Volume 8, Number 1 July 2015

Geo-Studies Forum

An International Journal of Environmental & Policy Issues

A Publication of the Department of Geopgraphy
and Environmental Management
University of Ilorin

TABLE OF CONTENTS

Scanned with CamScanner

CLIMATE CHANGE AND CHALLENGES OF FRESH WATER RESOURCES TO SUSTAINABLE LIVELIHOOD IN SOME STATES IN NORTHERN NIGERIA

Abdulkadir A[1]. Abdullahi J[2]., Abubakar A.S[1]. Saidu S[1]., Sakoma J. K[2]. and S. Y. Muhammad[1]

[1]*Department of Geography, Federal University of Technology, Minna, NIGERIA*
[2]*Department of Geography, Ahmadu Bello University, PMB 1069, Zaria, NIGERIA*
[1]*Department of Geography, Niger State College of Education, Minna, NIGERIA*
Correspondence: (+234-805-302-0742; abuzaishatu@futminna.edu.ng)

Abstract

Nigeria is highly vulnerable to climate change like any other developing nation. This, coupled with increasing population and urbanization is exerting pressure on the fresh water resource that is basic for most human needs. Hydrological Growing Season (HGS) and potential evapotranspiration were derived and analysed to depict moisture stress. In addition, questionnaires were administered to determine available water sources used, access, distribution and members of the family that source for water. The results depict decline in increased potential evapotranspiration and decreased hydrological growing season between 1950 -1978 and 1980 - 2006, an indication of high water stress signifying the impact of climate change. In addition, the result reveals that despite the fact the country has abundant water resource (surface and underground), its availability and access is still a major challenge as indicated in available sources of water used and the number of hour's women and children spend searching for water per day. Therefore, management and sustainability of water resources should focus on scientific understanding of the challenges to the sustainability of the resource and using the available technology to identify and monitor its depletion, degradation and spatio-temporal distribution.

Key words: Climate change, water resources, water resources, aridity and sustainable management

Introduction

Climate change and variability have continued to aggravate the intensity and frequency of extreme weather events, flooding, storms and droughts as evident in weather-related disasters have become more frequent in recent times. Climate change is likely to have negative impacts on efforts to achieve Nigeria's development objectives, including the targets set out in Nigeria Vision 20:2020 and the Millennium Development Goals (BNRCC, 2011). Nigeria is highly vulnerable to climate change like any other developing nation, this coupled with increasing population and urbanization is exerting pressure on fresh water resource that is basic for most human livelihood. The changes in climate are producing devastating and destructive weather events that are impacting negatively on both the living and non-living things (Odeku, 2013). Thus, making fresh water resource to be inadequate in both quantity and quality as it is a limiting factor in poverty alleviation, healthy livelihood, productivity and socio-economic development. Darren (2011), states that water is the primary medium through which people in Africa will experience climate change impacts.

Thus, climate change and human activities have been aggravating degradation and depletion of the freshwater resources and ecosystems across the country thereby endangering the natural environment and human livelihood. More importantly, the risk of the impact of climate change is higher in agricultural sector which is the main source of survival and livelihoods of the rural population in developing countries (McMichael *et al.*, 2007). Degradation of fresh water is a common phenomenon in recent times particularly in northern Nigeria, as most perennial rivers are now seasonal with their valleys filled with sand instead of water during the dry season. This generally, affects basic socio-economic sectors and often results in chronic poverty and hunger particularly, the vulnerable poor in the rural areas who rely on fresh water resource for their livelihood.

Globally, water abundance is not the problem; the problem however, is the availability of water in the right place at the right time in the right form. Open water cover 74% of our planet surface, more than 97% of the total volume is in the ocean, most of this is saline and unfit for direct human consumption. Ice caps and glaciers accounts for about 2% (2.2%) and about 0.60% exist as ground water, however only about (0.01%) of this is held in soil and rocks near the earth surface. About 0.02% of the total volume is in rivers and lakes. Thus, the amount of water for which all the people, plant and animals on the earth compete for is less than 0.05 of the earth's water. Also, water levels are low and are getting lower, rivers have retreated from their banks and lakes are shrinking, escalating aridity. **Barnett and Adger (2007) reported that** climate change is increasingly undermining human security in the present day and will increasingly do so in the future by reducing access to, and the quality of natural resources that are important to sustain livelihoods. However, this is significant for mankind despite the fact that it exist in small percentage. Water is one of the basic needs of human life and globally it is estimated that nearly one billion people in the world are without clean drinking water. Water scarcity has been argued to be one of the fastest growing pandemics of the world currently (Kelechi 2012).

In Nigeria, climate change, increased human activities and changes in lifestyles are putting increased pressure on the available water resources which are imperative to both human and ecosystems. People depend on a reliable, clean water supply for drinking and other domestic activities, for health, livelihood and its sustainability is threatened by adverse human activities and overexploitation. Over 40% of the earth's land surface are dry lands that are home to approximately 2.5 billion people (Frase *et al.*, 2011). Most socio-economic sector depend fundamentally on availability of water; agriculture, energy production, navigation, recreation and manufacturing. Undoubtedly, climate change is a threat to all aspects of human endeavours and its impact seems to be creating huge gap towards the attainment of regional and international developmental goals of many developmental programmes such as the Millennium Development Goals (MDG's) (Chambwera and Stage, 2010). In Nigeria, water shortage is a problem of most communities; urban or rural as well, increase in runoff is escalating flood across the country. Many areas across the country, especially the Northern parts are currently faced with water scarcity problem thus, escalating southward migration as apparent in the farming settlements springing up across the middle-belt of Nigeria. Respondent with such settlement in Wuya Kede Niger State confirmed that they migrated from northwest to new settlement because of the availability of fresh water resource for agriculture and fishing. There is increasing concern over the consequences of global warming for the food security and livelihoods (**Marie-Caroline *et al.*, 2010**). The sustainability of available water in this region is already threatened by climate change and increase population. Hence, the need to use historical data to depict and illustrate freshwater degradation as well as, the challenges for its sustainability to guide policy formation on freshwater monitoring, exploitation and development of a realistic and sustainable water resource utilization scheme.

Materials and Methods

Monthly rainfall, maximum and minimum temperature data for four selected globally reference meteorological stations in Northern Nigeria; Katsina, Zaria and Maiduguri (1950 -2006) and Minna 1970-2006 were sourced from Environmental Management Programme, Department of Geography, Federal University of Technology, Minna. **These were used to illustrate and depict the evidence of climate change and its challenges for sustainability of freshwater resources in Northern Nigeria using potential evapotranspiration and hydrological growing season values (1951-2006).** In addition, two thousand questionnaires were administered and returned by student during local studies on water resource availability and challenges in some wards in Minna metropolis (Maikunkele, Chanchaga, Kpakungu and Sabon–gari). **The respondents view on** available water sources used, access and distribution as well members of the family that source for family water were extracted and analysed using descriptive statistics to depicts the challenges of access to safe and clean water.

Potential Evapotranspiration (PET) was quantified to indicate the expected soil moisture loss from the earth to the atmosphere through evaporation water and transpiration from plants. Hargreaves (1985) model was adopted for the computation of evapotranspiration; this uses mean monthly temperature (Tmean), mean monthly temperature range (TD) and extraterrestrial radiation (R_a - radiation on top of atmosphere) to calculate PET, as per the equation below:

$PET = 0.0023\ R_a\ (Tmean + 17.8)\ TD^{0.5}\ (MJ\,m^{-2}\,day^{-1})$1.0

The extreme northern states (Katsina and Maiduguri) fall between zones of windy locations with large ΔT (large temperature range), while sub-humid Zaria and Minna fall within light wind conditions combined with low to moderate values of ΔT, suggesting that Hargreaves formula may give adequate estimation of evapotransipiration in the zone. The mean monthly temperature (Tmean), mean monthly temperature range (TD) required for computation are readily available.

Furthermore, this requires the calculation of estimated extraterrestrial radiation (R_a). This procedure assumes a planar surface that receives equal solar radiation at every site on the plane (Allen *et al.*, 1998). Following Hargreaves (1985) method, R_a is calculated theoretically as a function of latitude and the month of the year;

$$R_a = \frac{118}{\pi}\left\{\cos^{-1}(-\tan\delta\tan\phi)\sin\phi\sin\delta + \cos\phi\cos\delta\sin\left[\cos^{-1}(-\tan\delta\tan\phi)\right]\right\} MJm^{-2}day^{-1} \quad 1.1$$

δ is the Calculated declination; $\delta = 0.4102\sin\left(\frac{2\pi}{365}(J-80)\right)$ 1. 2

J= Calculated day of the year, Jan= 15, Feb=45......Dec=345

Φ is the Latitude Converted to radians;

$$\Phi = \left(latitude * \frac{\pi}{180}\right) \quad 1.3$$

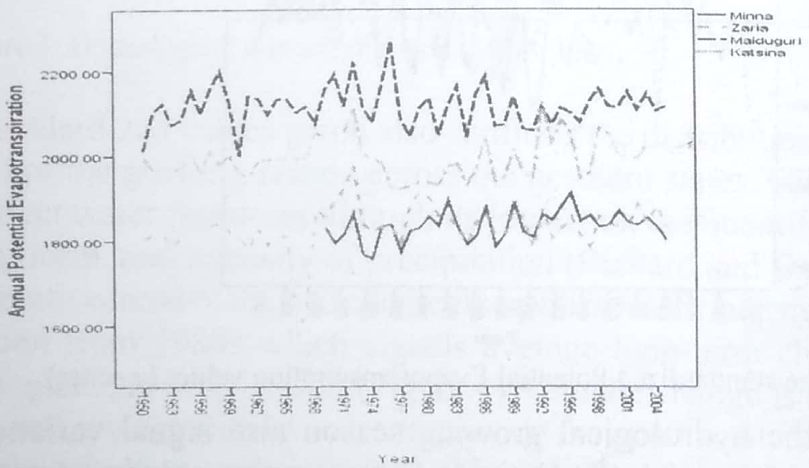
R_a is calculated in $MJ\ m^{-2}\ day^{-1}$. this was changed to mm day^{-1} according to the method of Allen *et al.* (1998) 1 $MJ\ m^{-2}\ day^{-1}$ = 0.408mm day^{-1}.

Thus $PET = 0.408 * 0.0023 \cdot R_a \cdot (Tmean + 17.8) \cdot TD^{0.5}$ *(mm/d)* 1.4 similar approach was adapted by (Vicente -Serrano, *et al.* 2007).

Equation 1.4 was used to determine potential evapotranspiration in the region. **Ravazzani, et al. (2014)**, shows that a simple temperature-based approach for computing the evapotraspiration is sufficiently accurate for performing hydrological impact investigations of climate change. Furthermore, Intra-Seasional Rainfall Monitoring Index (IRMI) (Usman and Abdulkadir, 2012) was used to determine Real Monsooon Onset (RMO), cessation and HGS for four states (Katsina, Maiduguri, Minna and Zaria). Descriptive analysis was used to calculate standardized values (z scores); these were plotted graphically to visualizee and illustrate the effect of climate change on freshwater resources. In addition, the extracted responses were summarized using descriptive statistics and plotted graphically.

Result and Discussion

The result depicts the spatio-temporal variability that characterized moisture quality and its effects on the availability of freshwater resource in some states in Northern Nigeria. **The derived potential evapotransporation of the four states varies over space (Minna to Maiduguri) and time (1950-2006). It's revealed increased variability, positive trend as well as changed pattern of potential evapotranspiration from 1980s which by implication ins the effect of climate change with its impact.**



The increase in annual total evapotranspiration and its spatio-temporal variability poses major challenge for sustainability of freshwater resources. Accessing the future effects of climate change on water availability requires an understanding of how precipitation and evapotranspiration rates will respond to changes in atmospheric forcing **(Ravazzani et at., 2014).** Consequently, plotting of the calculated standardized values (z score) confirms the positive trend in total annual potential evapotranspiration as 1970 and was gradually above the mean beyond 1970s. Furthermore, the values were characterized by positive variability after 1980s such that from 1995-2006 the entire standardized values were characterized by positive variability (Figure 1). This is an indication of average long-term changes in the potential evapotranspiration patterns across zones and these have negative impact on availability and distribution of freshwater resource. Climate change has introduced large uncertainties into the estimation of future water resources **(Kundzewicz et at., 2008)**

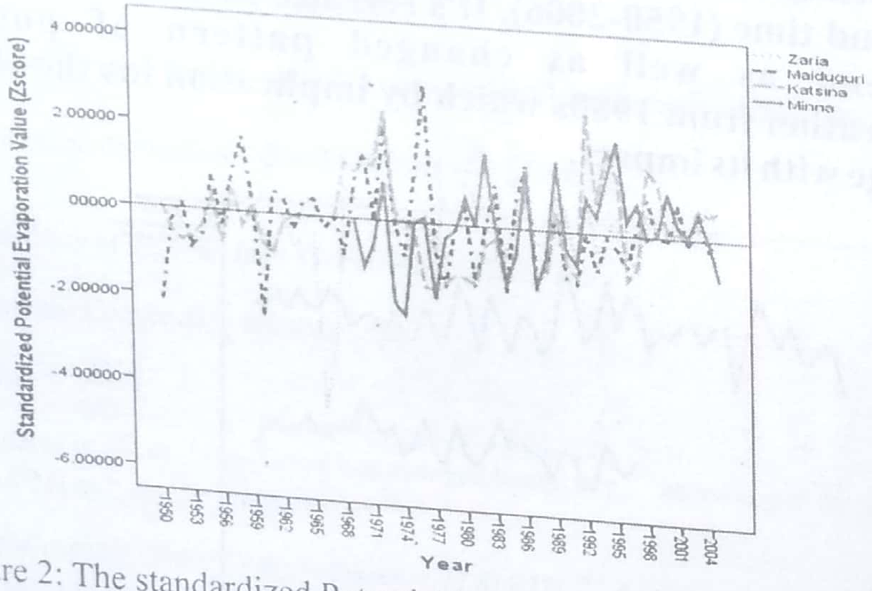


Figure 2: The standardized Potential Evapotranspiration values (z score)

Similarly, the hydrological growing season also signal variation in the spatio-temporal variability typical of the growing season across the four states. As expected Minna and Zaria (lower latitudes) record longer hydrological growing season while the intersection that characterized the hydrological pattern of Katsina and Maiduguri shows that the growing seasons in the two states are similar, that is, short growing season (Figure 3). Furthermore, the hydrological growing season in the states are characterized by temporal (1950-2006) variability besides, the graph indicates a downward trend from 1980s particularly across the four states but less in Minna, gradual across Zaria than in Katsina and Maiduguri. **Conway** *et al.* (2011) reported that rainfall behaviour in Ethiopia shows no marked emergent changes and future climate projections show continued warming but very mixed patterns of rainfall change.

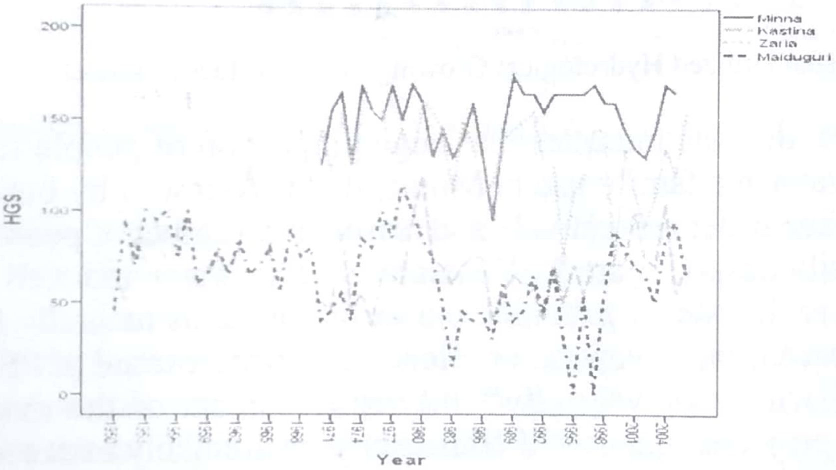


Figure 3: Hydrological Growing Season (1951- 2006)

The standardized values graph also confirms the distributional anomalies typical of the growing season across the northern states. Climate change will affect water resources through its impact on the quantity, variability, timing, form, and intensity of precipitation (Richard and Dannele 2008). The negative trend of the hydrological season is reaffirmed by the negative deviation from 1980s which signals average long-term changes in the hydrological growing season (Figure 4). Climate change is also likely to undermine the capacity of states to provide the opportunities and services that help people to sustain their livelihoods **(Barnett and Adger, 2007)**. This directly and indirectly is a threat to availability of freshwater resource and sustainability of rural livelihood in a region where over 70% depends on agriculture.

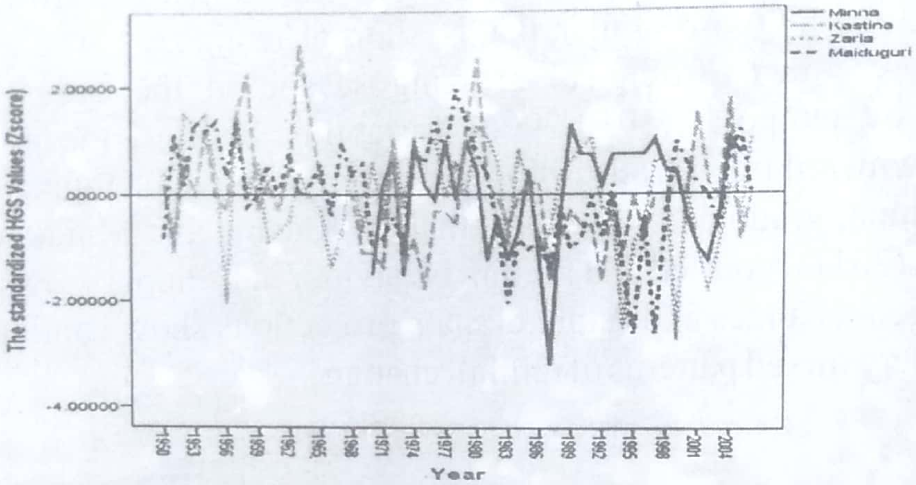


Figure 4: The standardized Hydrological Growing Season values (z score)

Questionnaire analysis indicates that large proportion of people rely on pipe-borne water for family use in Minna, this is followed by borehole, well and surface water respectively and reasonable number of people buy water on a daily basis (Figure 5). Generally, surface water and well water are naturally replenished by rainfall and surface water is naturally lost to the atmosphere through evaporation. Hence the positive trend of PET and shorter HGS will negatively affect the replenishment of the available sources. The projected impacts of climate change are likely to exacerbate the problems of water scarcity and equitable access unless appropriate adaptation strategies are adopted and resilience is built (Pierre, 2010).

Primarily, despite the fact that large proportion of the people depend on pipe-borne water, its availability is highly erratic as evident in the number that have access to water Every Day (ED), three times per week (3xW), once per week and those that cannot even predict or say specifically when water will be available for use (Figure 6). In most of the rest of the world water scarcity at a national scale has as much to do with the development of the demand as the availability of the supply (Frank, 2006). These have continued to force people to buy or spend valuable hours of the day searching for clean and safe water which according to respondents ranges between one to four hours on average per day. In addition, these force them to fetch water from any available source which could lead to outbreak of water-borne diseases like cholera.

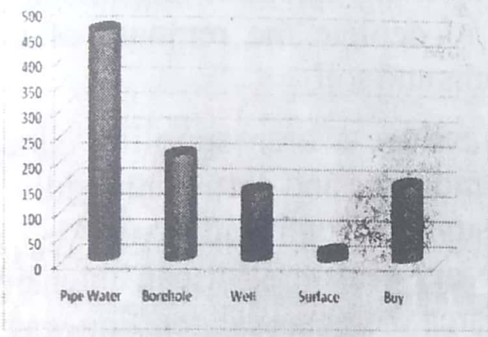


Figure 5: Sources of Water Available

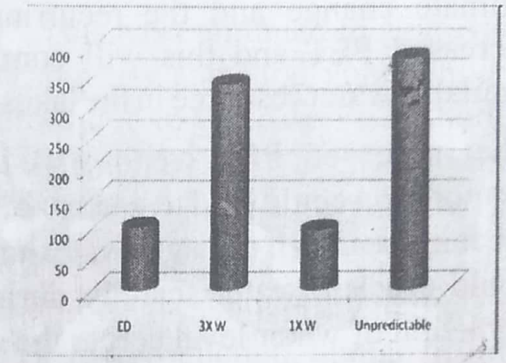


Figure 6; Availability of Pipe water

Similarly, 68% of the respondents indicate that children are the ones that search for water from any available source for family use; of this number 82% show that female children are the ones that search for water and according to the respondent only 12% of men get water for family use. It is known that poor households often suffer from poor water provision and this result in a significant loss of time and effort, especially for women (Caroline, 2002). These could deprive them of their leisure hours and for the worst, deny them from going to school and accomplishing the daily duty.

Challenges for Sustainable Livelihood

Changes in the availability and distribution of surface waters is apparent from the increase in potential evaporation and shorter hydrologic growing season across the study area resulting to shrinkage of dams, conversion of perennial rivers to seasonal and agricultural land-use changes. Onuoha (2008) concluded that impact of Lake Chad basin depletion is being felt by population who depend on the lake for their means of livelihood. The identified positive trend since 1980s in the inter-annual potential evapotranspiration (PET), which is the likely water lost to the atmosphere by the two processes of evaporation and transpiration is a threat to the sustainability of freshwater resource. Evaporation, which is an important factor in the water balance at the basin scale, is a critical variable in the determination of local available water resources (**Jin-liang** *et al.*, 2012). Climate change and the recurring drought in the zone significantly increased PET and this will continues to deplete the remnant of the available water resource in the lakes, streams and soil.

The increased PET trend will likely reduce water supplies, since evaporation could lead to decrease in soil moisture and particularly during the rainy season it can aggravate the intensity of drought and flood. Also, it could escalate water scarcity during the dry season as it can intensify depletion of water level across the study area thereby exaggerating water scarcity that is already typical in the region. Peter *et al.* (2008) concludes that adapting to these hazards and unknowns becomes increasingly urgent and important to ensure economic growth, peace and security in African nations and equally and important, locally sustainable socio-economic and environment development.

The analysis of hydrological growing season shows clear indication of the impact of climate change as indicated by the decline in the hydrologic growing season from 1980s. Abdulkadir *et al.* (2013) indicates rapid advancement of desert condition such that areas of deficient moisture zones grew significantly. These decline does not necessarily imply decline in the amount or intensity of rainfall, apparently escalating runoff into rivers and lakes, washing of sediment, nutrients, pollutants, trash and other materials into available water sources which aggravate sedimentation and shrinkage of surface water source. Furthermore, increased human activities, population trend and short HGS which could escalate flood can lead to contamination of available water resource that could results in water-borne illnesses such as diarrhoea.

Apparently, the positive trend of PET and decline in HGS will worsen the depletion of water resources and will threaten sustainable availability and access to fresh water resources. There is large consensus that in West

Africa one of the major climate change impact will be on rainfall, making it more variable and less reliable (Beno, 2012). This has become a major problem for most communities across northern Nigeria particularly, in the rural areas where it is posing serious threats on human livelihood, relevant socio-economic sectors like agriculture. This has continued to aggravate crop failure as well as intensify hunger, poverty and rural vulnerability. Thus, depletion of available water sources due to increase PET, shorter HGS and increased human activities will continue to intensify water scarcity and availability there escalating poverty, hunger, malnutrition, health risk, as well threaten human livelihoods across the states.

Generally, the impact of climate change on water availability and water quality can affect many sectors such as energy production, human health, agriculture, and ecosystems. Hence, there is need to develop a better understanding of the challenges, management and sustainability of fresh water resource across the zone. In recent times, reduction in the amount of energy generated and distributed across Nigeria is attributed to low gauge level of reservoirs. Similarly, climate change and variability could threaten agricultural production, livestock and most socio-economic activities in the country.

In Nigeria, like most developing countries, declining water quality and quantity has been a major problem in most cities; this is evident in the increasing number of people searching for this scarce resource that is unevenly distributed across the country. In addition, the scarcity have continued to force individuals and communities to rely on exploitation of ground water to meet their daily water needs as indicated in large proportion of the respondents who depend on boreholes, leading to its depletion particularly during the dry season. There is increasing evidence of environmental change impact on ecosystem processes and services, yet there is poor understanding of the relative contributions of land use and climate change to ecosystem services variations (Pan *et al.*, 2015). These generally have significant environmental and socio-economic impact across the country, hence, there is need to develop scientific and technical understanding of its challenges as well as the life-supporting capacity for sustainable livelihood.

As rightly observed by United Nations Environment Programme (UNEP), our planet is changing at a fast pace and without intervention our society will use up all the resources that we use to function. Climate change will escalate water scarcity; this and its mismanagement will lead to depletion of available source also, drought, famine and southward migration are apparent in recent times. Thus, it is fundamental to understand the challenges to the sustainability of freshwater resource; identify and monitor its depletion. degradation and ill-treatment. These will guide positive decision and policies on the sustainability of this crucial resource for enhanced human livelihood. Freshwater resources is perhaps our most precious resource that is essential to our daily life, thereby for us to derive its maximum benefit, we must recognize the need to identify it challenges, the carrying capacity and evolve sustainable practices for utilization.

Generally, with growing population and increasing impact of climate change sustainability of freshwater and attainment of food security is a great challenge. Nigeria's population census records showed that the country population was 30.42 million in 1953 which have continued to rise steady to 55.6, 88.9, and 140 million in 1963, 1991 and 2006 respectively. These signify an increase of over 450% by implication, is there similar increase in available water sources and the amount of freshwater proportional to the increasing population. Hence, this is a prime problem for the sustainability of water resource across the country which is intensified by climate change and its impact. In most cities particularly across the slum settlement, many women and young girls spend valuable hours to source water for the family and this prevent some of them from pursing their education at the right time and at the same time endanger family health. Thus, there is need to develop a realistic understanding of climate change and its impact on freshwater resource, sustainable water resource utilization schemes such that will enhance the availability and accessibility of clean and safe water for all as well increase population resilience to climate and sustainable livelihood.

Conclusion

The impact of climate change on freshwater resource as evident in increase variability and changed evapotranspiration and hydrologic growing season pattern coupled with increased population and ever-increasing demand for the declining resource constitute a major challenge for it sustainability. Gradual and drastic changes from normal will threaten sustainability of freshwater resources as well as human livelihood since higher potential evapotranspiration and shorter hydrological season will affect availability and access to the resource. Climate change is directly and indirectly a threat to availability of freshwater and distribution as indicated in spatio-temporal variability and change observed. Freshwater resource is perhaps the most precious resource that is essential to our daily life. Therefore, for us to derive its maximum benefit we must recognize the need to identify it challenges, the carrying capacity and evolve sustainable practices for utilization. Finally, there is need to develop a realistic and sustainable water resource utilization schemes such that will enhance availability, accessibility and sustainability of the resource through public awareness, positive decision and policies on sustainability of this crucial resource for enhanced human livelihood.

References

AbdulKadir A., Usman M.T. and A.H. Shaba (2013) Climate Change, Aridity Trend and Agricultural Sustainability of the Sudano-sahelian Belt of Nigeria. International journal of development and sustainability (IJDS), (Special Issue: Development and Sustainability in Africa – Part 1) Vol.2 No.2 Pages 1436 -1456

Allen, R.G.; Pereira, L.S.; Raes, D. & Smith, M. (1998). Crop evapotranspiration – Guidelines for computing crop water requirements. *FAO Irrigation and Drainage Paper*, No. 56, FAO, Rome

Barnett J. and Adger W.N. (2007) Climate change, human security and violent conflict. *Political Geography*, Vol.26, Issue 6. Pages 639–655

Jin-liang R., Qiong-fang L., mei-xiu Y. and Hao-yang L. (2012) Variation trends of meteorological variables and their impacts on potential evaporation in Hailar region. *Water Science and Engineering*, Vol 5 (2) pp. 137–144. Kelechi D. Ibe - Lamberts (2012) The relationship between water scarcity awareness by Transnational Nigerians and its effect on the willingness to contribute to water scarcity relief efforts in Nigeria. Published Master Thesis www.ideals.illinois.edu. (Accessed 23/04/2015)

Kundzewicz Z.W., Mata l. J., Arnell N. W., Döll P., Jimenez B., Miller K., Oki T., Şen Z. and Shiklomanov I. (2008) The implications of projected climate change for freshwater resources and their management, Hydrological Sciences Journal, 53:1, 3-10

Marie-Caroline B., Edward H. A., Ashley S.H., and Nicholas K.D. (2010) Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, Vol.34, Issue 3 Pages 375–383

McMichael A.J., Powles J.W., Butler C.D., Uauy R. (2007) Food, livestock production, energy, climate change, and health. *The Lancet*, 370(9594):1253–1263.

Odeku K.O. (2013) Shifting towards Sustainable Events by Using Alternative Energy and Energy-Efficient Devices. *Mediterranean Journal of Social Sciences*, 4(14):835-845.

Onuoha F.C. (2008) Environmental degradation, livelihood and conflicts : a focus on the implications of the diminishing water resources of Lake Chad for North-Eastern Nigeria. African Journal on Conflict Resolution, Vol.8 Issue.2 pp 35-61

Pan T., Wu S., Liu Y. (2015) Relative Contributions of Land Use and Climate Change to Water Supply Variations over Yellow River Source Area in Tibetan Plateau during the Past Three Decades. PLoS ONE 10(4): e0123793. doi: 10.1371/journal.pone.0123793

Peter B., Anthony J. and David S. (2008) The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States. U.S. Climate Change Science Program Synthesis and Assessment Product 4. http://www.usda.gov/oce/climate_change/SAP4_3/CCSPFinalRep

Benoıt S. (2012) Present and future climate change in the semi-arid region of West Africa: a crucial input for practical adaptation in agriculture. *ATMOSPHERIC SCIENCE LETTERS Atmos. Sci. Let.* (wileyonlinelibrary.com) DOI: 10.1002/asl.368. (Accessed 11th Feb. 2015)

Building Nigeria's Response to Climate Change (BNRCC) project (2011) Climate Change Adaptation Strategy Technical Reports – Nigeria (CCASTR). A Compendium of Studies Commissioned and Pubished by Building Nigeria's Response to Climate Change (BNRCC) Project. Pp: 49-68

Caroline S. (2002) Calculating a Water Poverty Index. *World Development*. Vol. 30, Issue 7 Pp. 1195-1210

Chambwera M. and Stage J. (2010) Climate change adaptation in developing countries: issues and perspectives for economic analysis. International Institute for Environment and Development Publication, London, UK http://pubs.iied.org/pdfs/15517IIED.pdf (accesses 27th /04/2015)

Conway D., Lisa E. and Schupper F. (2011) Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. Global environmental Change, Volume 21, Issue1, Pages 227–237

Darren T. (2011) Climate Change Threatens Africa's Biggest Water Sources. VOA Report. http://www.voanews.com (Accessed 23/04/2015)

Frank R.R. (2006) Water scarcity: Fact or fiction? *Agricultural Water Management*, Vol. 80, Issue 1-3, PP. 5-22

Fraser, E. D. G., A. J. Dougill, K. Hubacek, C. H. Quinn, J. Sendzimir, and M. Termansen. (2011) Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. *Ecology and Society* **16**(3): 3. http://dx.doi.org/10.5751/ES-03402-160303 (Accessed 27th /04/2015)

Hargreaves, G.H., and Samani, Z.A. (1985) Reference crop evapotranspiration from temperature. *Appl. Eng. Agric. 1 2 (1985), Pp 96–99* ort.pdf (Accessed 11th March, 2015)

Pierre M. (2002) Water access, water scarcity and climate change. *Environmental Management*, 45: 1027 -1039.

Ravazzani G., Ghilardi M., Mendlik T., Gobiet A., Corbari C. and Mancini M. (2014) Investigation of climate change impact on water resources for an Alpine basin in northern Italy: implications for evapotranspiration modeling complexity. PLoS One 9(10): e109053.

Richard M. A. and Dannele E. P. (2008) Choices 1st Quarter 2008 | 23(1), Magazine for Food, Farm and Resource Issues. JEL Classification: Q25,Q54

Usman M.T. and Abdulkadir A. (2012) On Determining the 'Real' Onset Date of Seasonal Rains in the Semi-Arid and Sub-Humid Areas of West Africa. Natural Hazard (NHAZ). *Volume 66, Issue 2, pp 749-758.*

Vicente-Serrano, S.M., Lanjeri, S. and Lopez-Moreno, J.I. (2007) Comparison of different procedures to map reference evapotranspiration using geographic information systems. *International Journal of Climatology 28(8): Pp 1103 - 1178*

Wikipedia, Water distribution on Earth. http://en.wikipedia.org (Accessed 23/04/2015)