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Vulnerability of Water Resources to Climate Change: Adaptation and Resilience Strategies for Sustainable Development in Nigeria

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Abstract
Nigeria faces inexorable climate change in recent times. This phenomenon will have a profound effect on the long-term sustainable socio-economic development and is also likely to jeopardize achievement of economic development of the country. All economic and social sectors will be adversely affected. The water resources sector is one that will be strongly impacted by climate change. Against a background of increasing demand for potable water, sea-level rise may lead to flooding of lowlands and seawater intrusion into coastal aquifers, while variability in climate may see more intense rainstorms resulting both in increased run-off leading to increased flooding and reduced recharge leading to aquifer depletion. Such impacts are already having negative ripple effects on other vital aspects of the economy such as the tourism, recreational, agricultural and industrial sectors. Unfortunately, adequate management of water resources in Nigeria is sorely lacking. Extensive studies to quantify the likely impacts of future climate change and climate variability on water resources in Nigeria are not available. In many cases, baseline data which may be used to track changes are sparse or non-existent. The impacts of climate change and economic value of water resources will form the basis for the development of adaptation strategies with regards to the sustainable management of regional and national water resources. This paper therefore explores the probable effect climate change will have on water resources in Nigeria, the fall-out from these effects and strategies for mitigating potential negative impacts for sustainable development.

Keywords: Water Resources, Climate Change, Resilience/ Adaptation, Mitigation, Strategies

Introduction
Water is life, for people and for the planet and the importance of water cannot be over emphasized. Water is an economic commodity and is perhaps the most precious of natural resources, and the resource most threatened by climate change. Surface and groundwater resources are fundamental to the development of the numerous socio-economic needs of man (domestic, agriculture, irrigation, aquaculture, horticulture, industry, and hydropower. Groundwater is the primary source of drinking water for half of the world's population. In Nigeria and many parts of Africa, the reliance is even greater as climate change and rapid population growth have placed considerable stress on groundwater to meet the various water demands [1].

Water is essential to the well-being of humankind and a basic requirement for the healthily functioning of all the world's ecosystems. It is critical to fighting poverty and hunger, safeguarding human health, reducing child mortality, as well as managing and protecting our natural resources.But it is under increasing threat from climate change" [2]. Water scarcity is already a major problem for the world's poor. The number of people impacted by water scarcity is projected to increase from about 1.7 billion people today to around 5 billion people by 2025, independent of climate change. Climate change is projected to further reduce water availability in many water scarce regions, particularly in the subtropics, due to increased frequency of droughts, increased evaporation, and changes in rainfall patterns and run-off [3].Inadequate access to safe drinking water and sanitation, combined with poor hygiene practices, are major causes of ill health and life-threatening disease in developing countries. At present, these diseases already kill an estimated 213 million people per year in developing countries, of which about 90 percent are children under the age of five. Women are particularly exposed to water-associated diseases through their traditional chores of washing and water collection.Water is crucial for life, but its accessibility at a sustainable quality and quantity is endangered by many factors, of which climate plays a leading role. The Intergovernmental Panel on Climate Change defines climate as "the average weather in terms of the mean and its variability over a certain time-span and a certain area" and a statistically significant variation of the mean state of the climate or of its variability lasting for decades or longer, is referred to as climate change [4]. Climate change, according to the definition by the Intergovernmental Panel on Climate Change refers to any change in climate over time whether due to natural variability or as a result of human activity [4]. It is one of the most important globalenvironmental challenges, with implications for foodproduction, water supply, health, energy, etc.

Climate Change and Contributions of Human Activities

Atmospheric concentrations of carbon dioxide and other greenhouse gases are increasing. There is a growing body of evidence that this is already contributing to changes in climatic conditions, with impacts on hydrological cycles evident at some locations [5]. Global change scenarios anticipate further large increases in greenhouse gas emissions over the course of this century, with consequences for climate including increased surface temperature, changes in the amount and pattern of precipitation and increased potential evaporation [6]. The nature of these changes is projected to vary across the globe. The critical threats to groundwater (and dependent systems) from these changes is reduced availability of groundwater, due to reduced groundwater recharge, increased demand or groundwater contamination. The implications for socio-economic and environmental conditions in vulnerable regions could be very serious.

Human activities contribute to climate change by causing changes in Earth's atmosphere in the amounts of greenhouse gases, aerosols (small particles), and cloudiness. The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide gas to the atmosphere. Greenhouse gases and aerosols affect climate by altering incoming solar radiation and outgoing infrared radiation that are part of Earth's energy balance. Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

Implication of Climate Change on Water Quality

In many areas, aquifers provide an important source of freshwater supply. Maintaining water quality in these aquifers is essential for the communities and farming activities dependent on them. In shallow aquifers, groundwater temperatures may increase due to increasing air temperatures. In arid and semi-arid areas increased evapotranspiration may lead to groundwater salinization [7]. Groundwater quality depends on the chemical, physical and biological characteristics of the resource; thus, it responds to changes in climate and associated anthropogenic activities due to the influences of recharge, discharge, and land use on groundwater systems. In many areas, aquifers provide an important source of freshwater supply.

Additionally, even if climate change does not cause any significant changes in groundwater quality, changes in the amount of groundwater entering other water systems will change the quality of groundwater and those of other water systems (Figure 1)[8]. Groundwater quality has direct implications for the health standards of drinking-water [9, 10]. Usually, groundwater quality is a major limiting factor for its use. The sustainability of water supplies under future climate scenarios depends on the quantity and quality of groundwater resources as well as the physical, chemical, biological and hydrogeological characteristics of the aquifers. Both thermal and chemical properties of groundwater may be affected by climate change.

The projected variability in precipitation patterns will likely affect the quality of groundwater under future climate scenarios in many ways [10, 11]]. Changes in recharge rates, mechanisms and locations will affect contaminant transport, and spatial and temporal variability in groundwater quality. Since precipitation is chemically dilute, majority of the dissolved material in most aquifers are derived from the interactions between rock formations and groundwater. Climate change may likely alter the amount of time for the interaction or the chemical conditions during the interaction; this will degrade the quality of groundwater. Also, the spatiotemporal variability in precipitation patterns will result to substantial infiltration events. Large, pore-water salt reservoirs in the vadose zone, mainly chloride and nitrate, will likely be flushed into many aquifers leading to increased groundwater salinization [12, 13]. Thus, groundwater quality in many aquifers may likely deteriorate substantially if these large chemical reservoirs reach the aquifer.Because precipitation is chemically dilute, the majority of the dissolved material in most aquifers used for human water supplies derives from water-rock interactions in the subsurface. Mixing with high-salinity water from other sources and evaporative concentration of dilute waters are other mechanisms for increasing salinity. If climate change alters the amount of time for, or the chemical conditions during, water-rock interaction, it could cause degradation in groundwater quality. Similarly, changes in the rates of evaporation or saline-water inflows into less-salty aquifers could also cause groundwater quality to suffer. Reduced hydraulic gradients resulting from reductions in groundwater recharge could lead to longer residence times in aquifers; increased residence time allows greater water rock interaction and typically leads to increased levels of salinity [14, 15].

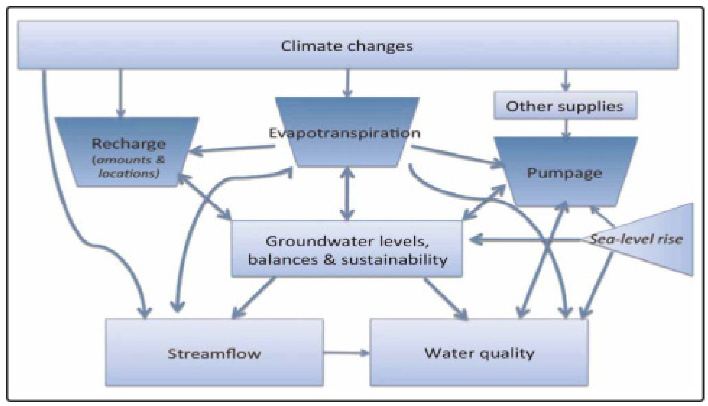

Figure 1: Conceptual diagram illustrating major relationships between climate factors and various aspects of the water cycle [8].

Because reduced recharge could lead to increased groundwater salinity, it might seem that increased recharge would necessarily yield higher-quality groundwater. However, increased recharge can also result in increased salinity, albeit for different reasons. Increased recharge could cause increased flushing of salts from the unsaturated zone which in turn might increase groundwater salinity [12]. Of particular concern in this regard is nitrate, the consumption of which can cause methemoglobinemia. While nitrate is susceptible to increased leaching in many different climate zones nitrate leaching may prove to be especially problematic in arid areas where large reservoirs of nitrate accumulate in unsaturated zones by natural processes [12, 16].

Declines in groundwater storage (and the associated falling groundwater levels) resulting from reductions in recharge and/ or increases in pump age would be expected to result in smaller groundwater contributions to streamflow. A common impact of decreased baseflow in streams is increased streamwater temperature, because groundwater in many settings is cooler than water than has traveled over land to (and through) stream channels.Warmer stream temperatures may have significant impacts on species viability [17, 18]. In contrast, where recharge increases, greater groundwater contributions to streams are unlikely to cause temperature stress among existing biota. Streamwater chemical quality may also be changed if groundwater contributions to streams change in response to climate, although the overall effect will depend on the relative qualities of groundwater and stream water.

Globally, sea levels have risen by about 22 cm in the 20th century. Sea levels are expected to continue to rise, probably increasingly rapidly, in response to global warming, as ocean waters warm and expand and major icesheets melt into the seas [19].In coastal areas, these higher sea levels are likely to increase the potential for intrusion of ocean water into freshwater aquifers, thus threatening to increase groundwater salinity [20, 21].Sea-level rise, spatial and temporal variability in precipitation patterns and evapotranspiration, which affect recharge and increase groundwater abstraction, will result to increased saline-water intrusion into fresh groundwater [4, 20, 22-24]. The increasing sea-level rise will lead to increased groundwater flow towards low-lying inlands areas and decrease groundwater flow towards the sea [24, 25].

Increased recharge in coastal aquifers will lead to increased groundwater flow towards both low-lying inland areas and the sea. Thus, brackish and saline-water in low-lying areas will be pushed back and saline-water intrusion may increase in the low lying areas; this will increase salinization and degrade groundwater quality in most low-lying areas and hence effect its ecology and drainage systems [25]. Conversely, changes in groundwater quantity and quality also influence ocean chemistry, especially near coasts [26]. Although the volume of groundwater discharge to the oceans is only about 6% of streamflow discharge into the oceans, groundwater's annual salt input to the oceans is about 30% of the amount contributed by streamflow [26]. Changes in the quality of groundwater could thus alter near-coast ocean chemistry and nutrient cycling [26]. Changes in sea level and groundwater levels could change the volume of groundwater discharging to the oceans by altering the magnitude and/or direction of the hydraulic gradient between aquifers and oceans.

In areas where rainfall intensity is expected to increase, pollutants (pesticides, organic matter and heavy metals) will be increasingly washed from soils to water bodies [5]. Where recharge to aquifers occurs via these surface water bodies, groundwater quality is likely to decline. Where recharge is projected to decrease, water quality may also decrease due to lower dilution and in some cases may also lead to intrusion of poorer quality water from neighboring aquifers [5, 7]. In areas where groundwater levels rise, waste stored underground in the unsaturated zone may become saturated and contaminate the groundwater resource.Over withdrawal of groundwater combined with increasing dry periods may lead to substantial decline in groundwater quality in many coastal aquifers [27].

Location of Nigeria and Spatial Distribution of Water

Nigeria lies within the tropics and is located on Longitudes 20 15'E and 140 45'E; Latitudes 40 10'N and 130 50'N with a land area of 923766 km2and population of about 170 million people. Climate is characterized by two ecological zones, the Humid South and the Dry North respectively, resulting from interplay of the two contrasting air masses SW Monsoon and NE Trade winds. Annual Rainfall decreases both in magnitude and duration with increasing latitude with over 2000mm p.a. in the south near the coast and below 500mm p.a. at the extreme north-east area. Average annual temperature is 230C to 320C.

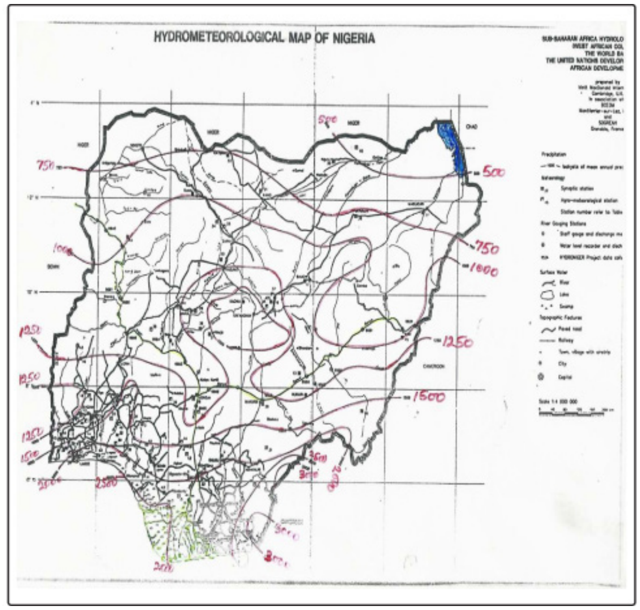

Figure 2: Hydrometeorological Map of Nigeria

Table 1: Potential water availability in units of 109cubic meter (Source: Water Resources Management and Policy FMW/EU, 2006)

	NW	NE	CW	CE	SW	SE	Total
Surface Water	22.40	8.20	32.60	83.00	35.40	85.79	267.30
Ground water	4.34	5.58	8.18	11.38	9.02	13.43	51.53

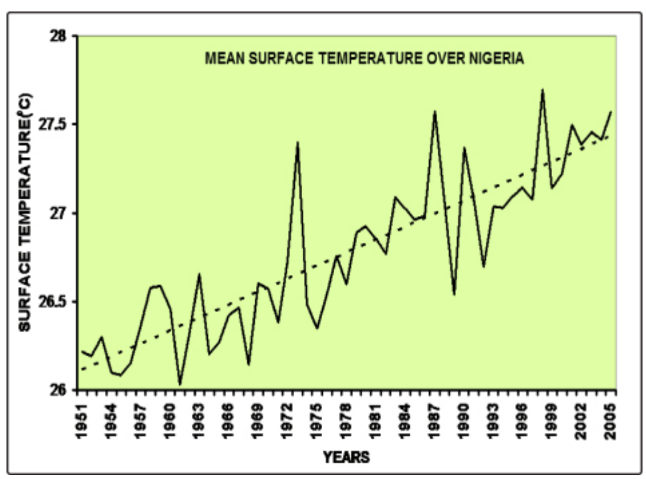

Figure 3: Climatic Trends in Nigeria (temperature) (Source)[28].

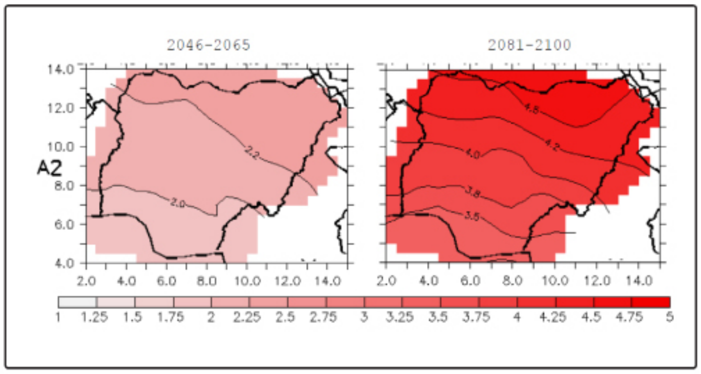

Figure 4: Projected Increases in Maximum Daily Temperature over Nigeria (0C relative to the present day climate) (Source) [28].

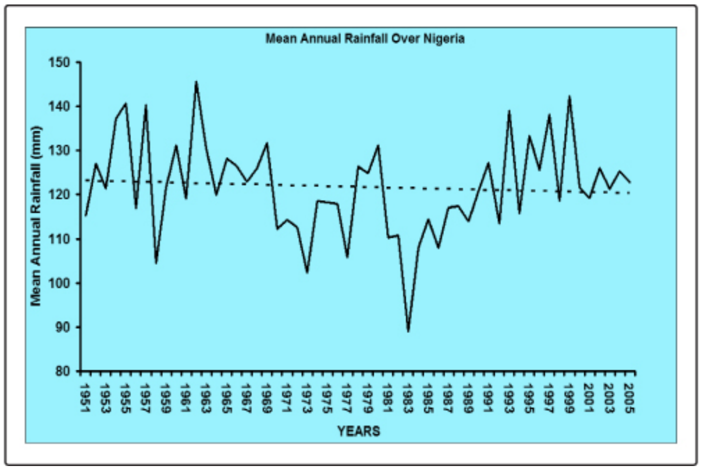

Figure 5: Recent Climatic Situation in Nigeria (rainfall) (Source) [28].

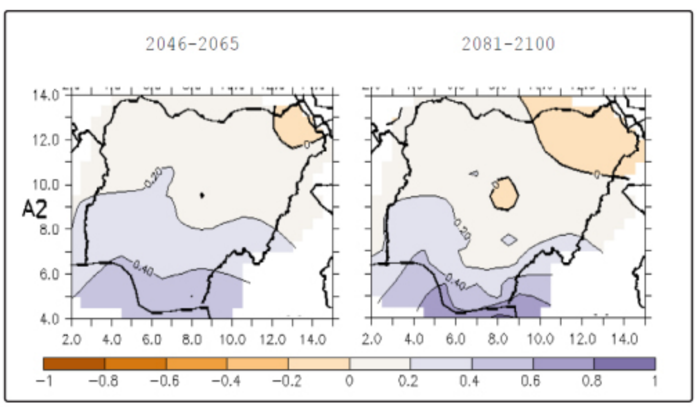

Figure 6: Projected Changes in Average Daily Rainfall over Nigeria (mm/day relative to the present day climate. (Source) [28].

Vulnerability of Nigeria's Water Sector to Climate Change

(i). Alter the hydro-climatological systems of the different ecological zones in the country, with their consequences on the availability of water resources (eg. Lake Chad).

(ii). May increase our dependency on groundwater resources in some areas of reduced rainfall.

(iii). Climate change-induced reduced river flow will reduce hydropower reservoir storage, further curtailing our capacity for clean hydro-energy production.

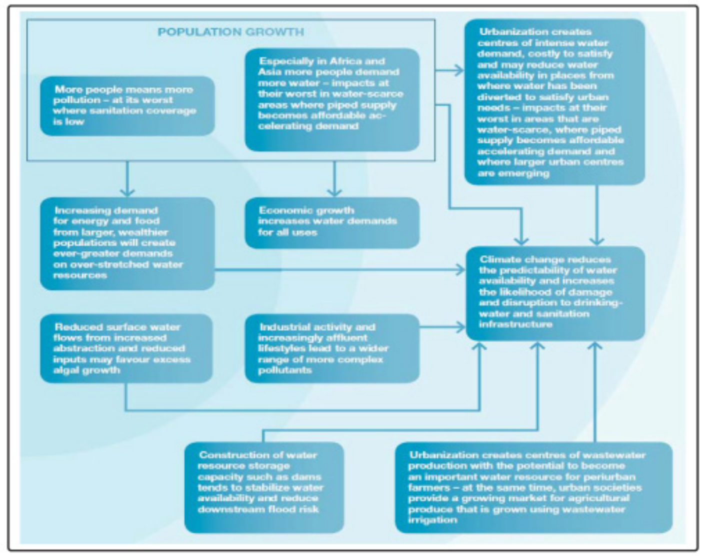

Figure 7: Impacts of climate change in a context of multiple challenges water (Source) [5].

Nigeria is more vulnerable to the impacts of climate change because of its size and population among others. Impact of climate change in Nigeria will include shifts in the boundaries of major ecological zones, alteration in animal and plant composition, greater soil erosion and flooding in areas of higher rainfall, heightened drought and desertification in the northern regions, accelerated sea level rise and salt water intrusion along the coastal belt[1]. Consequently, various sectoral activities will be affected.Agriculture remains a major source of food and industrial raw material; and a means of earning foreign exchange. It employs close to 70 per cent of the Nigerian population.

1. Agricultural practice in the country is dominantly rain-fed and therefore particularly vulnerable to the impacts of climate change. Similarly, livestock production, which involves herding of cattle, goats and sheep raised principally in the northern states, is heavily dependent on rainfall and thereby equally vulnerable.
2. Climate change is real. It is going to affect everyone, but the worst hit will be the hundreds of millions of small-scale farmers, fishers and forest-dependent people who are even now, already vulnerable to food insecurity scenario.
3. Government is hereby kindly requested to climate proof the Water and Agriculture sector to forestall livelihoodand insecurity as an urgent priority
4. Offshore and onshore areas, as well as estuaries and lagoons, support artisanal and industrial fisheries accounting for more than 75% of fishery landings in the country. Apart from food supply, fisheries are very important for labor employment. Significant rise in marine and freshwater temperature consequent on climate change will impact adversely on fisheries just as saltwater intrusion would seriously damage inland fisheries in rivers, lakes and aquaculture installations.
5. Although the country is well endowed with water resources,

the demand has always continued to outstrip the supply. It is been projected that in the year 2030, the demand will rise to 34,563 million liters per day while supply will only be 16,997 million liters per day (NFNC-UNFCCC, 2003)

6. While one is tempted to assume that enhanced rainfall that may be associated with climate change may naturally benefit water resources sector, reduced rainfall can spell disaster in terms of insufficient rainfall harvest, low groundwater recharge rate, low volume of water in the rivers to the extent of even impair hydroelectricity generation.
7. The figures quoted above are those indicated in the Nigeria First National Communication under the United Nations Framework Convention on Climate Change submitted in November 2003.
8. With respect to energy, it is a two-way vulnerability for Nigeria. First, Nigeria is vulnerable to the adverse impacts of climate change. In this regard, the most important significant impact of climate change on energy will include higher electricity demand for heating, cooling and pumping water; reduced availability of hydroelectricity and fuel-wood; and extensive damage to petrochemical industrial installations presently concentrated in the coastal belt from sea-level rise.
9. Inadequate supply of power is already forcing the closures of many industries thereby rendering several Nigerians jobless. This, in turn, will aggravate our macroeconomic problem of unemployment and accelerating poverty.

Table 2: Examples of adaptation technologies for water supplies Source: [29].

Use Category		Supply side	Demand side
Muncipal or Domestic		• Increase Reservoir capacity. • Desalinate. • Make inter-basin transfers.	• Use "grey" water. • Reduce Leakage. • Use non-water-based sanitation. • Enforce water standards.
Industrial Cooling		• Use Lower-grade water	• Increase efficiency and recycling.
Hydropower		• Increase reservoir capacity	• Increase turbine efficiency
Navigation		• Build weirs and locks	• Atler ship size and frequency of sailing
Pollution Control		• Enhance treatment works. • Protect and restore wetlands.	• Reduce effluent volumes. • promote alternative to chemicals
Flood management		• Build Reservoir and levees. • protect and restore wetlands.	• Improve flood warnings. • Curb floodplain development.
Agriculture	Rain-fed	• Improve soil Conservation	• Use drought-tolerant crops
	irrigated	• Change tilling practices. • Harvest rainwater	• Increase irrigation efficiency. • Change irrigation water pricing

Efforts/Interventions in the Water Sector Aimed at Ameliorating Climate Change Impact

Various efforts have been made in the water sector.highlighted the following:[1, 30].

1. The Nigeria Hydrological Services Agency (NIHSA), a parastatal under the Federal Ministry of Water Resources is carrying out Groundwater Level Monitoring activities in some parts of the country in order to quantify the impacts of climate change on groundwater.
2. NIHSA is also implementing a number of IAEA-assisted projects using Isotope Hydrology Techniques which are applied as an integral part of investigations of water systems and offer good support for climate change studies.
3. The Federal Ministry of Water Resources implements policies and programmes aimed at sustainable development and management of water resources in Nigeria with a view to providing adequate water for domestic, irrigation, industrial and hydropower generation.
4. Efforts are also being made towards ameliorating the environmental impacts of declining groundwater availability and climate change.
5. A good number of Multi-Purpose Dams have been constructed mostly in the semi-arid parts of the country which reservoirs assist in improving groundwater recharge in respective areas.
6. The Nigeria Hydrological Services Agency (NIHSA), a parastatal under the Federal Ministry of Water Resources is carrying out Groundwater Level Monitoring activities in some parts of the country in order to quantify the impacts of climate change on groundwater.
7. NIHSA is also implementing a number of IAEA-assisted projects using Isotope Hydrology Techniques which are applied as an integral part of investigations of water systems and offer good support for climate change studies.
8. Isotope Hydrology Techniques provide quick and reliable information on hydraulic inter-connections between aquifers as well as water bodies; the origin of groundwater; age (resident time), flow direction, recharge and discharge rates, existence of palaeowaters, vulnerability to pollution, contaminant transport dynamics, among others.
9. Artificial Recharge technique like infiltration galleries is also being applied in some parts of Borno State by the Chad Basin Development Authority (CBDA) to boost recharge of the aquifers.
10. The Nigeria Metrological Services Agency (NIMET) possesses a number of real time data capturing devices, forecasting hardwares and softwares for study of the major climate parameters: rainfall, temperature and relative humidity, at different locations in the country. Their Seasonal Rainfall Predictions (SRP) in the first quarter of every year provide information on timing, intensity and duration of rainfall events are useful to many sectors. 5. NIHSA presents Annual Flood Outlook (AFO) thereafter, based on NIMET predictions.
11. There is the Great Green Wall Project aimed at afforestation of the frontline States in the drought prone areas (latitude 110N and above) in the northern parts of the country with a view to checking desert encroachment.
12. The Nigeria Erosion and Watershed Management Project (NEWMAP) have the objective of checking gully and sheet erosion menace in some parts of the country. Stabilization of the soil would facilitate groundwater recharge.

13. Many groundwater systems in Nigeria (including surface waters) are trans-boundary and are also vulnerable to pollution and over-exploitation. The Federal Government participates in multi-lateral consultation with relevant countries for sustainable management of shared aquifer systems and basins under the auspices of multi-lateral organizations like Lake Chad Basin Commission (LCBC), Niger Basin Authority (NBA), International Atomic Energy Agency (IAEA) and Observatory of Sahara and Sahel (OSS).
14. Some national projects are also being implemented through funding support from Development Partners like UNDP, GEF, IMF, ADB, etc.

Decision-Making Options, Policy and Legal Framework for Water Management

Water stress in Nigeria is becoming a significant challenge for many sectors. The situation is made worse where poor management practices collide with declining availability occasioned by climate change and climate variability[1]. Factors such as increasing rates of abstraction as a consequence of growing water demand, pollution from agro-chemicals and other contaminants, inefficient and inadequate water storage facilities, failure to exploit recycling technologies and implement water-use efficiency measures all compound the problem. Institutional arrangements are often fragmented, entities have overlapping responsibilities, there is no clear coordination mechanism, and in many cases institutions are self-regulating. Clearly there is no single prescription for achieving efficient water management, as approaches will of necessity vary from place to place and must be appropriate to local circumstances. However, there is an emerging consensus from the literature that there are certain critical policy elements that ought to be considered in the design of an effective strategy. These include but are not limited to the following:

1. Demand-side management, which may include incentives (and sanctions, whereappropriate) for conservation and use optimization;
2. Comprehensive assessment of existing and future demands, by sector
3. Assessment, repair and replacement of aging infrastructure;
4. Forecasting and risk assessment of extreme events, i.e. droughts and floods, whichimpact communities and sectors in different ways, and hence require differentmanagement approaches;
5. Monitoring for quality assurance and control;
6. Implementation of integrated watershed management practices, which can play animportant role in the rationalization of resource use and allocation and protection ofsources (both surface and groundwater);
7. Rationalization and updating of legislation, paying attention to effective enforcement.

Finally, no policy, however well-intentioned and conceived, will achieve the desired outcome if stakeholder education is not an institutionalized element of the implementation process. Thismay require strategies aimed at effecting behavioural and attitudinal change, dispelling falsenotions (e.g. that the resource is *'limitless'*) and enhancing public awareness and understandingof the 'true' cost of providing water, arguably one of the most undervalued natural resources.

Education, Training and Research & Development

Development of mitigation and adaptation strategies to protect water resources in Nigeria is required if national socio-economic goals are to be attained. However, in recognition of the limited financial resources such strategies must be designed and implemented in a cost effectivemanner. An important impediment is the lack of skilled water resources professional. The technical expertise required to mitigate existing water resources problems and to develop sustainable water resources programmes generally is not available in Nigeria. Furthermore, in many water resources agencies, important decisions related to water resourcesmanagement are made by individuals with minimal formal training in the important core scientificand engineering disciplines. As a result, the scientific and engineering studies needed are ofteninadequate or poorly done. This inevitably results in significant liabilities given the emergingthreats posed by:

1. changing land use patterns,
2. increasing demands for water from multiplestakeholders including agricultural, industrial, and recreational users, and
3. Emerging pollutionthreats from pharmaceutical products and pathogens, all likely to be acerbated by climatechange. Groundwater is likely to be most severely affected, with the groundwater table dropping due to reduced recharge. Strict groundwater management systems should be put in place with early warning mechanisms to report depleted groundwater reserves. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential under projected climate conditions.

Recommendationsfor Climate Resilient Water Resources Management for Nigeria's development

The followingare recommended:
1. Water use in the country should be made to meet nature's need and be consistent with sustaining resilient and functioning ecological systems under changing climate;
2. Firm steps should be taken immediately at federal, state and local government levels to value water appropriately, and promote its wise use and conservation by establishing appropriate water conservation guidelines and practices for an IWRM.
3. Early warning systems should be established and/or strengthened to harmonize national flood protection strategies.
4. Governments at all levels should design and sustain water supply infrastructure based on ecological principles and adaptation to a changing climate.
5. There must be comprehensive and continuous monitoring of the surface and ground water resources of the country to provide up-to-date information required to manage water effectively in a changing climate.
6. Water must be recognized as a human rightintegral to security and health.
7. Holistic approaches to managing watersheds through collaborative governanceshould be supported.
8. The technical knowledge base on the impacts of climate change on water will have to be enhanced in order to be able to foresee and interpret more precisely the impacts of climate change on the components of the water cycle in the future, as well as outlining the actions to be carried out to cope with these changes.
9. Financial arrangements for state and urban water boards and

basin authorities must be diversified (including using the public private partnership approach) in order to allow greater flexibility when facing the onset of unexpected occurrences, and so as to be able to relieve the current dependency on funds from the federal and state governments.
10. Better use must be made of existing science as well as investing in the research and development of new technologies to prepare a response that is more adapted to the challenge of climate change in the water sector.
11. The importance of groundwater must be recognized and governments at all levels must understand and value its role in creating a sustainable and resilient future for the country.
12. Coordinated long-term national strategies for sustainably managing water in the face of climate change should be valued and developed.
13. The country should advance policy reform (including sustainable implementation of the new policy) and champion a new Nigerian Water ethic in the face of changing climate.
14. Capacities of national and state water management institutions should be strengthened for climate resilience approach to water resources management
15. The management practices of state and urban water boards and basin authorities will have to be adjusted to take into account the new demands imposed by the changing climate, as part of a more holistic vision of the role of water in sustainable development processes.
16. A climate change awareness Programme should be developed that could be rolled out at local level to provide local government officials with the necessary tools to engage with this issue and implement the strategies that are identified.

The Way Forward

In 2017, leaders of over 189 nations agreed on the Global Declaration that outlined the fundamental goals, Climate change challenges and the achievement of the Sustainable Development Goals (SDGs) as related to national poverty eradication and sustainable development objectives, before 2030. Nigeria was proudly represented as leader in Africa.Unless concrete and urgent steps are undertaken to reduce vulnerability and enhance adaptive capacity of poor people, and these actions integrated in national strategies for poverty eradication and sustainable transformation development, it may be difficult to meet some SDGs by 2030.

The demand for water in Nigeria is expected to increase due to population increase, increased agricultural and industrial productivity, and the growth of recreational and tourism industries. Unfortunately, future climate change and climate variability will likely have negative impacts on the quality and quantity of water available from natural sources. Meeting future water demand given the threats to water resources posed by climate change will require significant improvements to water resources management. This will require significant investments to support

1. Capacity building initiatives using regional and national institutions,
2. Development of legal and policy frameworks to facilitate improved management frameworks,
3. Increased environmental monitoring and resources assessments, and
4. Increased data collection, analysis, and storage.

Recommendations

Climate resilient water resources management for sustainable development in Nigeria will also involve:

1. shifting from blue water use to green water use;
2. shifting towards green growth, green economy and green water supported by green societies;
3. shifting from short term water resources planning to more strategic and long-term planning;
4. strengthening governance of water resources;
5. developing new systems without repeating the mistake done in the past;
6. putting in place integrated strategies to support systemic changes in the sector for integrated, complementary and mutually reinforcing water development pathways; and
7. Linking policymakers to water end-users.

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