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CLIMATE VARIABILITY AND WATER SUPPLY: A REVIEW OF RURAL WATER PLANNING TECHNIQUES FOR SEMI-ARID REGION OF NIGERIA

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Abstract

This paper present a synthesis of climate variability and its potential impacts on rural water availability in semi-arid region of Northern Nigeria. The paper discusses the impact of climate variability on water availability, its seasonal and geographical distribution as well as the management and planning of the available water for various uses. The semi-arid region of Northern Nigeria is susceptible to climate impact basically due to its fragility and sensitivity to even minor changes in precipitation and the rates of water loss via evaporation. The impending water scarcity can be minimized or reversed when there is proper management and planning techniques. In this regard, two basic recommendation were proposed by this paper: 1. The impacts of current trend of climate variability could be averted locally through educating the rural people, that they are partly the construct of their meteorological misfortunes, via bush burning and deforestation. 2. The two extreme scenarios posed by climate variability (floods and drought) can be utilized through riverbank filtration and aquifer recharge and recovery system. This can be done where excess water that eventually results to floods can be abstracted via riverbanks, injected and stored in the deeper aquifers which can later be pumped out during water shortages in the dry period. The benefits accruable from these systems are tripartite; 1. Flood control, 2. Reduced evaporation and 3. Providing water at the time of crucial demand.

Keywords: *climate variability, water supply planning, riverbank filtration, aquifer recharge and recovery, semi-arid, Nigeria*

INTRODUCTION

In most parts of the arid and semi-arid regions of the world (including Northern Nigeria), fresh water availability comes naturally in the form of seasonal rains. However, there are a lot of uncertainties in the timing and duration of the rain likewise its temporal and spatial distribution. In spite of its variability and unreliability, it is still the only source of annual recharge for both surface and sub-surface water storages (Reza et al 2007). There is an increasing fear of future water scarcity particularly in arid and semi-arid regions owing to increasing climate variability. Several billions of people were projected to face water scarcity by 2030, most of which would be located in drier climate and rely on various rivers for their water supply (Ayoade, 1988, Enete and Ezenwanji, 2011).

The consequences of the increased variability in climate (precipitation) in recent past was the observed increasing floods and drought events in tropical areas. Thus, in Nigeria the coastal boarders suffered from increased flood events due to increased precipitation, whereas in the semi-arid region, the consequences of decreased precipitation is manifested in the repetitive droughts.

Thus, the characteristics and the basic components of hydro climatological systems in this zone is altered. In its annual rainfall prediction the Nigerian Metrological Agency (NIMET) reported that; rainfall is expected to fall slightly below its normal level over large portion of the country in 2016. This is likely to create water shortage in lakes, dams and rivers. The annual rainfall is expected to vary from 400-1200mm in the northern half of the country to an increase from 1200-2800mm in the southern half, implying high surface runoff (NIMET, 2016). This situation may upsets water and agricultural resources planning and can paralyze many socio-economic activities of the country (Enete and Ezenwanji, 2011). Thus, the arid and semi-arid region of the country with its limited sources of water and harsh meteorological conditions, is increasingly facing future water resource predicament and its availability is under tyranny of future climatic behavior.

There should be some amendments in management and planning strategies in this fragile region in order to balance future water demand and supply using hydrological modelling in integrated fashion. This will assist in the simulation and prediction of the linkages between climate variability and future water resources availability in the area.

Climate Variability and Change

It is important to point out that the global climate or climate of any part of the earth has never been stationary. Variability is an inherent characteristic of climate. What is crucial is magnitude and duration of the variability (Roma and Africa, 2009). Minor fluctuations or variations constitute not more than a noise in climatic scores and man can easily adapt to such minor variations. However, when instabilities in climate constitute significant departures from the normal climate or become prolonged to constitute a new climate state, then there may be problem of adjustment. Depending on the region's fragility and societal economic viability, the entire ecosystem and the socio-economic activities of the affected region(s) may become susceptible and vulnerable to even minor climatic changes (Ekpoh, and Nsa, 2011).

Climatic variations occur on various temporal scales, varying from a few decades to millions of years. Several nomenclatures are used to describe climatic variations depending on the time scales within which such variation occur. Thus, we have such expressions as climatic trends, climatic cycles and climatic change. This is in addition to such general terms as climatic fluctuations and climatic variability which emphasizes the inherently dynamic nature of the climate (Herrera-Pantoja and Hiscock, 2015).

Climate change is therefore a situation when climatic variations or fluctuation over a long period of time occur (approximately 35-40 years) to produce a shift or a change in the type of climate prevailing over an area. In other words, climate change represents a significant difference between two mean climatic states or climatic normals with significant impact on the ecosystem (Ayoade, 2003; Smith, 1996).

Changes in weather and climate have been known to profoundly affect many resources and activities, but the most vulnerable are water and agriculture which are entirely climate dependent. Climate Change will bring overall less rainfall and also heavier individual rainfall events in a single day, this may upsets water and agricultural resources planning. Thus, paralyzing many socio-economic activities of a country or a region (Enete and Ezenwanji, 2011). The semi-arid region of the country with its limited sources of water and harsh meteorological conditions, is increasingly facing future predicament of water resource availability for various uses.

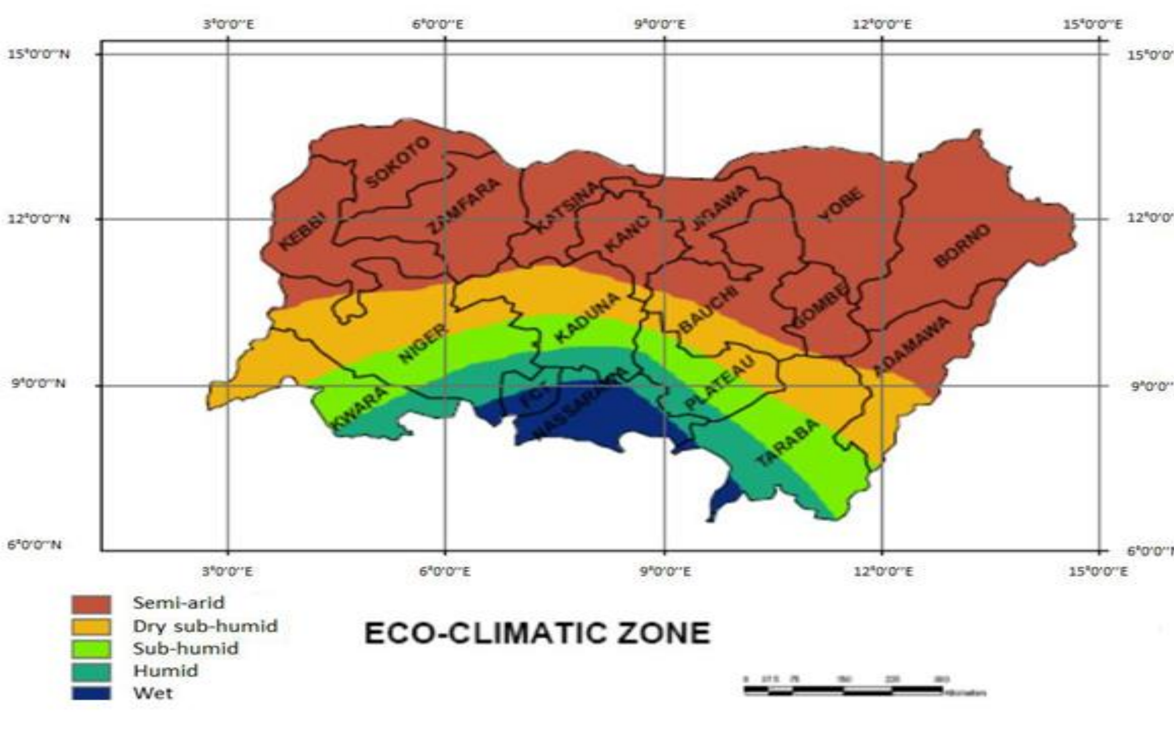

Figure 1: Map of Northern Nigeria showing the eco-climatic zone (after AbdulKadir et al 2015)

The Semi-arid region of Nigeria

The semi-arid region otherwise called drought prone areas of northern Nigeria lie within the Sudano-Sahelian region roughly north of Latitude 100N, delineated by latitude 140N; and between longitudes 2^0 44' E and 14^0 42'E (Olofin,1987; AbdulKadir et al 2015; Sawa Sawa, B. A.1, Ati, O. F., Jaiyeoba, I. A., Oladipo, E. O. 2015)
The zone cuts across Sokoto, Kebbi, Zamfara, Katsina, Kano, Jigawa, Yobe Borno, Bauchi, Gombe, and Adamawa States respectively (Sawa et al 2015). This dry region forms an undulating plain at a general elevation from about 450m to 700 m. More than half of the region is covered by ferruginous tropical soils which are highly weathered and evidently laterised.

A large proportion of the region is also characterized by sandy-fixed undulating topography. The sandy soil is usually low in organic matter, nitrogen and phosphorus and may degrade rapidly under conditions of concentrated rainfall (Mortimore, 1989). When put under over-use, denuded patches may appear, with addition pressure of blowing wind the sand becomes mobile. Average annual rainfall in this region varies from 300mm in the north-eastern part to 1,000mm in the southern part. However, it is unpredictability and unreliability that characterized the pattern of rainfall in the region. Similar to the condition obtainable in other arid and semi-arid areas of the world, the worries are not just about the total amount of rainfall received, but the timing and distribution of the rain (Bobe 2006; Araya et al 2010). Thus, the pattern of rainfall in the region is highly variable in both temporal and spatial dimensions with an inter-annual variability of between 15 and 20 percent. The nature of the rainfall in the region rarely supports any other vegetation beside the savanna types (Medugu et al 2011).

The historical antecedent of drought and aridity in this region has started with the "Great Drought" otherwise called "Sahelian Drought "of the early 1970s (more precisely 1968-1973) (Tabari et al 2012).This left the region with the most remarkable environmental thumbprint on the physical, social and economic landscape of the entire country, particularly the extreme northern part of country. In 1973 the drought resulted in shrinking of Lake Chad to one-third its normal size and thus significantly reduced in term of its importance as an international water body (United Nations, 1978).
The tenacious failure of rains in the region have turn into loss of crops and livestock production, which unescapably lead to loss of livelihood by the inhabitant of the region (Medugu et al 2010). The subsequent repercussion were starvation and diseases. In many instances reports were made on the outbreak of meningitis, which was linked to water shortage in the affected zones. As the region is the most productive region in term of agricultural produce, the nation as a whole has persistently suffered for the overall decline in agricultural production.

Water Availability and Sources
Water dominates not less than 70% of the Earth's surface, but most of that is ocean. By volume only 3% of all water on Earth is fresh water, and most of this is largely unavailable, this is because about three quarter of all fresh water is locked away in the form of ice-caps and glacier located in polar region far removed from human habitation. The water found in lakes, rivers and those at shallow underground level are the easily accessible fresh water and are only 1% of the total water on Earth. Only this amount is regularly renewed by precipitation to which its sustainability is threatened by

the alarming climate change phenomena. Therefore, in all, only 1% of the world's total water supply is considered accessible for human use (Barabas, 1986). Globally, between 12.5 and 14 billion cubic meter of water are deemed available for human use on an annual basis. This amount to about 9,000 cubic meters per person per year as estimated in 1989 (Alaba, 2001).

By the year 2025, global per-capital availability of fresh water is projected to drop to 5,100 cubic meters per person, as another 2 billion people join the world's population. Even then, this amount would not be enough to meet human needs if it were to be distributed equally among the world population. But the world available fresh water is not distributed evenly around the globe throughout the season or from season to season due to inter-annual variability of rainfall as one of the consequences of climate variability. This inter-annual variability is more noticeable in arid and semi-arid climate such as the arid and semi-arid region of northern Nigeria. The disparities in the distribution of rainfall around the globe can be seen, in that in many cases water is not where we want it, nor is it in sufficient quantities. In other cases, we have too much water, in the wrong place, and at the wrong time. (Malin, 1989, 1991).

If not because climatic parameter such as rainfall are not largely controlled by humankind, how could about 20% of the global average rainfall each year falls in the Amazon basin? (Region with less than 10 million people, a tiny fraction of the world's population). Similarly, the Congo River and its tributaries account for about 30% of the entire African Continent's annual run off but this water shed contain only 10% of Africa's Population. However, the disparities in water resources sharing are more blatant when it comes to access to this vital resources -the water. (Postel, 1997).

Freshwater Resources and their Management

By mid-21st century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes in the dry tropics, some of which are presently water- stressed areas. By 2020, about 75 million people are projected to be exposed to increased water stress due to climate change. Several billions of people could face water scarcity by 2030, particularly those relying on various rivers for their water supply. If coupled with increased demand, this will adversely affect livelihoods and exacerbate water- related problems (IPCC, 2007).

Rural Water Supply Planning

Water supply is the provision of water for drinking, domestic purposes and irrigation. Its availability is controlled by global water distribution, (Oteze, 1988). Water supply planning therefore, is the collection, analysis and interpretation of hydrologic and geohydrologic data, followed by field reconnaissance surveys, geophysical investigation supported by test drilling and physical examination of core samples,(Oteze,1988). The sources of rural water supply in this region are mostly the available surface water in rivers and lakes complemented by other groundwater sources. Although both sources depend on the amount and distribution of rainfall over the geographical areas, however surface water are more attached to rainfall irregularities. This is because the groundwater may have been recharged from other underground riparian sources. Thus, the aquifer may contained substantial amount of ambient water resources from other sources. Beside the rural inhabitant prefer the use of surface water even though is less hygienic compared to groundwater sources. The groundwater resources can be assessed by isolating the water bearing horizons (aquifers), which will enable estimates of their water resources potentials and to establish the quality of the groundwater resources. Considering the water quality variation, both water resource sources (surface and subsurface) may require various treatment steps. Thus, beside consideration of the availability of water, its purification to meet the required standard is also another management and planning steps to ensure safe water to the rural inhabitant for various uses. The types of treatment for water purification depend on the physical, biological and chemical characteristics of the water to be used.

Alongside climate variability challenges, rural water supply planning is constrained by rapid population growth and the settlement pattern of rural homes. Most of the rural homes are usually built in scattered fashion. This makes rural water planning and supply tedious. However, in rural areas where a population of 5,000 or more are spread over a relatively short distance or a villages with over 500 households, a small-scale safe water supply should be provided. Rural water supply planning should however be seen in an integrated fashion involving sociologists, town planners and environmental hydrologists among others. To ensure convergence among scarcity, demand and supply of water to rural population, more climate research is needed in this fragile region and awareness campaign is as well demanded on the danger of using raw water from surface sources such as lakes and rivers without prior treatment. Since untreated water may contain many micro-organisms that cause diseases such as typhoid fever, dysentery, gestroenteries infection, hepatitis and amoebic dysentery.

The whole idea of water supply planning depends on the availability and sources of water which is directly controlled by hydrological cycle. Water cycle dictates where and when rain will fall, that is its reliability, amount and distribution which the water demand and supply criteria should take cognizance of according to population demand criteria. Thus water resource planning is aimed at achieving an orderly development of water resources to meet present and future demands.

Rural water supply and the MDGs

There are still at least 1.1 billion people across the world that do not have access to safe drinking water. Many of these people live in rural areas and are among the poorest and most vulnerable to be found anywhere in the world. In sub-Saharan Africa, 300 million people have no access to safe water supplies and approximately 80% of this people live in rural areas. Therefore, significantly increasing the coverage of rural water supply in Africa is fundamental to achieving many of the internationally agreed Millennium Development Goals (MDGs). Without safe water near to dwellings, the health and livelihoods of families can be severely affected; children's education suffers as the daily tasks of survival take precedence over all other concerns.

Fronting up the Water Crisis

Water is the defining link between climate and agriculture. But even without increasing climate change and variability, the semi-arid region of Nigeria is in serious trouble, mostly due to increased population and urbanization. Competing demands combined with mismanagement of this critical resources means that water availability is presently and will be the future challenge to the rural inhabitants of this region (semi-arid region of northern Nigeria). Typically, the most extreme shortages are experienced by those least able to cope with them, the most impoverished inhabitants of developing countries. Climate change will exacerbate the already critical situation. Water has already proven to be a critical limitation for many poor people (Moorhead, 2009). Fig. 2 shows a point of rural water supply.

Figure 2 Point of rural water sources in the drier period at Hadejia river system (Modified after Halliru and Umar 2012)

Impacts of Climate Change on Rural Water Supply

The hydrological cycle driven by solar energy involves water changing in form and moving from one storage to another. Consequently, climate change will lead to the intensification of the global hydrological cycle with consequences for the major water storages in this region (semi-arid of Northern Nigeria). The changes in the volume (magnitude), timing and distribution of water resources would necessitate changes in management strategies in order to balance water supplies and demand, since the hydrological cycle comes with no guarantees for human-kind. Water will be available where it is not needed and will completely disappear where it is most required (Postel, 1998).

Various methods have been employed to assess the impact of climate change on hydrology and water resources at various geographical scales from the globe to regions and of course to the river catchments. This includes the following;

i. Statistical analysis of long-term concurrent variation in run off and meteorological elements especially air temperature and precipitation over past periods.
ii. Studies of the hydrological consequences of past periods of very warm or cold, wet or dry condition.
iii. The use of methods of water balance over a long period of time to assess the impact of increased temperature and decreased precipitation on run off and soil moisture storage.

iv. The use of General Circulation Models (GCMs) of the atmosphere to obtain changes in the climatic and hydrological characteristics of a large area using different green house gases emission scenarios.

v. Use of deterministic hydrological conditions using input of climatic data including outputs from (GCMs).

The methods above have their strengths and weaknesses when used to assess the impact of climate change on hydrology and water resources (IPCC, 1990b).

From the results of several studies conducted using the above approaches, here are the extracts that correspond to Nigerian situation;

i. River catchments will be very sensitive to even small changes in climatic conditions especially those in arid and semi arid region where the annual run off is highly variable, as the case at hand (semi-arid region of Nigeria)

ii. Global warming is likely to influence the runoff regime, leading to variability in flow within the year (high and low flow extremes).

iii. There will be increase in rate of evaporation/evapotranspiration which will lead to reduced soil moisture storage and reduction in total annual volume of run off. This is particular in areas where precipitation remains unchanged or decreases in amount or fails to increase in amount large enough to offset the increases in rates of evaporation (IPCC, 1990a).

iv. There may be decrease in infiltration rates where rain drop sizes increases or rainfall intensities increase with consequent adverse effects on soil moisture, ground water recharge and ground water levels.

v. There will be changes in demand for water resources (both domestic and agricultural), water consumption will increase with increasing dryness and/or heat all things being equal. The radiational index of dryness RW/LP (where RW is the net radiation of a wet surface, P is precipitation and L is the latent heat of condensation) provides an indirect measure of water consumption. The greater the value of the index the higher the water consumption rate (IPCC, 1990b).

vi. Regions that depend on unregulated river systems (as the case with most rural Nigeria) will be more vulnerable to hydrological changes induced by climate change. (IPCC; 1990c, Umolu, 1995).

With these impacts of climate change on water availability and distribution, the need for water supply planning especially in the semi-arid region of northern Nigeria which is predominantly rural has arisen if future water supply crisis is to be averted. The current population growth of 3.4% is alongside exacerbating the problem of water resources scarcity. Over the years, access to clean water has been a key indicator of measuring the quality of life in nations and regions across the world and has been associated with longevity, as access to clean water do reduces incidence of water borne diseases. Thus, improving health and high standard of sanitation.

The Role of Riverbank Filtration (RBF) and Aquifer Recharge and Recovery System (ARR) in Improving Water Supply in the drier period

Change and or variability in climate has in recent years dominated the political and public atmosphere world over. There has also been a growing concern over the potential impacts of this change and variability in climate on our societal resources and activity particularly water resources (Villeneuve etal., 2012). This is so because, severe weather has been occurring more frequently and with greater severity worldwide, which could affect the reliability of water supply on various regions of the world more especially the arid and semi-arid regions (United Nation Women Watch, 2009). It seems the projected World War III if it could happen, could be over water not oil or other resources (Falkenmark, 2001, The World Bank, 2009). In the midst of dwindling water resources, increasing demand for water from growing population, widespread pollution, and increasing extreme weather events, the world is facing a more and more serious water challenges since the beginning of the 21st century (Wan Hassan, 2007, Falkenmark, 2013). It has been forecasted that by the year 2030, several billions of people across the world could face water stress (IPCC, 2012). These integrated challenges can only be addressed by a combination of integrated and robust techniques or solutions. Integrating riverbank filtration and aquifer recharge and recovery system are some of these techniques and can provides a lasting solution to water scarcity especially in arid and semi-arid climates (Caldwell, 2006 Umar etal 2017). Using these integrated systems, the excess water potentially seen to cause floods in the rainy seasons will be abstracted via riverbanks and be stored in the deeper aquifers which can later be pumped out during water shortages like in the drier seasons (Caldwell, 2006, Ray, 2008). The benefits accruable from these systems are tripartite; flood control, reducing escape of water via evaporation and providing water at the time of water shortages (Ray, 2008).

Conclusion

Planning of water resource essentially centered on three fundamental issues; the availability of water resource, future demands, and how these can be sought. The most important thing is the water availability, how can the diminishing water resources be conserved or improved in the face of increasing climate variability, this calls for a redress on some of the identified causes of climate variability, especially those contributed by the rural inhabitants whether deliberately or inadvertently. The most escalating of such activities is deforestation which was reported as the highest contributor to greenhouse gases concentration (50-60%). Deforestation also reduces the essential tropospheric sinks of carbon (the vegetation). At present, carbon concentration in the troposphere is approaching 400 mg/kg and it is predicted to reach 450 mg/kg by the year 2050, if nothing is done to cut down its emission at both local, regional and international level (Umar, 2000).

However, most rural societies were unaware about the danger of their actions and inactions (e.g. bush burning and deforestation) unknowingly to them, this was and is still one of the major contributing factor to the increasing atmospheric carbon concentration and thus global warming. The reckless deforestation engaged by the local people, even though it may be poverty driven, but there should be an enforced law to its minimization and a replacement to the felled trees considering the role played by vegetation via micro climate amelioration, soil stabilization, and more importantly their role in absorbing the excess carbon from the troposphere, which when in excess contributes immensely to the global warming phenomenon. The warming intensifies heat and encourages evaporation, contradicts rainfall reliability and further aggravates the fear of water scarcity. This local phenomenon (deforestation) alone was reported to have accounted for over 1.6 billion tons of carbon emission in 1980s (Haughton, 1993, Umar 2000). Thus, man is partly responsible for his environmental misfortune.

Recommendations

Nigeria in general and the semi-arid region in particular needs blue revolution in the first instance to conserve and manage the little available water resource in the face of growing demand. Moreover, factors affecting climate negatively should be minimized (e.g. bush fire and deforestation). Besides the broad recommendation, the Local, State and Federal authorities should adopt the following;

- Educate the rural households on how to use water wisely and on dangers involved during water shortages.
- Provide a legal frame work to guide the activities of industries sited in the rural areas so as to ensure no toxic waste contaminate water bodies.
- Punished the non-law abiders through taxes.
- Involve qualified companies while awarding contracts on rural water supply, those capable of assessing, harnessing and distributing the available water accordingly.
- Educates the rural people on significance of climate change on water resource availability, temporally and spatially.
- Improve upon the available water supply system, such as dams, reservoirs.
- Educate the rural people about the danger of their local actions such as bush burning and deforestation that contribute immensely to change in climate.
- Involve the supply of water through desalinization of ocean water and salt water for public consumption, especially among coastal rural population.
- Improve in water re-use system especially where industries are located in rural areas. This involves the sequential water use. (e.g. household→ industrial→ agriculture).
- Finally, the government should invite experts in the field of climate change, water resource engineering, geologists and many more relevant disciplines to develop and present proposal on how to establish aquifer recharge and recovery (ARR) and riverbank filtration (RBF) used recently for filtration and storage of excess surface water resources during rainy period. Thus, the excess precipitation potentially seen to cause floods can be stored in the deeper aquifers, which can later be pumped out during period of serious water shortages. The benefits accruable from these systems (RBF and ARR) are tripartite; flood control, reduce evaporation and providing water at the time of water shortages.

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