due to melting of Arctic and Antarctic glaciers. Rise in sea level causes flooding of coastal and low-lying areas, leading to salination of sources of agriculture and drinking water. Sustained salinization of coastal water and soil, is associated with the risks of massive extinctions of aquatic biodiversity, loss of aquifers, soil fertility in Ecosystems. These negative impacts on fisheries and aquaculture increase protein-calories malnutrition, especially among the poor and vulnerable [3,28].

3.5 Human Exposure to Chemicals

Climatic change may alter human exposure to chemicals. Extreme precipitation, storms and floods affect water quality, by increasing chemical waste in surface and ground water. Flooding increases the concentration of non-volatile chemicals and toxic metals in water. Increased temperatures make volatile chemicals to disperse more quickly in the air [5].

3.6 Air Pollution-Related Illness

Climate change is associated with increase in ground level ozone (O_3). There is strong evidence that ground level ozone is associated with increased frequency and severity of asthma attacks amongst children, due to sensitivity of children to ozone at lower levels. The associated increase in incidence of emergency Respiratory visits and hospitalizations are independent with temperature [5].

3.7 Natural Disasters (droughts, floods, storms and bush fires)

Effects of natural disasters on health are difficult to quantify, because secondary and delayed

consequences are poorly documented or reported. The increasing trend in natural disasters is partly due to better reporting, partly due to increasing population vulnerability, and may include a contribution from ongoing climate change. El Nino events influence the annual toll of persons affected by natural disasters [42]. The number of people killed, injured or made homeless by natural disasters has been increasing rapidly, especially in developing countries.

Developing countries are poorly equipped to deal with weather extremes, even as the population concentration increases in high risk areas like coastal zones and cities. Especially in poor countries, the impacts of major vector-borne diseases and disasters can limit or even reverse improvements in social developments. Even under favourable conditions, recovery from major disasters can take decades.

4. THE NIGER DELTA

4.1 The Study Area

The Niger Delta region is situated in the southern part of Nigeria (Fig. 4) and bordered to the south by the Atlantic Ocean, and to the east by Cameroon. It occupies a surface area of about 112,110 square kilometers [43] and it occupies 7.5% of Nigeria's land mass. Historically and cartographically, the Niger Delta consists of the present day Bayelsa, Delta and Rivers states. In the year 2000, President Obasanjo added Abia, Akwa-Ibom, Cross River State, Edo, Imo, and Ondo States (of the Federal Republic of Nigeria) to the Niger Delta geo-political region. The Niger Delta region is distinct from the Nigerian South-South Zone. The Nigerian South-South Zone is a geo-political zone comprising of only six states, namely: Akwa-Ibom, Bayelsa, Cross River, Delta, Edo and Rivers states. The present day Niger Delta region includes nine (9) States, including: Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and Rivers [43].

Part or all of each of the nine (9) States of the Niger delta region, is located in the Niger Delta, of the Federal Republic of Nigeria. The Niger Delta is the downstream of the 2,600 miles (4,200 km) long Niger river, which rises in Guinea at $9^{\circ}05' N$ and $10^{\circ}47' W$ on the Eastern side of the Fouta Djallon (Guinea). The Niger river, which drains a total area of 730,000 square miles (1,900,000), emerges at Aboh or Abo, a city in Ndokwa East Local Government Area,

Delta State, in the Delta region, separating into many branches, and intricate network of rivers and creeks, before reaching the Gulf of Guinea, of the Atlantic Ocean, to become Africa's largest delta. Geographically, the Niger delta extends over a total area of 14,000 square miles (36,000 square km), stretches for nearly 150

miles (240 Km) from north to south, and spreads along the Atlantic Coast for about 200 miles (320 Km). The Niger delta is being gradually extended seaward, by the increments of silt brought down by the Niger river and its tributaries, with mangrove swamps observed to mark its coastal edge [17].

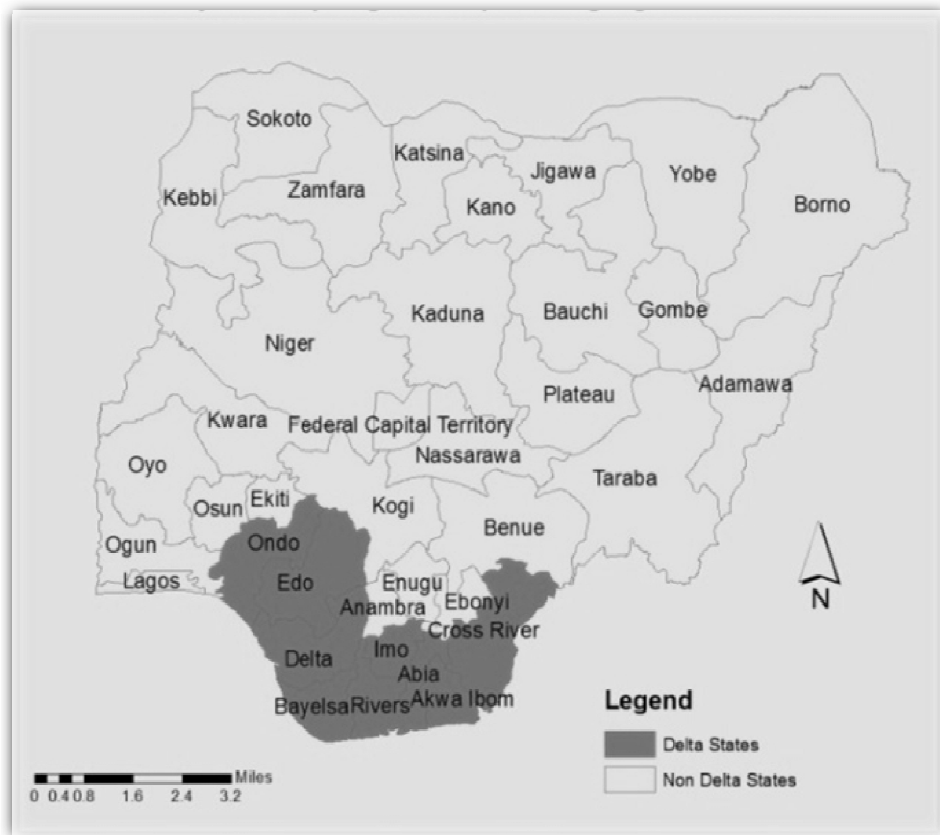


Fig. 4. The Niger delta region and the states of the Federal Republic of Nigeria

Table 2. Geographic characteristics of the Niger Delta States

State	Land Area (Square kilometers)	Population (Projected to 2005)	Capital city
Abia	4,877	3,230,000	Umuahia
Akwa Ibom	6,809	3,343,000	Uyo
Bayelsa	11,007	1,710,000	Yenegoa
Cross river	21,930	2,736,000	Calabar
Delta	17,163	3,594,000	Asaba
Edo	19,698	3,018,000	Benin
Imo	5,165	3,342,000	Owerri
Ondo	15,086	3,025,000	Akure
Rivers	10,378	4,858,000	Port Harcourt
Total	112,110	28,856,000	

Source: GTZ Population Projection based on 1991 Census & NDRDMP Demography & Baseline sectors study; Agriculture and Rural Development Sector Study

4.2 The Study Population

The population of the Niger Delta region is about 31 million people (Fig. 5 and Table 2), of more than 40 ethnic groups, that speak about 250 dialects. The ethnic groups include the Binis, Efik, Ibibio, Igbo, Annang, Oron, Ijaw, Itsekiri, Isoko, Urobo, Ukwuani, and Kalabari; they are characterized by distinctly colourful cultures and traditions [44].

Economically, 48% of employed persons in the Niger delta earn less than 5,000 Naira per month. The unemployment rates in the Niger delta are higher than the national average (5%), except in Abia, Edo, and Ondo States, with other states showing higher rates e.g. 18.2% in Akwa Ibom, 19.1% in Rivers and 16.6% in Cross Rivers States. The Niger Delta region is characterized by developmental contrasts (Fig. 6 & Fig. 7), international controversy over

devastating pollution, poverty, genocide, and human rights violation.

4.3 Petroleum and Gas Extraction

The Niger delta is an oil-rich region. About 2 million barrels (320,000 m³) a day are extracted from the Niger Delta (Table 3). Together oil and natural gas extraction (Fig. 9) comprise “97% of Nigeria’s foreign exchange revenues”. The Niger-Delta is West Africa’s biggest producer of petroleum and natural gas.

Much of the natural gas extracted in oil wells in the Delta is immediately burned, or flared (Fig. 9), into the air at a rate of approximately 70 million m³ per day. In 2002, 99% of excess gas was flared in the Niger Delta, constituting the largest single source of greenhouse gas emissions on Earth, causing local pollution and contributing to climate change [45,46].

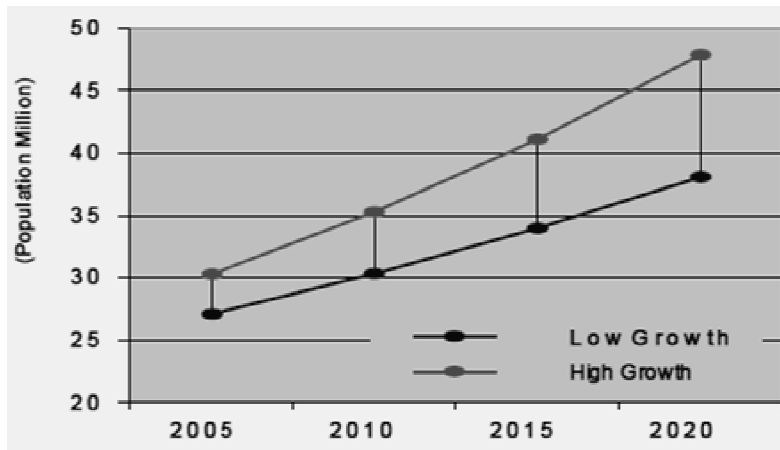


Fig. 5. Population projections for the Niger Delta Region (2005-2020)

Source: NCR Master Plan baseline survey



Fig. 6. A rural household in the Niger Delta



Fig. 7. Modern housing project in Aggrey road, Port Harcourt

Source: Federal Republic of Nigeria. Niger Delta Region. Land and People. Niger Delta Regional Development Master Plan



Fig. 8. An offshore oil drilling rig in the Niger Delta Region

Source: Federal Republic of Nigeria. Niger Delta Region. Land and People. Niger Delta Regional Development Master Plan

Table 3. Niger delta oil and gas summary profile, 2004

Contribution of crude oil export to national foreign exchange	Over 80%
Average daily crude production	2mill BPD
Number of wells drilled in the Niger delta Region	5,284
Number of flow-stations for crude oil processing	257
Length of oil and gas pipelines in the region	Over 7,000km
Number of export terminals	10
Land and area within which the network of pipelines are located	31,000Sq km
Number of communities hosting oil/gas facilities	Over 1,500
Gas flares-out target date	2008
Number of petroleum training institutes in the region	1
Number of free export	2
Number of gas plants in the region	10
Number of marginal oil fields farmed out to local companies	30



Fig. 9. Gas flaring in the petroleum and gas industry

4.4 Pipeline Vandalization & Oil Bunkering

Illegal oil bunkering is effectively Nigeria’s most profitable private business [47]. Vandalization of pipeline leads to oil spillages that endanger highly diverse ecosystems which are supportive of numerous species of terrestrial and aquatic fauna and flora [48] including humans. Spillages

have been associated with respiratory symptoms, mutagenicity, carcinogenicity due to bioaccumulation of lipophilic aromatic hydrocarbons, which are common constituents of petroleum oil, in organic tissues [49,50,51].

“some experts in the oil sector are in consensus that the persistence upsurge of

illegal bunkering in the Niger Delta is due to high levels of youth unemployment, armed ethnic militia, ineffective and corrupt law enforcement agencies and other state actors who are often part of an international syndicate. They argued that oil theft and pipeline vandalism continued to thrive in Nigeria in spite of government's efforts because of some vested interest of powerful persons involved in the business and the lack of political will to deal with it. They believed that the Nigerian leaders especially the political class is benefiting from illegal oil bunkering hence lack political will to confront it. They further argued that if the leaders are not benefiting directly or indirectly, they must have come up with measures or legislation to stop the menace [52]"

5. ECOLOGICAL VULNERABILITY OF NIGER DELTA TO CLIMATE CHANGE

5.1 Ecological Zones in the Niger Delta

The Niger-Delta region of Nigeria is one of the mega-deltas of the world. There are five ecological zones in the Niger Delta: the Mangrove Forest and coastal vegetation; Fresh water swamp forest, lowland rain forest, derived savannah and Montane region. The impact of climate-related hazards on the ecosystems is compounded by extreme poverty, and devastating environmental degradation by oil spillages and gas flaring associated with the petroleum industry.

5.2 The Mangrove Forest and Coastal Vegetation

The mangrove zone is up to 40 km wide, bordered to the south by the Atlantic Ocean, is exposed to the hazards of climate - related sea rise, including life-threatening sea surges, coastal erosions, extreme flooding events, intrusion of saline sea water into fresh water system, with risks of alterations of ecosystems.

The dominant vegetation in the 40 km mangrove zone, is freshwater swamp forest with occasional small salt marshes where sea water washes over the beaches. The mangrove floor provides habitation for innumerable smaller flora and fauna (e.g. shrimps and microscopic algae) illustrating the global importance of the mangrove ecosystem. Greenhouse gas emissions and environmental degradation from petrochemical industrial activities in the Niger delta promote

climate change and directly threaten the biodiversity of the rich mangrove ecosystem. As the soils are poorly drained and sandy, soils are not conducive for farming, there is little direct conversion of mangrove forest to agricultural land. Local communities are exposed to sea surges, flooding, live on stilts and elevated homes; main subsistence is fish farming and with a high index of poverty [43].

5.3 The Fresh Water Swamp Forest

The fresh water swamp forest (Fig. 10) covers approximately 17,000 km² or about half of the Niger delta region. Rich in timber and rare and endangered wildlife. It is susceptible to hunting and deforestation which compromise the biodiversity of the ecosystem.

The swampy forests are subject to the silt-laden 'white water' of the Niger floods with very high fishery and agricultural potential. The 'white water' sector is divided into two broad zones: (a) the Upper Delta or Flood Forest zone and (b) the Swampy Tidal Freshwater zone and (c) the 'Transition or Marsh forest zone (permanently swampy, tidal – freshwater zone, with more narrow and sandy channels, that lies between the flood forest and the mangrove zone). The 'Upper Delta' or Flood Forest zone (Aboh to Bomadi and Oporoma) has large sandy river channels, high flood levels and numerous flood plain lakes. Prolonged flooding periods and shortened season for farm crops are compensated for by very high fishery and fertile silt from the flood –high agricultural potential [43].

5.4 Low Land and Rainforest

The Low land (Fig. 11) and Rainforest (Fig. 12) zone occupies the non-riverine or 'upland' areas has been largely cleared for agriculture by the demands of an increasing population. Low land and rainforest are in high demands for seasonal crops [33].

5.5 Derived Savannah Zone

Derived Savannah Zone (Fig. 13) is found in the northern part of the Niger delta. The vegetation is largely a re-growth after the original vegetation has been cleared for agriculture. It comprises Savannah type grasses and shrubs with a few scattered trees. It is densely populated. As a result of the constant pressure on vegetation for fossil fuel, it is virtually impossible for trees to grow to maturity, leading to constant deforestation [43].



Fig. 10. A village in the fresh water Swamp in Delta State

Source: Federal Republic of Nigeria. Niger Delta Region. Land and People. Niger Delta Regional Development Master Plan



Fig. 11. Low land

Source: Federal Republic of Nigeria. Niger Delta Region. Land and People. Niger Delta Regional Development Master Plan



Fig. 12. Rain forest in Niger Delta Region



Fig. 13. Derived Savannah Vegetation

Source: Federal Republic of Nigeria. Niger Delta Region. Land and People. Niger Delta Regional Development Master Plan



Fig. 14. Obudu cattle ranch in the Montane Ecozone

5.6 The Montane Zone

The Montane Zone (Fig. 14) is confined to the north eastern part of Cross River State, around Obudu/ Sankwala area. It is approximately 900 to 1,500 m above sea level. It has low species diversity compensated for, by high floristic diversity, with high eco-tourism potential [43].

5.7 Vulnerability to Climate Change

Vulnerability is the susceptibility to harm, in terms of a population or a location. Vulnerability to climate change is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate variability and change [53]. Vulnerability is dynamic and may itself be

influence by climate change (e.g. extreme weather events affecting health infrastructure)

From a health perspective, vulnerability can be defined as the summation of all risks and protective factors that ultimately determine whether a sub-population or region, experiences adverse health outcomes due to climate change [54]. Characteristics of a region, such as baseline climate, abundance of natural resources (e.g. access to fresh water), elevation, infrastructure and other factors can alter vulnerability. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system or population is exposed, its sensitivity and its adaptive capacity.

The vulnerability of a population to the potential impact of climate change depends on factors such as: population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care [55].

5.8 Impacts in Coastal Areas and Low-lying Areas

- i. The Coastal Areas, Low-lying Areas, and river banks, in the Niger delta region are at increased risk of extreme weather events, and impacts of climate change, due to large populations and high exposure to sea level rise, storm surges, coastal erosion, and river flooding, exacerbated by increasing human-induced pressures on coastal areas, especially oil spillages and gas flaring.
- ii. Risk is increased by relatively low adaptive capacity to climate change, already existing tropical storms, and local coastal subsistence agriculture.
- iii. Small islands would be especially vulnerable due to exposure of population and infrastructure to recurrent and projected climate change impacts.
- iv. Ocean acidification and warming have the potential to impact negatively on the aquaculture and fisheries in the Niger delta.
- v. The poor, dwelling in often rapidly expanding communities, located near rivers and coasts, and who use or depend on climate sensitive resources, are vulnerable to extreme weather events.
- vi. Increase in the economic and social costs of disruptive events with the potential to

displace populations, due to more intense and/or more frequent, extreme weather events, especially storms, extreme precipitation and flooding [1].

5.9 Sectoral Vulnerability

- i. *Agriculture*: Lack of access to improved seeds, prolonged droughts and/or floods
- ii. *Ecosystems*: threats to rich but fragile biodiversity, habitat loss, over-harvesting of selected species, the spread of alien species, hunting and deforestation
- iii. *Water*: poor access to clean drinking water and sanitation, overfishing, industrial pollution, sedimentation with degradation of local water sources.
- iv. *Climate and weather*: complex maritime and terrestrial interactions, extreme and prolong flooding cause migration, cultural separation and collapse of communities, increased risks of diarrhoea, cholera and malaria, economic and human losses
- v. *Economic Stressors to Climate Change*: endemic Poverty, complex governance and institutional dimensions' limited access to capital including markets, infrastructure, and technology; ecosystem degradation, complex disasters and conflicts.
- vi. *Population*: Social vulnerability to climate-related impacts is determined by poverty, inequality; marginalization, food security, access to insurance, and housing quality.
- vii. *Others*: complex interaction of socio-economic, political, environmental and cultural factors, regional conflicts, variability of weather and climate, volatile commodity prices and the various influences of globalization, increase in the spread of HIV/AIDS and Ebola Virus Disease (EVD) due to economic stagnation and low progress in education which produce a 'freefall' in the Human Development Ranking [1].

5.10 Character of Climate Variability in the Niger Delta

The Niger-Delta region is bordered to the south by the Atlantic Ocean and coastal communities are exposed to the hazards of climate-related sea level rise; increased precipitation; prolongation of seasonal Flooding in non-coastal areas characterized by riverine creeks and flood plains (especially, Aboh to Bomadi and Aporoma) [37,43].

5.11 Magnitude of Climate Variation in the Niger Delta

Life threatening sea surges, coastal erosions, extreme flooding events; prolonged flooding can shorten farming season, increase risks of displacement, water contamination, mosquito breeding, overcrowding, with vulnerability to excess morbidity and mortality from malaria, malnutrition, diarrhoeal diseases, respiratory diseases and possible land disputes; intrusion of saline sea water into fresh water system with; risks of alterations of ecosystems [27,43].

5.12 Rate of Climate Variation

Meteorological evidence of variations in climatic elements (Temperature, Rain, and Wind, Sun, etc.) exists, with increased frequency of precipitation in all the ecological zones of the Niger Delta: Mangrove Forest and Coastal Vegetation; Freshwater swamp Forest; Lowland Rainforest; Derived Savannah and Montane Region. Climate variation increases the magnitude of vulnerability to climate change, increased risk and frequency of extreme flooding events [28,43,56].

Nigeria's Future Climatic Variation has been measured. Validated differentials of datasets (1950-2000), obtained from four meteorological stations (Lagos, Owerri, Port Harcourt, Bauchi) of the Nigeria Meteorological Service (NIMET), Oshodi Lagos State, were randomly applied to the future temperature and rainfall from the Worldclim model, to obtain the database for the future (2001 – 2050) temperature and rainfall for Nigeria, using the Statistical Downscaling Approach [57].

Measurements predict an increase in climatic variations of both temperature and rainfall in the Niger-delta region, between 2000 and 2050. In the low-lying coastal areas, due to rise in sea level, there will be intensified flooding, with inundation of wetlands, with erosion of beaches and increase in salinity of rivers, ground water, bays, and harbors.

There is evidence that Spectral analysis of observed and Climate Research Unit (CRU) data, can be used for the prediction of climate variations, e.g. temperature was predicted to increase by 0.65–1.6 °C and precipitation was predicted to decrease by 13–11% in the next two decades (i.e., 2016–2025 and 2026–2035)

relative to 1961–1990, in the Lake Chad basin (LCB) [58,59,60,61].

Access to accurate predictions of future climate variations, including weather forecast, should serve as opportunity to promote and support simultaneous actions on mitigation and adaptation, for full transformation of economies of vulnerable communities, groups and individuals.

5.13 Sensitivity of Population or System to Climate Variation

Sensitivity of population of the Niger Delta to climate variation is determined by level of awareness of climate change, cause, effects, mitigation and adaptation, poverty, inequality, marginalization, food entitlements, access to insurance, housing quality and lack of resources (including meteorological services, political will), for appropriate response to climate change including building adaptive capacity through community mobilization [5,43].

5.14 Community Adaptive Strategies to Climate Change

Historically, communities in the region have adopted cultural practices compatible with the flood regimes and the associated fluvial processes. But, with the increase in population pressure, accompanied by urbanization, industrial development and agricultural expansion, the subsisting equilibrium has been altered dramatically, leading to the situation in which flooding is impacting negatively on the land and people of the region. The result is that the area of the arable land that can no longer be cultivated owing to annual floods, environmental degradation from industrial wastes and drainage problems has increased [43,21].

6. RESPONDING TO CLIMATE CHANGE IN THE NIGER DELTA REGION

6.1 National and Niger Delta Region

The Federal Republic of Nigeria, in Partnership with the nine State Governments of the Delta Region, should bring together gender-diverse, and youth sensitive, multi-sectoral, multi-jurisdictional, multidisciplinary, decision makers, including, civil society, local authorities (CBOs, FBOs, Traditional Leaders, Youth organizations, NGOs, women leaders), and international

organizations, to urgently address mitigation and adaptation to the vulnerabilities and impacts of the Niger Delta region to climate change, and to develop ambitious solutions toward a full transformation of economies, in line with sustainable developmental goals (SDGs), as follows:

- i. A national and regional transition to renewable energy, such as, wind or solar power, that is not depleted when used.
- ii. sustainable and resilient infrastructure, cities and communities;
- iii. sustainable agriculture and management of forests and oceans;
- iv. resilience and adaptation to impacts of climate change;
- v. alignment of public and private finance with a net zero economy;
- vi. strengthen economies, create jobs, ensure cleaner air, preserve natural habitats and biodiversity and protect the environment from gas flaring, air pollution, oil spillages and biodegradation;
- vii. end subsidies for fossil fuels and GHGs-high-emitting agriculture and shifting towards renewable energy, electric vehicles and carbon smart vehicles;
- viii. carbon pricing that reflects the true cost of GHG emissions, including impact to climate change, and health impacts of air pollution;
- ix. transition from fossil-fuel driven economy to new technologies based on cheaper and more sustainable solar and onshore wind engineering options;
- x. Accelerating the closure of coal plants, halt the construction of new ones, replace jobs with healthier alternatives, for a just, inclusive and profitable, climate-sensitive and sustainable transformation of the Niger Delta region [11,12,16,53].

6.2 State governments in the Niger Delta

- i. Adopt or adapt the national adaptation strategies, especially emergency preparedness, for flooding events, for local implementation in the nine states.
- ii. give infusions of resource support to our public, health infrastructure and disaster preparedness programs and always remembering a specific focus on vulnerable populations, the needs of children and future generations.

- iii. Increased education of primary and secondary school children about the need for communities to think and act in ecologically sustainable ways, and about the ways of lessening personal and family exposure to environmental hazards consequent upon global environmental changes.
- iv. Replace biomass fuels or bio-fuels, with clean renewable energy. Biomass fuel is a fuel produced by dry organic matter or combustible oils produced by plants. These fuels are considered as renewable as long as the vegetation producing them is maintained or replanted, such as firewood, alcohol fermented from sugar, and combustible oils extracted from soya beans. Their use in place of fossil fuels cuts greenhouse gas emissions, because the plants that are the fuel sources capture carbon dioxide from the atmosphere.

There is Evidence from Multivariate Panel Data Analysis that there exists a statistically significant and positive relationship between renewable energy production and economic growth for both developed and developing economies [62].

- v. Develop “smart” local electrical grids to reduce GHGs emissions, prevent new emissions, prevent cardiovascular diseases and deaths, and get necessary energy to households.
- vi. Improve public transportation and create bike lanes, to reduce need for personal vehicles on the roads, decrease road congestion, reduce noise, decrease air pollution, promote health, and save money.
- vii. Strengthen traditional diet and advocate ‘eat low on food chain’, local and organic, when available, to support local farm/economy, improved nutritional quality, prevent obesity, and lower the risk of chronic diseases.

The demand for local food, by consumers, have been fuelled by increasing consumer curiosity regarding the ingredients in their food, concerns about the environmental impact of the non-local food system and the desire for an authentic brand story. Consequently, food outlets, including grocery stores, restaurants, and universities, have sought to incorporate locally sourced products on their shelves.

The demand for local food is helping to support the recovery of the agricultural industry that

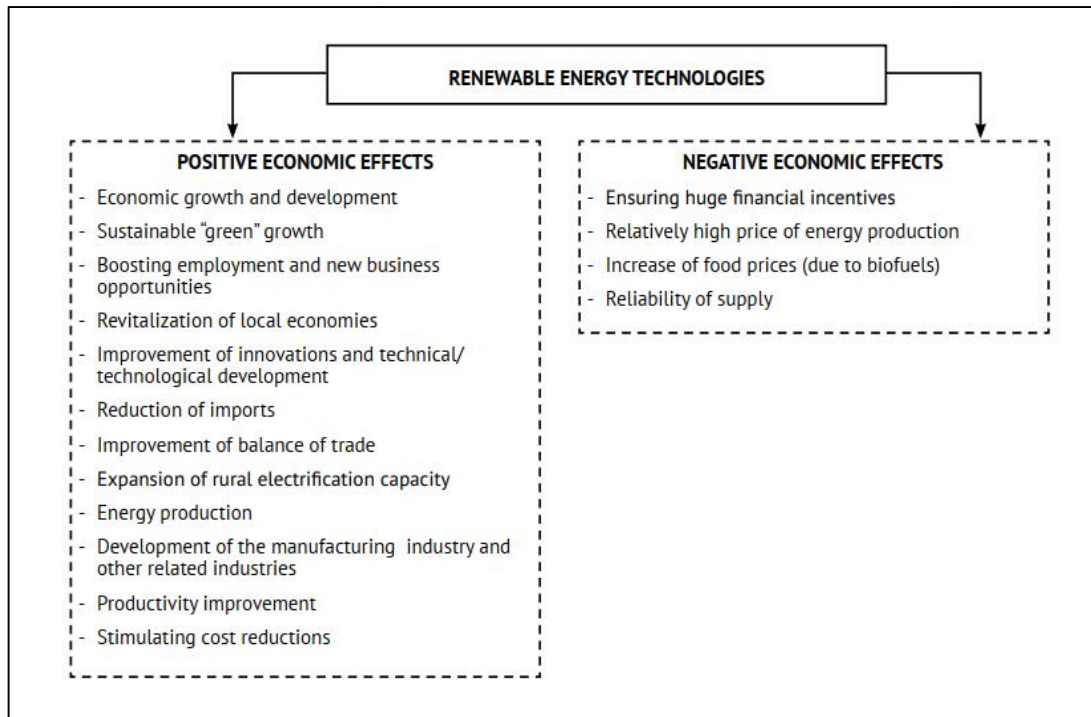


Fig. 15. Renewable energy technologies

Source: Maradin, D., Cerović, L., & Mjeda, T. (2017). *Economic Effects of Renewable Energy Technologies*. *Naše gospodarstvo/Our Economy*, 63(2), 49–59. DOI: 10.1515/ngoe-2017-0012.

suffered a decline, with growth of both number and size of farms, with increasing median age of farmers. The financial impacts of increase in the sales of local foods, especially of fruits and vegetable farms, with gross annual revenue under \$350,000, will likely result in positive net farm income and increased farm viability, due to low operating expense ratios.

Compared with wholesale imported food marketing, direct marketing of local farm products, can create up to 21.5 additional jobs for every \$1 million in revenue, as a result of direct marketers purchasing a greater share of inputs, locally (89 percent compared with 45 percent) [63].

- viii. Green the environment, including active Tree planting, with enforcement of appropriate policies, strategies and implementation through community-based action.
- ix. Strengthen coastal defences against rising sea levels.
- x. Manage local and regional fisheries sustainably, in order to maintain nutritional (especially protein) supplies.

- xi. Town planning and enforcement of public health laws with free drainages, to mitigate flooding.
- xii. Improved Public transportation to reduce individual carbon footprint, by reducing the number of individuals driving their own cars.
- xiii. Efficient and effective implementation of Environmental sanitation policy to avoid blocked drainages and transmission of communicable diseases.
- xiv. Housing policy with strengthening and protection of public infrastructures (schools, health institutions, power lines, etc.) from adverse impact of extreme weather conditions.
- xv. Each of the nine states should create awareness of climate change, ensure participation of individuals, institutions, communities and states, in decision-making on adaptation, and empower positive adjustment to consequences of climate change – variability, thermal extremes and flooding, with emergency preparedness, sensitive to vulnerable groups, in the Niger delta region [5,26,53, 64].

6.3 Individuals, Institutions, Communities

- i. Everyone from individual, institutions, communities in the nine states of the Niger delta region should be empowered on basic information on climate change, mobilized to participate in the strategic decisions for mitigation measures and adaptation to climate change, through community mobilization.
- ii. Individuals should alter clothing and recreational behaviour, especially of children, to reduce exposure to ultraviolet (UV) radiation. 'There is nothing like bad weather, what there is, is inappropriate dressing' [5,7,26].

7. DISCUSSION

1. The Niger Delta region of Nigeria is vulnerable to both actual and projected impacts of climate change. There was a 2-4 mm increase in rainfall (e.g. in Port Harcourt), between 1941 and 2000. Data from the Nigeria Meteorological Agency (NIMET) has predicted that the Niger Delta region would experience projected impacts of climate change in the Niger delta region, including increased temperature, increased average annual rainfall, increased rainfall variability, increased rainfall events including storms and floods, due to increasing sea level rise.
2. The vulnerability of Niger delta region to adverse impacts of climate on the biodiversity of the existing ecosystem and human health is exacerbated by bunkering of petroleum products and vandalization of oil pipelines leading to spillages of petroleum products that endanger highly diverse ecosystems, which are supportive of numerous species of terrestrial and aquatic fauna and flora, including humans. Spillages have been associated with respiratory symptoms, mutagenicity, carcinogenicity due to bio-accumulation of lipophilic aromatic hydrocarbons (which are common constituents of petroleum oil), in organic tissues.

8. CONCLUSION

8.1 Climate Change

Climate change, with global warming, is unequivocally attributable to human activity,

especially the growing use of fossil fuel energy, with the expansion of the global economy.

Climate change, characterized by global warming and extreme climate variability, is attributable to greenhouse gas emissions, especially Carbon dioxide. Long term changes in climate, observed at continental, regional and ocean-based scales, include, increase in arctic temperatures and melted ice, increased ocean salinity, extreme wind patterns and extreme weather events, such as, prolonged droughts, heavy precipitation, heat-waves, with increased intensity of tropical cyclones. The phenomenon of climate change will have devastating effects, if global warming is left unchecked or left to rise above 1.5°C. Global warming and extreme weather events increase incidence of climate sensitive injuries, water-borne, food-borne, vector-borne and heat-related illnesses and deaths.

The Niger Delta region of Nigeria is vulnerable to both actual and projected impacts of climate change.

8.2 Hazardous Activities of Petroleum and Gas Industry in the Niger Delta Region

The vulnerability of Niger Delta region to climate variability, environmental degradation and adverse impacts of climate, is exacerbated by gas flaring, bunkering of petroleum products and vandalization of oil pipelines leading to spillages of petroleum products that endanger highly diverse ecosystems, which are supportive of numerous species of terrestrial and aquatic fauna and flora, with the potential to cause food insecurity, increased morbidity and mortality.

8.3 Vulnerability of Niger Delta Region to Climate Change

The Niger delta constitutes 32% of the total land mass of the geographic area occupied by the Niger delta region. The 200 miles (320 Kilometres) extensive coastal boundary of the Niger delta with the Atlantic Ocean, exposes the vulnerable Coastal Areas and Low-lying Areas, and river banks, in the Niger delta region, to storm surges, coastal erosion, and extreme flooding events, due to sea level rise. The vulnerability of large populations and communities of the Niger delta region to extreme flooding, and other climate change-related extreme weather events, is compounded by extreme poverty, low adaptive capacity, poorly implemented mitigation measures, risks of

internal displacements, 'water stress', with increased morbidity and mortality.

8.4 Response to Climate Change in the Niger Delta Region

Appropriate response to climate-related hazards in the Niger delta region requires collective political will of the nine states of the Niger delta region. Action would include: regional strategic plan for mitigation measures and adaptation; meteorological services; creation of public awareness of climate change, cause, effects, mitigation and adaptation, through community mobilization; and building 'human capital' with adaptive capacity for emergency response to extreme weather events.

To be effective, credible, profitable, climate-sensitive, and sustainable, appropriate response to climate change, requires gender-diverse, youth-sensitive, multi-sectoral, multidisciplinary, and multi-jurisdictional, bottom-up decision-making, by National and Regional governments, for a just and inclusive plan, that must show the way toward a full transformation of economies and environments of the Niger Delta region, in line with sustainable developmental goals (SDGs).

9. RECOMMENDATION

1. There is a need for urgent response to actual and projected impacts of climate change in the Niger Delta region, by Federal and Regional governments.
2. The Federal Government of Nigeria should provide leadership and mobilize resources to implement the 'National Policy on Climate Change and Response Strategy (NPCC-RS)', and the UNFCCC Policies, especially as regards reduction of emission of obnoxious substances (GHGs and petroleum products) into the environment, in line with the United nations legal instruments (The Kyoto protocol and Paris Agreement).
3. The Federal Ministry of the Niger Delta and the Niger Delta Development Commission (NDDC) should develop programmes that respond to the needs of coastal communities exposed to sea level rise, storm surges, coastal erosion, to control coastal erosion, ensure emergency preparedness, environmental rehabilitation, and protect the shores, water, schools, health care, and hospitals.
4. All State Governments should have an official vision statement on climate change, with integration of the National Policy implementation strategies for mitigation measures and adaptation to climate change, into all existing and new Development Plans, policies, PHC, States' annual Budgets and programmes.
5. Each State Government should have a focal Ministry, Department or Agency mandated to lead and provide strong coordination of inter-ministerial, inter-agency and public-private partnership, all the climate change mitigation and adaptation activities, including monitoring and evaluation.
6. Local Governments, in collaboration with the Federal and State Governments, to build the resilience of communities to climate change, through active participation and ownership of decisions to buy into the opportunities presented by climate change, for socio-economic transformation of their environments.
7. The Organized Private sector, Civil Society Organizations (especially Women and Youths Organizations, Faith-based Organizations, and Traditional Rulers), International Organization and donors should be fully involved to ensure youth participation and gender-sensitive programmes, including sponsorship of research into climate change, in compliance with the sustainable development goals (SDGs).
8. Households, individuals, including children should learn about climate change and how to reduce their carbon foot-prints, by eating local food products, and greening their environments.
9. Develop skill-based school curriculum and appropriate teaching strategies and techniques to empower children and young persons, at pre-primary, primary, secondary and tertiary levels of education.
10. Adequate media coverage of climate change, to create public awareness of climate change, causes, impacts, mitigation, adaptation, including disaster management, emergency preparedness and care of vulnerable groups.
11. Retrain health care workers to appreciate emerging climate change health impacts within the context of immunization, and other comprehensive healthcare delivery.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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