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Survey Article

Impacts of Groundwater Development on Poverty Reduction and Alleviation in Nigeria

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Abstract. Water is one of the most important resources on earth and a basic life need; all human activities towards social-economic developments depend on the availability of water. Groundwater accounts for about 0.06% of Earth's available water and represents about 98% of the fresh water readily available to humans. Harnessing this important resource for productive uses such as irrigation, domestic and industrial water supplies would help to reduce poverty and vulnerability to water borne disease particularly in rural settlements. Groundwater development, exploitation, and supply chain in Nigeria is relatively low and needs a major transformation. Groundwater resource is required to meet the need of the rapid growth in population, urbanization, industrialization and competition for economic development. Although the management of groundwater in Nigeria is lagging behind the pace of development, and often, very little control is exercised in its exploitation, groundwater has gainfully impact on the rate and level of poverty and has transformed rural economies in most parts of the country, thereby alleviating poverty, reduce the rate of water related diseases and enhance economic growth. This paper emphasizes the impacts of groundwater developments on poverty reduction in Nigeria. The opportunities and economic sustainability presented by groundwater resource development are presented. Integrated approaches/strategies for sustainable management of groundwater resources with relevant recommendations for groundwater resource management are advocated.

Keywords. Groundwater resources; Development; Poverty reduction; Economic growth

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1. Introduction

Studies have highlighted the strong link between water provision and poverty alleviation, though the causes of poverty and their relation to water are very complex, the necessities of groundwater cannot be overemphasized. Poverty is a multi-dimensional experience of a large number of men, women and children in Nigeria, especially in rural areas. It is not simply a matter of having a low or irregular income, but of lacking a wider set of assets (human, social, physical, natural as well as financial), and being vulnerable to changes which the less-poor can more readily survive.

According to Ndem [24], there is the need for poverty alleviation programmes to be implemented within the framework of economic growth with equity, sound economic management and good governance, among others. Different regimes of the Nigerian government at different times have been launching different poverty alleviation programmes, yet the outcome is always a deviation from expectations.

Despite the huge groundwater resources, water resources development has not been able to keep pace with the phenomenal population growth (Oteze [30]). Water resources represent a major prerequisite and driver of socio-economic development. Economic sectors that water caters for include domestic, agriculture and fisheries, industry, recreation, municipality including waste/effluent disposal, and water transportation. It also plays a prominent role in power and energy generation: hydroelectric power generation's share of total power production has decreased from over 70% in 2004 to the present proportion of about 40% (Oyebande [32]). Groundwater is widely used because of its high quality. Groundwater development unfolds rapidly once a minimum level of technology and energy become widely available. Compared to surface water, groundwater use often brings large impacts in economic benefits per unit volume, because of ready local availability, drought reliability and good quality requiring minimal treatment (UN/WWAP [39]). The reliable supply of groundwater, uniform quality and temperature, relative turbidity and pollution free, minimal evaporation losses, and low cost of development are attributes making groundwater more attractive when compared to other sources (Menon [23]). Yet, at the same time population and economic growth have led to ever more demands on the resources.

Groundwater has emerged as the primary democratic water source and poverty reduction tool in Nigeria's rural areas. Groundwater is one of the Nigeria's most important natural resources and an important source of water for domestic supply and agriculture. On account of its near universal availability, dependability and low capital cost, it is the most preferred source of water to meet the requirements of various user sectors in Nigeria. Groundwater has made significant contributions to the growth of Nigeria's economy and has been an important catalyst for its socio-economic development. Its importance as a precious natural resource in the Nigerian context can be gauged from the fact that it accounts for more than 40 percent of the Nation's public water supply. In addition, more than 40 million people, including most of the rural population, supply their own drinking water from domestic wells. Groundwater is often called a 'hidden resource' because it cannot be seen in the same way as water in a river, lake or reservoir. The volumes of groundwater are large; however-it is estimated that there is about one hundred times fresher groundwater on earth than all the fresh water in rivers and lakes. As a result, groundwater is an important source of much of the water used for drinking and irrigation. It is the Nation's principal reserve of freshwater and represents much of the potential future water supply. Groundwater is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats for plants and animals.

Aside from the aforementioned, certain features make groundwater attractive as source of potable water supply. Firstly, there are aquifers in several parts of the country that can frequently be tapped at shallow depths close to the water demand centers in response to the dispersed nature of rural settlements. Secondly, water stored in aquifers is for most part protected naturally from evaporation and pollution, and well yields are in many cases adequate, offering water supply security in regions prone to protracted droughts as is common in the northern parts of Nigeria. Thirdly, with adequate aquifer protection, groundwater has excellent microbial and chemical quality, and requires minimal or no treatment at all. Fourthly, the capital cost of groundwater development as opposed to the conventional treatment of surface waters is relatively modest and the resource lends itself to flexible development, capable of being phased in with rising demand. Lastly, groundwater development is fast, does not require a large initial financial investment, delivers a better service to the people, steadily improves social welfare and is significantly less prone to corrupt practices. The overwhelming availability of groundwater resources globally, which are also naturally better protected against contamination, clearly indicates that the future of humanity is intimately linked to the quantity and quality of the world's groundwater resources.

Some of the impacts of groundwater development are linked to the inherent characteristics of groundwater resources: most aquifers provide large water storage space and help stabilize water supply during peak of dry season and droughts; the sluggish flow of groundwater through small voids helps in purifying water, necessitating lower or no treatment costs prior to its use as drinking water; the general availability of groundwater makes it a resource easy to access; and in areas of extensive aquifers groundwater development can increase recharge and also decrease flood intensity.

Poverty reduction is a serious matter that requires serious attention. No doubt, the Federal Government of Nigeria has at different times instituted different poverty alleviation programmes. Yet, evidence shows that poverty is still on the increase rather. Inadequate access to safe water for domestic purposes (drinking, cooking, personal and home hygiene) is an important measure of poverty. Extending and enhancing the development of water resources in general, and of groundwater in particular, can have significant beneficial impacts on poverty alleviation and livelihoods. In this paper, it is advocated that clear and unambiguous identification of the roles and impacts of groundwater in poverty reduction and directing such programs will improve the situation in Nigeria. Also attempts to identify the impacts groundwater development on poverty reduction and poverty alleviation in Nigeria.

1.1 State of the Matter

Unsustainable management of groundwater affects developing countries due to the complex and intractable nature of the problem. There are also important implications for poverty. When left unmanaged, groundwater can negatively affect the livelihood and food security of those dependent upon it because overexploitation leads to cycles of boom and bust (Moench [22]; Janakarajan and Moench [19]). Most of those affected live within the densely populated and agriculturally productive plains of Southwestern Nigeria. Equally important, albeit less understood, is the problem of "under-development" of groundwater resources and the opportunities for productivity gains and poverty alleviation lost thereof. There are two dimensions of the "under-development" issue. First, there are vast areas such as in Southwestern Nigeria where there is high groundwater potential and high recharge potential. Here groundwater can be geared towards poverty alleviation without significantly stressing the resource base or creating excessive environmental impacts. Second, there are locations mostly in North-western Nigeria where the resource is less exploited and as a result, uncertainties and misconceptions emerge about the development potential. But there is emerging evidence that farmers are increasingly resorting to groundwater for irrigating high value crops. Here, there is much optimism among the policy and developmental professionals that groundwater can play an important role in enhancing productivity and alleviate poverty.

Groundwater quality hazards such as fluoride and arsenic that may be naturally occurring and heterogeneously distributed within aquifers is another challenge. It is also important that any major increase in groundwater development for agriculture takes into account the threat posed by diffuse groundwater pollution to aquifers from fertilizer and pesticide inputs. A distinguishable form of groundwater overuse is that of groundwater 'mining', or irreversible depletion of non-renewable (fossil) or poorly renewed groundwater. This is mainly limited to North Africa and the Middle East and sometimes occurs in a strategic manner (Abderrahman [6]), but more often it happens in an unplanned manner.

1.2 Access to Groundwater

Access to water is a basic human right, but for many of Nigeria's poor, water is only available at a price, and supplies are often not safe. The human cost of lack of access to safe water is huge, reflected in the high child mortality rates. Reliability and accessibility of data, especially data on "informal" access to water for various purposes such as agricultural (livestock and crop production) and small-scale industrial uses are almost nonexistent, and certainly not systematized. Externally-driving approaches to poverty alleviation in general, and groundwater development in particular, have made significant progress in extending people's access to water. Technical solutions in which the users typically contribute less than 10% of the capital cost, and in which insufficient time is set aside to bring about full community participation and management, suffer major problems of lasting maintenance and functionality. The almost exclusive use of externally-driving approaches in Sub-Saharan Africa in general, and in Nigeria in particular has led to an aid-mentality in which people often wait for governments or NGOs to act for them, and are reluctant to take initiatives for themselves. There is need to apply all possible measures to instil local ownership and responsibility (including financial responsibility) for operation and maintenance, and to ensure appropriate on-going support or check-stopping is available. However, in cases where there is no other option than that of deep or hard rock drilling, then externally-initiated solutions, using mechanized drilling are necessary.

The technology innovation, existing technologies (hand percussion, hand augering, sludging, jetting and their variants and combinations) need to be modified and adapted to local geological and economic environment. Particularly, equipment needs to be manufactured locally from readily available parts and components (e.g., standard pipes and fittings, flexible hose, timber, rope, centrifugal pumps), and using simple fabrication technologies (e.g., cutting, hardening, welding, threading). On the other hand, small enterprises need to be introduced to ”new” technologies, trained in their use, and then provided with business training. They may need additional support in kind (e.g., equipment, transport) or in cash (seed capital or credit) in the short term, as well as longer term assistance until they become viable business entities. The development of the market refers to both demand creation among potential water user (who may also require short-term credit facilities to access the technology), as well as assistance with market linkages for the output of productive water uses, especially crops.

The greatest possibility for poverty reduction in Nigeria would appear to lie in the application of these technologies through small enterprises developed or strengthened to deal directly or indirectly with households, farmers, communities and institutions. There are signs of hope, not least in the growth of indigenous entrepreneurship, and in the growing number of case studies of successful development of groundwater for poverty alleviation in Sub-Saharan Africa region. Underlying the issues highlighted are several weaknesses which are challenging:

(i) Resistance in the public sector which professionals experience when they try to change design standards or practices;

(ii) Limited expertise, and even more limited resourcing, at local government levels to permit adequate contract management and supervision;

(iii) Difficulties for the indigenous private sector of “doing business” - obtaining loans on realistic terms, importing of spare parts and consumables, competing fairly in a transparent operating environment, and having some assurance of a sufficient workload;

(iv) Insufficiently detailed knowledge of groundwater conditions, introducing uncertainties into contract specifications.

1.3 Groundwater Responsible Growth

There is a re-emerging consensus that groundwater development and management are essential to generate wealth, mitigate risk, and alleviate poverty. Thus, alleviating poverty demands that many developing countries will need to make large investments in water infrastructure at all levels. This development must be undertaken building on the lessons of experience, with much greater attention to institutional development, to the environment and to more equitable sharing of benefits and costs. The challenge of "Responsible Growth" is to grow while at the same time embracing both environmental sustainability and social development. A responsible path is particularly important in water development because, given the longevity of water infrastructure, many of these decisions will have long-term consequences. Furthermore many decisions – both decisions to act and not to act – may have irreversible consequences.

2. Geology and Hydrogeology of Nigeria

Nigeria (Figure 1) is located on the west coast of Africa in south of the Sahara Desert, It is bordered by Niger and Chad to the north, Benin in the west, Cameroon in the east and Gulf of Guinea in the south (Figure 1). The country lies between latitudes 4°N and 14°N and longitudes 2°E and 15°E. The land area is approximately 925,000 Km^2, with abundant groundwater resources, enough to cater for the needs of her teeming population of about 140 million. The climate of Nigeria varies from equatorial in the south through tropical in the central to arid to the north. Nigeria experiences consistently high temperatures throughout the year. The temperature ranges between 21 and 33°C (Iloeje [18]). The mean annual rainfall along the coast is more than 4000 mm while it is less than 250 mm in the north with an average of 1180 mm (BGS [11]).

2.1 Geology and Groundwater Basins

The geology of Nigeria consists of two main lithological units. These are the Precambrian Crystalline Basement and Cretaceous-Tertiary sedimentary rocks (Figure 1). The basement complex rocks are of metamorphicigneous-volcanic origin. The main rock types include units include: Migmatite-Gneiss Complex (migmatites, gneisses), Schist Belts (schists, quartzites, metaconglomerates, amphibolites, phyllites), Older Granites (granites) and Younger Granites (basalts, rhylolites, tuff), Oyawoye [34].

The sedimentary basins include the northern inland sedimentary basins consisting of the Sokoto and Chad Basins while the middle belt and southern coastal basins is made up of the Nupe, Benue, Benin and Niger Delta Basins. The sedimentary sequences in these basins were broadly divided into basal non marine sandstones, siltstones, and mudstones; a middle marine shales and limestones intercalated with sandstones and siltstones and an upper sandstone sequence that is continental or paralic (Petters [35]).

The Sokoto Basin of north-western Nigeria is the southern sector of the Iullemenden Basin transboundary aquifer shared by Mali, Niger, and Algeria. The depth of water level in the Sokoto Basin aquifers is typically in the range 15 to 75 m (BGS [11]), while the Gwandu aquifer has an estimated yield of 10 to 35 L/s (Akujieze et al. [9]). The Chad Basin consist of three main aquifers: an upper aquifer at 30 to 100 m depth with yield of 2.5 to 30 L/s, a middle aquifer about 40 to 100 m thick having a yield of 24 to 32 L/s and a lower aquifer consisting of sands and clays at a depth of 425 to 530 m with yield of 10 to 35 L/s (Akujieze et al. [9]; BGS [11]).

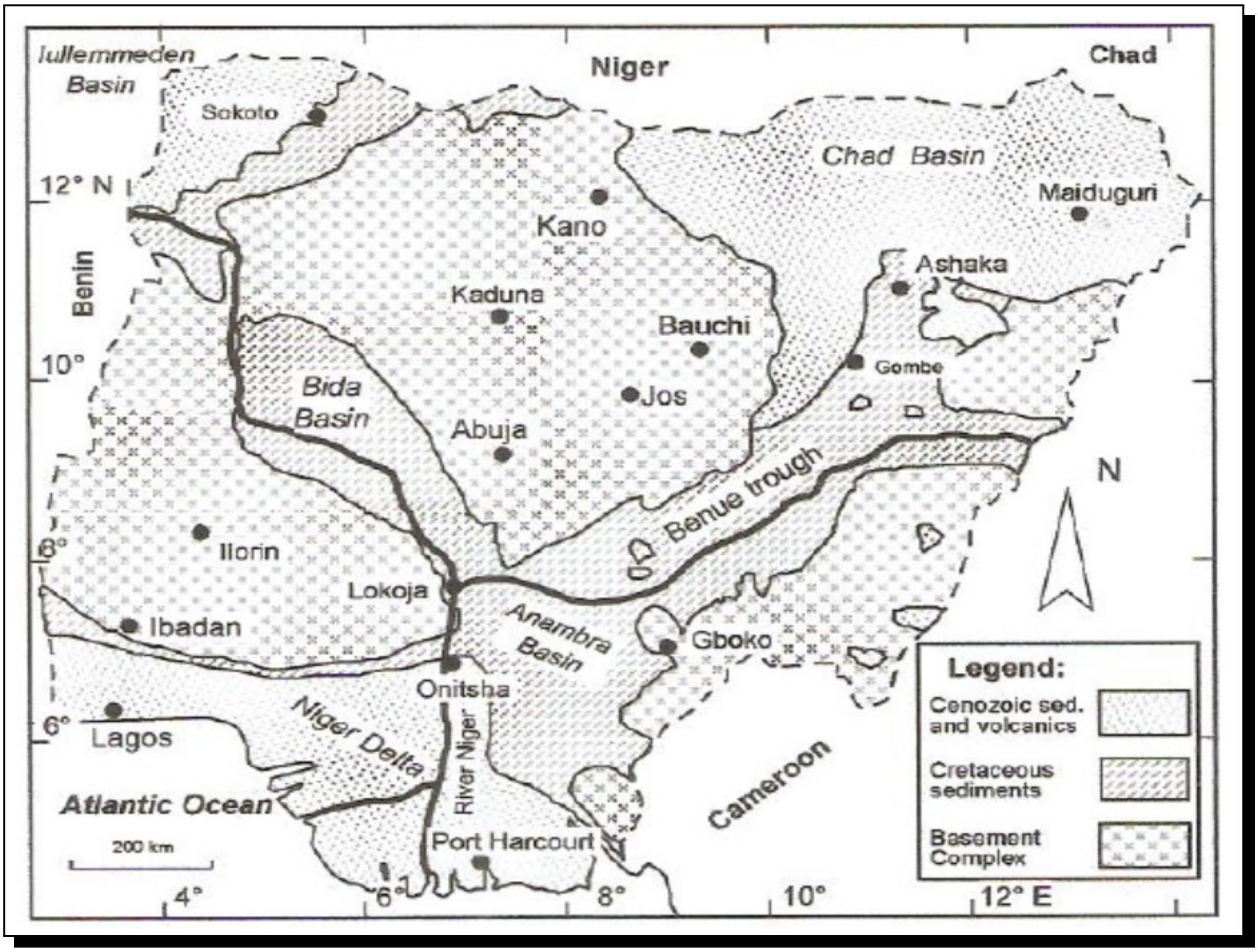

Figure 1. Generalized geological map of Nigeria including the basement complex and some sedimentary basins (Adapted from Adelana et al. [5])

In the Benue Basin, three broad hydrogeological groups were identified in the southern Benue Basin (Uma and Onuoha [41]; Adelana et al. [5]). These include the first hydrogeological group underlain predominantly by shaly formations. The thickness is in the range of 10 to 40 m and water levels are generally < 20 m. The second hydrogeological group consists of mainly sandy and shaly horizons with yield in the range of 3 to > 30 L/s while the lower hydrogeological group consists predominantly of sands, sandstones and clays. The upper Benue Basin has the Gombe Sandstone and Kerri Kerri Formations as the main aquifers. These aquifers consist of coarse grained and highly permeable materials. The Kerri Kerri aquifer has yield of 1.25 to 9.5 L/s (Akujieze et al. [9]).

The Nupe Basin contains significant groundwater resources with occasional artesian conditions. Good aquifers are present in the Tertiary and Quaternary sediments of the southern coastal areas (Benin and Niger Delta Basins). The water level varies between 0 and 9 m while, the specific capacities, were in the range 90 to 1400 m3/d/m, Offodile [26].

The groundwater storage in the crystalline basement is small. Groundwater availability is largely limited to fracture zones and areas of deep weathering (Ajayi and Hassan [7]; Olorunfemi [28]; Edet [13]; Edet and Okereke [15]; Edet et al. [14]; Okereke et al. [27]). Generally, the principal source of groundwater is from hand dug wells. Details on the hydrogeology of Nigeria are contained in Offodile [26], Akujieze et al. [9], BGS [11] and Adelana et al. [5]. A summary of the hydrostratigraphic units in Nigeria is presented in Table 1.

2.2 History of Groundwater Development in Nigeria

Adekile and Olabode [1] provided a history of groundwater development in Nigeria. Prior to colonization and up to independence most of the groundwater abstraction was from unlined hand dug wells. Between 1930 and 1933 the Geological Survey of Nigeria experimented and perfected the 1.2 m diameter lined dug well. In 1947, the Public Works Department took over the construction of rural water supplies. A cable tool rig was purchased and the first rural boreholes were constructed. Rotary water drilling was introduced into the country by Balakhany Chad (a British company) in 1951 mainly for drilling in township. The first major water supply drilling programme was between 1956 and 1962 when 280 boreholes were drilled in the north eastern part of the country to explore the artesian aquifers of the Chad basin. The drilling was carried out by government drillers and Balakhany Chad. Between independence and the beginning of the Water and Sanitation Decade in 1980, several other operators came into the country from Italy, Germany, Britain and Greece. In the mid-1980s when the Nigerian economy went into recession, some of the expatriates company closed down and left their equipment on lease to their local employees. Some of the employees who were laid off also set up their own drilling companies. Several water supply interventions involving borehole drilling have been embarked upon by the Federal Government or its agencies. Some of these are: National Borehole Programme (1981-1985), Department of Food, Roads and Rural Infrastructure (DFRRI) (1986-1992), Petroleum Trust Fund (PTF) Water Supply Project (1996-1999), Improved National Access to Water Supply and Sanitation (2000-2001), Presidential Water Initiative (2003-2009), Millennium Development Goals Water and Sanitation Projects (on-going).

Age	Benin Basin	Niger Delta Basin	S.E Benue Trough	N.E Benue Trough	Chad Basin	Nupe Basin	Sokoto Basin
Quaternary Pliocene Miocene Oligocene	Alluvial aquifer Deltaic aquifer Benin aquifer	Benin aquifer	Benin aquifer	Kerri Kerri aquifer	Chad aquifer Kerri Kerri aquifer	Patti aquifer	
Eocene	Ilaro aquifer Akimbo/Oshosun aquifers	Agbada aquifer	Ogwashi-Asaba aquifer Nanka sand aquifer Ameki aquitard				Gwandu aquifer Kalambaina aquifer Dange aquiclude Wurno aquifer
Paleocene	Imo Shale aquitard Ewekoro aquifer	Akata Shale aquitard	Imo Shale aquitard				
Maastrichtian Campanian	Nkporo Shale aquitard	Nkporo Shale aquitard	Nsukka aquitard Ajali Sandstone aquifer Mamu aquiclude Nkporo Shale aquitard Enugu Shale aquitard	Gombe Sandstone aquifer	Gombe Sandstone aquifer	Lokoja Sandstone aquifer	Dukumaje aquiclude Taloka aquifer
Santonian Coniancian	Abeokuta aquifer		Agwu aquitard Agbani Sandstone aquifer Amaseri Sandstone aquifer New Netim marl aquitard	Lamja Sandstone aquifer Numanha aquifer Sukuliye aquifer Jessu aquifer Gulani aquifer	Fika Shale aquitard		
Turonian Cenomanian			Ekenkpon shale aquitard Eze Aku aquitard Markurdi Sandstone aquifer Agala aquifer Ezillo aquifer Odukpani aquitard	Pindiga aquitard Yolde aquifer Bima Sandstone aquifer	Gongila aquifer Bima Sandstone aquifer		
Albian			Asu River aquitard				Illo-Gundumi aquifer/aquiclude
Pre-Abian	Basement Complex	Basement Complex	Basement Complex	Basement Complex	Basement Complex	Basement Complex	Basement Complex

Table 1. A summary of the hydro-stratigraphic units of Nigeria (Petters [35]; Offodile [26]; Akujieze et al. [9]; Adelana et al. [5])

Apart from the interventions listed above, there are others sponsored by external agencies. Also the various State and Local Government have been carrying out borehole programs Water well drilling activities is presently carried out in Nigeria by both public and private sectors. Manual drilling is now common in Nigeria and is well patronized. Hand drilling was introduced into the northern parts of the country in the early 80,s through the Fadama studies carried out by the World Bank to evaluate the irrigation potential of the alluvial aquifers of the floodplains of major rivers in the Northern parts of Nigeria. This technique which is otherwise known as hand turning has now been massively adopted as a method of exploiting groundwater for domestic needs in most of the states of Nigeria where the method is feasible. The hand drillers are presently being patronized by house holders and owners of small scale industries. Some are well educated and display some level of entrepreneurial skills. PVC casing and screen are manufactured locally. Steel casings and screens and drilling chemicals are imported and stocked by local dealers. Light and medium duty rigs using reconditioned engines are fabricated locally in Kano, Lagos, Kaduna, Ibadan, and in some other places in the country.

2.3 Innovative and Participatory Approach to Groundwater Governance

This provides a framework for both explicit representation of poor people in decision making and transparent consideration of trade-offs associated with different development pathways, such as small-scale irrigation versus intensive irrigation, also to evaluate governance processes under which groundwater can be used sustainably for poverty alleviation. For a workable democratic ideology, a national policy on every infrastructure needs regional and local administration to ensure its implementation. A regional framework is necessary to ensure an integrated policy approach, bringing together economic, social and environmental objectives leading to more effective policy-making. The governments need to set up regional development agencies to provide assistance with implementation and establish an integrated basis to be able to overcome water crisis which will alleviate water security in the communities. But a degree of flexibility in planning and implementation will always be necessary, because what may be seen as sustainable in one region of the country is not necessarily the solution in another, but principles remain the same.

Government must be committed to an overall strategy that will aim at economic prosperity, raising standards of living for its people, protects and enhance accessibility to good potable water. At state levels, there must be a framework which adopts an integrated policy approach that is based on appropriate action through community participation. Any water management system requires the support of an appropriate governance framework. A bottom-up approach seems the best way to achieve participatory management. Surface water irrigation communities constitute a good example. Thus, top-down control has proven insufficient in most places due to this intrinsic complexity of groundwater governance. This is the reason why user communities are often advocated as the most plausible solution to ensure adequate groundwater resources management. Groundwater user associations are still fairly scarce. In any case, since groundwater user associations are a relatively new feature, their ultimate implications on groundwater sustainability are yet to be seen.

According to Nwankwoala and Mmom [25] there is relationship between water availability and economic development in Nigeria. Availability of water is one of the factors controlling the distribution of population in Nigeria. Webb and Iskandarani [42] defined water security as an access by all individuals at all times to sufficient safe water for a healthy and a productive life. Water security is the absolute quality and quantity of water reliably supplied to perform cultural normal life. Water supply is however so important that no government can wave it off among the services to be rendered to the citizens. Indeed, there is no welfare service that impinges more closely upon the daily life of the people or that more readily arouse peoples interest than water. It was the recognition of the importance of water supply that led to the passing of a resolution emphasizing the need for potable water supply before the year 2000 at the United Nations Habitat Conference in 1976. Consequently, groundwater enhancement is the pivot on which democratic principles can be aligned for appropriate development.

3. Groundwater Recharge and Quantity

3.1 Groundwater Recharge

Nigeria is blessed with large quantity of groundwater resources. For instance, Rijswljk [36] estimated the amount of groundwater resource in Nigeria to be 6×10^{18} m^3. The total renewable groundwater resources potential in Nigeria is estimated at 155.8 billion cubic metres per year (BCM/year), derived from estimated total annual groundwater recharge (JICA [20]) Table 2. Recharge is variable across Nigeria, controlled largely by climate. For example, in northern Nigeria, recharge is low, due to low rainfall and high evapotranspiration. Recent estimates use a combination of simplified empirical equations, stream-flow hydrographs, water table fluctuations, base-flow recession methods (Adelana et al. [3, 4]) as well as chloride-based methods supported by stable isotope data (Adelana et al. [3, 4]). In the Crystalline basement of south western Nigeria, groundwater recharge conditions are crucial for understanding the groundwater flow regime and infiltrating conditions. Studies in north western Nigeria showed considerable depletion in isotopic content (18O and 2H) and low deuterium excess in groundwater, reflecting the contribution of old meteoric water that recharged the Cretaceous aquifers in Pluvial times (between 5000 and 15000 year BP) (Adelana et al. [2]). However, present day recharge has been demonstrated for the alluvial aquifer in the area. Estimates from chloride mass balance method confirmed recharge rates are unevenly distributed over the area. In the Chad basin in north east Nigeria, there was also isotopic evidence of palaeo-recharge in the deep confined aquifers.

Table 2. Estimated groundwater regional recharge (JICA [20])

Region	**Estimated Groundwater Recharge (BCM/year)**
Niger North (Northwest Nigeria)	5.0
Niger Central (West-central Nigeria)	20.5
Upper Benue (East-central Nigeria)	19.3
Lower Benue (East Nigeria)	18.6
Niger South (South-central Nigeria)	31.9
Western Littoral (Southwest Nigeria)	23.4
Eastern Littoral (Southeast Nigeria)	32.8
Chad Basin (North-east Nigeria)	4.3
Total	**155.8**

3.2 Groundwater Use and Management

Groundwater is widely used in Nigeria for domestic, agricultural and industrial purposes. The cities of Calabar (coastal south-eastern Nigeria) and Port Harcourt (capital of Rivers State, south Nigeria) are totally dependent on groundwater. A 1996 survey by the Ministry of Water Resources found only 63% of Nigerian boreholes was in working order, with many out of action due to pump failure (JICA [20]). This is related to the management structure for boreholes: most are meant to be managed by communities, but only around one fifth of rural communities were identified as having borehole management organizations, so that actual management, including restoring non-operational boreholes, is not optimum (Ministry of Water Resources [21]). In 2013, about 65,000 boreholes or other groundwater points were drilled in Nigeria. These boreholes extract groundwater estimated to be about 6,340,000 m^3/day (JICA [20]; Ministry of Water Resources [21]). Most of this is used for water supply in rural areas and for small towns. Rural water supply boreholes are usually installed with hand pumps, which have a maximum pumping capacity of 10 m^3/day.

The groundwater access points identified were:

- Boreholes with motorized pump: 19,758
- Boreholes with hand pump: 44,736
- Shallow hand-dug wells: 13,108

3.3 Groundwater Development and Utilization

Generally, boreholes drilled in the crystalline rocks of Nigeria have low yields and a reputation for failures. The performance of 256 boreholes drilled in different parts of the crystalline rocks of south west Nigeria were reviewed to determine their failure characteristics. One hundred percent success was claimed for 105 boreholes constructed by one driller. Out of 111 other borehole records supplied by three other drillers 35 were abortive, representing a failure rate of

32 percent. In contrast, 24 owners of 40 boreholes reported 24 failures representing a failure rate of 60 percent (Ajayi and Abegunrin [9]). Table 3 provides details of the boreholes drilled during the period 1989-2002. The common causes of borehole failure and poor yield in the crystalline rocks of south west Nigeria are seasonal variations in water level, improper casing of the overburden, damage to pumps and other system failures such as blocked pipelines and malfunctioning tanks (Adelana et al. [5]). Non-penetration into the water bearing horizon also features as a cause of borehole failure, especially where exploration techniques are not employed prior to drilling. Detailed explanation on the causes of borehole failure and increased failure rate are presented in the work of Fellows et al. [16].

There are up to 1,000 private sector drilling companies in Nigeria (UNICEF/WHO [40]). Drillers have realized the benefits of small light duty rigs and are using them where appropriate. Of the sampled rigs, 30 percent are made in Nigeria. Manual drilling was found to be more cost effective than mechanized drilling where feasible. Unfortunately, contract packages tend to be small, discouraging long term investment in equipment. Boreholes are often drilled deeper than they need to be and there is a tendency to specify geophysics on all drilling sites even where it is not necessary. The capacity for proper supervision in terms of experienced personnel and equipment is limited at state level, and post-construction monitoring is rarely undertaken. It is suggested that proper construction, operation and maintenance of boreholes will reduce the incidence of borehole failures in crystalline rocks of south west Nigeria.

3.4 Ground Water Distribution

The distribution of groundwater in Nigeria occurs through eight hydrological areas with water resources totaling 51,930 m^3. Among the hydrological zones, the first four made up of North West I, Central West II, Central East III and IV contained sizable ground water resources estimated at 4,340-8,180 and 6,990 to 4,390 m^3. The other group of hydrological areas referred to as the South East V, South West VI, VII and North East VIII also have significant ground water reserves valued at 7,150-9,020 m^3, and 6,280-5,580 m^3. In comparing the present level of demands for water with a total of 260 m^3 and water use rates of mostly less than single digits percentage points, note the large differences between the first four hydrological areas from North West to IV and the remaining hydrological areas from South East V to North East VIII. From the break down, the present demand levels shows the North West I, and Central West II at the identical levels of 20 m^3 while the water needs in Central East III and IV stands at 15 to 5 m^3. The larger demands for water consists of 30-70 m^3 and 40-60 m^3 for the second group of hydrological areas. Elsewhere, the corresponding water use rates ranged from 0.4-0.2 for North West I, Central West II and Central East III whereas the rates for unit 4 stood at 0.1. For the other hydrological unit areas (South East V and South West VI), their demand rates stood at 0.4-0.8 percentage points followed up by units VII and North East VIII with 0.7-1.0 % (Table 4).

In comparing the present trends in volume of water demand and usage rates to the year 2020, there exist substantial differences under the measured categories. Based on the demand and water use rate, under projected totals of 3,920 m^3 and 8% nationwide in 2020, note the initial variations in the distribution of ground water volumes (of 290-260, 300-180 m^3) for the northern hydrological areas. The overall water demand levels of the remaining groups of hydrological units at 730-830 and 710-620 m^3 for 2020 far exceeds the present levels by very considerable margins. The intense level of water use is evident with projected user rates of 7-3% and 4% for the prime group of hydrological units (North West I, Central West II, Central East III and IV).

Table 3. Statistics of borehole information in Nigeria (Adelana et al., [5])

Period		**Number of boreholes with screens**	**Success rate (%)**
1989-2002	16,827	13,903	93

Table 4. Distribution of Ground Water Resources in Nigeria

Hydrological Areas	**Ground water resources m^3**	**Present towards**		**Year 2020**	
		Demand m^3	**Water use rate %**	**Demand m^3**	**Water use rate %**
North West I	4,340	20	0.4	290	7
Central West II	8,180	20	0.2	260	3
Central East III	6,990	15	0.2	300	4
IV	4300	5	0.1	180	4
South East V	7150	30	0.4	730	10
South West VI	9,020	70	0.8	830	9
VII	6,280	40	0.7	710	12
North East VIII	5,580	60	1.0	620	11
Total	**51,930**	**260**	**0.5**	**3,920**	**8**

Source: Okoye, 2007

Among the southern group of hydrological units, both the South East and South West will see a water use rate of 10-9% followed by 12-11% usage rates for units VII and North East VIII. With that, it is clear that Nigeria faces severe water stress by 2020 considering the anticipated demands (Table 4). This could have very serious impacts on different life forms in the country's already fragile ecological zones spread across various regions.

3.5 Groundwater Management Institutions

There are many bodies with responsibility for groundwater management in Nigeria. They include the government agencies: Nigeria Hydrological Services Agency (NIHSA) whose mandate is water resources (groundwater and surface water) assessment of the country; its quantity, quality, availability and distribution in time and space; Nigeria Integrated Water Resources Management Commission (NIWRMC) that is responsible for regulation of water use and allocation; State's Ministries of Water Resources and their Rural Water Supply and Sanitation Agencies (RUWATSSAN), responsible for provision of water to their various States; River Basin Development Authorities, which are also parastatals of the Federal Ministry of Water Resources involved in the provision of water supply to rural environments within their catchments; and professional bodies:

The Nigerian Association of Hydrogeologists (NAH) is the professional body concerned with due process and best practices in the exploration, development and management of Nigeria's water resources. The NAH disseminates information on the state of the nation's water resources through annual conferences and a journal, Water Resources. Through membership of the Hydrology and Hydrogeology Subcommittee of the National Technical Committee on Water Resources (NTCWR), the technical arm of the National Council of Water Resources (NCWR), the NAH contributes to the development of water resources policies and legislation, including the Water Resources Act 100 and the Nigerian Standard for Drinking Water Quality, and is currently involved in their review and/or implementation.

The Nigeria Hydrological Services Agency (NIHSA), an agency of the Federal Ministry of Water Resources, has responsibility for groundwater monitoring. There is a national groundwater level monitoring programme with 43 monitoring points, 32 of which are equipped with data loggers. These are sited in basement and sedimentary aquifers. The frequency of monitoring at sites with data loggers is daily, and sometimes twice daily. NIHSA has implemented a programme of drilling new monitoring boreholes for monitoring groundwater level. The new boreholes so far are focused on sedimentary aquifers used for urban water supply; with borehole depths of 80 to 100 m (Ministry of Water Resources [21]). The groundwater level monitoring data are stored at NIHSA headquarters in Abuja. The NIHSA is also responsible for water quality monitoring, but as yet a full programme is not in place due to lack of equipment. The National Water Resources Master Plan recognizes current problems in the effective acquisition and management of groundwater data, and recommends strategies for improving this situation (Ministry of Water Resources [21]).

4. Efforts at Poverty Reduction

The Third National Development focused on development; that development should prevail simultaneously in all geographical areas of the country and emphasized that lagging regions can no longer be tolerated. Rural development involves conscious efforts to contribute to the overall rate of economic growth and the process of structural and attitudinal transformation of rural areas. Groundwater is a 'very popular commodity' with farmers. Since it is usually found close to the point-of-use (often only a well's depth away), can be developed quickly at low capital cost by individual private investment, is available directly on-demand for crop needs (given a reliable energy source for pumping) and thus affords small-holders a high level of control year-round, is well-suited to pressurized irrigation and high productivity precision agriculture, has 'democratized' irrigation by permitting irrigated agriculture outside canal command areas.

In developing and transforming nations the 'groundwater-irrigation boom' occurred at various economic levels from subsistence farming to large-scale staple-crop production and commercial cash-crop cultivation. It has brought major socioeconomic benefits to rural communities and in many countries has helped to alleviate agrarian poverty through increasing food security-by ensuring water availability at critical times for crop growth and mitigating devastating effects of drought on crop yields. In South Asia the groundwater boom has also largely been pro-poor, with marginal farmers of holdings smaller than 2 ha increasing their groundwater-irrigated area by three times more proportionally than farmers with more than 10 ha of land.

Groundwater resources tend to be undervalued, especially where their exploitation is uncontrolled-when the resource exploiter (in effect) receives the benefits of groundwater use but (at most) pays only part of the costs-and this undervaluation often leads to economically inefficient resource use.

Above all, government never considered qualitative and creative education as instrument that would reduce poverty. Even the 6-3-3-4 system, of which the first three years of a child's secondary education were to emphasize technical knowledge, was abandoned right from on-set. Government's efforts in 2002 to reduce poverty led to strengthening the National Poverty Eradication Programme (NAPEP) and perhaps the strategy for implementation. Budgetary allocation to the core poverty eradication ministries and agencies totalled N132.47 billion, was pooled into the Poverty Eradication Fund.

Water is very essential for food production as well as essential for plant growth. Water is needed for seeds to germinate, seedlings to emerge and for many plant growth functions. When water for plant growth is controlled by irrigation, average yield under comparable climatic conditions are generally higher than those obtained under rain fed conditions. Because yield on irrigated lands are higher and more consistent, water plays an important role in food production. The ever-increasing cost of foods in Nigeria is due to over dependence on traditional agriculture practice, which is mainly rain fed. Irrigation can help to increase food production if it is well embraced particularly where there is a general trend indicating decline in farming population.

The World Water Development Report (WWDR), states that the problems of poverty are inextricably linked with those of water – its availability, its proximity, its quantity and its quality. Improving the access of poor people to water has the potential to make a major contribution towards poverty eradication. The Millennium Development Goals Report (MDGR) of 2006 in Nigeria shows that there is a likelihood of achieving three of the eight goals in Nigeria; achieving universal basic education; ensuring environmental sustainability; and developing global partnership for development, while the health and poverty eradication MDG's remain daunting challenges for Nigeria.

The Obasanjo administration's, constituency projects were conceived, planned, designed and implemented by the relevant federal Ministries, Departments and Agencies (MDAs), and sponsored by members of the National assembly, each of whom was actively involved in identification and siting of the scheme(s) in their individual constituencies. However, a radical departure from this in the Yar'Adua administration saw to the delegation of this responsibility to the office of the Senior Special Assistant to President for the Millennium Development Goals (OSSAP-MDGs) under the title "2008 Quick Wins MDGs (QW-MDGs) Projects". In order to improve project delivery and achieve higher success rates, the OSSAP-MDGs has elected to utilize the significant resource base of indigenous architectural, engineering and quantity surveying consulting firms to contribute to the efficient, honest and timely execution of the 2008 QW-MDGs projects. It is no exaggeration that safe water supply underpins the achievement of most of the other MDGs. There can hardly be substantial human development without access to safe water; most classrooms will remain empty with pupils out looking for water, most hospital facilities will be stretched to the limit with people suffering preventable diseases as a result of poor water and sanitation facilities. Provision of water and sanitation should therefore be considered as the driving force of the poverty reduction programs of the government. One of the greatest contributions of water to the human development is health improvement and reduction in the time needed to search for water. It means that access to safe water will ensure the physical wellbeing of man and free his time for other activities and pursuits that will contribute to his economic freedom and that of the country at large, pupils will go to school on time, have time to read, women will have more time to be engaged in productive economic activities and infant mortality will be drastically reduced.

The MDG's programme effectively commenced in Nigeria in 2005, meaning it was already five years late, also the country had not been fulfilling its financial commitment of one billion dollars annual allocation to its implementation. The QW-MDGs 2008 Projects was effectively expected to commence on the 27th August 2008 with the programme preparation/initializing phase and to be completed on 30th June 2009 with the programme wrap-up/completion activities. The program has only attained between 60-70%, completion with some sites even yet to be surveyed. Unlike other sectors which are mostly construction that involve just one or two professionals with others often being artisans, borehole drilling is a specialized operation that requires specialized machines/tools and experienced experts. The machines and tools must suit the local geology and professional expertise must be combined with experience of the driller for any meaningful success to be achieved. Most boreholes failed as a result of inadequate drilling machines and tools and lack of professional experience by the contractors who are local based.

The main objectives of the water supply programme are to provide expanded access to safe drinking water for Nigerians (especially rural and semi-urban residents), thereby reducing incidence of water borne diseases; and also to provide water for livestock and other uses thereby increasing food production. Implementation of the 2008 QW-MDGs programme involved a number of organizations interacting at different levels with the Federal Government being the main client. Others include the National Assembly (NA), the Programme Steering Committee (PSC), the MDAs, the National Management Consulting (NMC), the State Project Consultants (SPCs), and the Contractors/Suppliers.

The National Management Consultant (ETAT Consulting Ltd) oversees the contractor/supplier selection process through the tender process, prepares the project designs, bills of quantities and other operational guidelines. The NMC generally monitors and control the implementation of the project in accordance with the approved design, schedules and specifications, and within the agreed contract price. The National Steering Committee (NSC) is the body set up by the federal government to oversee the entire activities of the MDG's, the committee works in conjunction with the National Assembly and the Ministries, Departments and Agencies (MDA's) in determining projects to be carried out under the programme. The Office of the Senior Special Assistant to the President on MDG's (OSSAP-MDG's) is the implementation arm of government that executes the projects determined by the NSC, this it does through the National Management Consultant (NMC) who in turn is responsible for State Project Consultants (SPCs) in each state. A critical barrier to planning for achievement of the MDG's continues to be the availability of up-to date data on most of the indicators. This is compounded by the limited funding available for data generation and management. But more importantly, the push to improve water supplies through the MDGs is thus a great contribution in the fight to combat poverty.

4.1 Groundwater Supplies on Livelihood Improvement

The push to improve groundwater supplies through the Millennium Development Goals is thus a great contribution in the fight against poverty. The Millennium Development Goal 7, Target 10 concerns increases in coverage of water supply-serving the un-served. This means more sources, more construction, and more capital investment. Achieving higher coverage through groundwater development requires better hydro-geological understanding for improved siting, reduced construction costs, and increased overall investment. The chronic poor (below the poverty line for 5 years or more) are naturally the most vulnerable in terms of security and survival-when disasters such as drought strike, they have the least protection. Long-term support that is able to lift people out of chronic poverty must reduce vulnerability and improve chances of survival. Thus, self-initiated approaches (also known as self-supply) are alive and well. Interventions to support such local initiatives offer significant promise, as they build on people's own attempts to solve their water problems, thereby enhancing ownership and the potential for long-term sustainability. Enterprise-response to user-demand approach combines technology innovation, small enterprise development, and market stimulation (or demand creation), to provide locally sustainable solutions to the water problems of farmers, households and communities.

4.2 Groundwater Sustainability and Impacts

Sustainable groundwater resources development implies use of groundwater as a source of water supply, on a long term basis, in an efficient and equitable manner sustaining its quality and environmental diversity. An understanding of the behaviour of a groundwater system and of its interaction with the environment is required to formulate a sustainable management and development plan to enhance its impacts. The sustainability of groundwater resources is a function of many factors, including decreases in groundwater storage, reductions in stream flow and lake levels, loss of wetland and riparian ecosystems, land subsidence, saltwater intrusion, and changes in groundwater quality. Each groundwater system and development situation is unique and requires an analysis adjusted to the nature of the water issues faced, including the social, economic, and legal constraints that must be taken into account. A key challenge for achieving groundwater sustainability is to frame the hydrologic implications of various alternative management strategies in such a way that they can be properly evaluated. “If sustainable development is to mean anything, such development must be based on an appropriate understanding of the environment-an environment where knowledge of water resources is basic to virtually all endeavours”.

The better-known (and widely contested) meaning of sustainability was given by the United Nation’s Commission on Sustainable Development in 1987: ‘to satisfy current needs without compromising the needs of future generations’. It defined sustainable development as “development which meets the needs of the present without compromising the ability of future generations to meet their own needs”. Water resources projects are sustainable, if water of sufficient quantity and quality at acceptable prices is available to meet demands and quality standards of the region now and in the future without causing the environment to deteriorate.

The goal of environmentally sound and sustainable development of groundwater resources is to develop and manage them in such a way that the resource base is maintained and enhanced over the long term. The following key principles reflect different aspects of concern in the evolution of sustainability in groundwater development: long term conservation of groundwater resources; protection of groundwater quality from significant degradation; and consideration of environmental impacts of groundwater development.

4.3 Groundwater Supply Sustainability for Lasting Poverty Reduction

Water constitutes the most important resource to man. The domestic requirement of water varies with the level of economic development of an individual. According to Gleick (2003) an overall basic water requirement of 50 litres of water per person per day as a minimum standard is required to meet four basic needs (drinking, sanitation, bathing, and cooking). The amount of water that people use does not depend only on minimum needs and how much water is available for use but on the level of economic development and extent of urbanization shouldering around democratic advancement. Freshwater demand per capita is rising substantially as countries develop economically. Withdrawals of water have grown tremendously beyond meeting the rising industrial demand, domestic demand and reliance of irrigation to produce of food. The level of water use reflects the level of urbanization in a country. Low household water use in developing countries today reflects difficulty in obtaining freshwater. Majority of people in developing countries get their water from public standpipes, community wells, rivers and lakes, or rainfall harvested off roofs. Water security in this aspect, is not only a commodity but also a natural resource and a perceived human entitlement. Water ranks higher than any other infrastructure in the survival and welfare of humanity.

A distinction must be made between developed and developing regions. Today, about one thousand million people live under the poverty threshold (i.e., those people who make a living with less than one dollar per day; whereas another two and a half thousand million make less than two dollars per day). While access to drinking water is often said to be related to poverty, very few studies show the potential importance of groundwater resources in reaching another of the United Nations Millennium goals: halving the number of people who suffer from malnourishment by 2015.

However, groundwater is already playing a key role on that front. Take for instance India, where groundwater irrigated surface has increased by over forty million hectares during the last decades. Largely as a consequence, India has not only achieved food security in practice, but has also become an important grain exporter, all these despite doubling its population in the last half century. This is an example of the 'more crops and jobs per drop' motto, which groundwater is generally more likely to achieve than surface water irrigation. However, this is not necessarily applicable in developed countries, where 'more cash and environment per drop' is probably more in touch with reality.

On groundwater use and social sustainability, groundwater irrigation has proven an excellent catalyst for the positive social transition of farmers in arid and semiarid regions worldwide. This is largely a consequence of groundwater's resilience against drought. Secured access to water during dry periods removes a sense of risk from farmers' minds. Thus, they are more willing to invest in new technologies, both from the agricultural (selective seeds, agrochemicals) and the technical point of view (drip irrigation). This results in increased revenues and allow for a greater degree of social welfare. In addition, farmers become able to provide a better education for their children, who may either move on to other economic sectors or return to agriculture with a more productive outlook. Issues of social justice may arise in some situations. For example, in some areas of India, deep boreholes drilled by wealthier farmers have caused the water table to drop below the reach of shallow wells, which are generally owned by the less resourceful. However, this seems to be a transitory state. In fact, rich farmers end up selling excess water to shallow-well owners. Since supply is seemingly large enough to ensure a competitive market, the less resourceful have access to water at reasonable prices. This allows them to continue making a living out of irrigation, while getting wealthier in the process. After a few years, poor farmers have been able to drill their own deep wells.

4.4 Groundwater for the Future

Groundwater could contribute to increasing future water demand and developmental growth by upgrading existing borehole infrastructure, switching from hand pumps to motorized pumps (JICA [20]). Several factors such as over-abstraction leading to water level decline and boreholes drying up, contamination of groundwater resulting from sea water intrusion and infiltration of domestic and industrial contaminants are affecting both yield and quality of groundwater in Nigeria: Modelling by JICA [20] suggested that climate change would lead to an overall decline in groundwater recharge in Nigeria, with the impact most likely greatest in the North Niger and Chad basins. This modelling suggested declining groundwater levels would occur, leading to previously productive boreholes becoming dry.

In Nigeria water resources, including rain harvesting, surface water and groundwater are obtainable in varying quantity from place to place. The least of these is the groundwater source, yet it is the most abundant, most reliable and cheapest to harness. While access to drinking water is often said to be related to poverty, very few studies show the importance of groundwater resources in achieving the United Nations Millennium Goals: halving the number of people who suffer from malnourishment by 2015.

Groundwater irrigated surface has increased by over forty million hectares during the last decades. Largely as a consequence, Nigeria can achieve food security in practice and become an important grain exporter. Groundwater irrigation has proven an excellent catalyst for the positive social transition of farmers in arid and semiarid regions worldwide. This is largely a consequence of groundwater's resilience against drought. Secured access to water during dry periods removes a sense of risk from farmers' minds. Thus, they are more willing to invest in new technologies, both from the agricultural (selective seeds, agrochemicals) and the technical point of view (drip irrigation). Increased revenues result, and allow for a greater degree of social welfare. In addition, farmers become able to provide a better education for their children, who may either move on to other economic sectors or return to agriculture with a more productive outlook.

Groundwater education appears a must, not only aiming at high level water decision-makers, but also at the general public and more importantly to farmers (generally the main groundwater users and polluters). Generally speaking, water managers and decision-makers have traditionally been trained to build and operate large surface water infrastructures. As a result, the importance of groundwater resources is often overlooked or even disregarded. This may provide an explanation for the generalized lack of accurate groundwater data. Besides, it appears to be the reason of the huge gap that currently separates water decision-makers from the main actors. Last, but not least, corruption is increasingly recognized as a potential 'cancer' for democratic systems. Water resources are not an exception. As stated by the Valencia Declaration, groundwater is less prone to corruption than large surface water infrastructures. This obeys two main reasons. First, implementation of groundwater development presents a comparatively shorter timeframe (often weeks or months in comparison with several decades taken to implement a surface water system based on dams and canals). Second, investments in groundwater development are generally much smaller, and usually carried out by individuals with little or no public funding. In contrast, large surface water infrastructures frequently require significant public subsidies or donations from international organizations. This setting (long implementation time, significant funds) allows more room for unethical practices. User participation requires a degree of hydro-geological education which is still absent in most places in Nigeria. Steps should be taken to make the peculiarities of groundwater resources known to all, from politicians and water decision makers to direct users as well as the general public. This should begin at the school level. Appropriate groundwater management requires a significant degree of trust among stakeholders. This implies that groundwater data should be transparent and widely available (via the internet, for instance). In addition, the system should be able to punish those who act against the general interest.

Existing groundwater data is often scarce or laden with uncertainty. This is largely a consequence of the relative novelty of intensive groundwater development, a phenomenon that has only become commonplace in the last four or five decades. Secondly, intensive groundwater use has been often carried out with little or no planning or control on the part of public water agencies, leading to chaotic development in most cases. Causes should be found in the historical past: for thousands of years (although more particularly in the 19th Century), water managers and decision makers have been trained to build and operate surface water infrastructures, while 'invisible' groundwater resources have received less attention. On the other hand, the private initiative has traditionally been the main driving development, particularly in arid and semiarid regions where irrigation is necessary for agriculture. Millions of farmers, modest for the most force behind intensive groundwater part, today drill their wells and pump groundwater at their own expense. Uncontrolled drilling and pumping has led to problems in some places. While some of these constitute an undeniable matter of concern, the majority have been magnified due to ignorance, institutional inertia, vested interests and corruption.

4.5 Impact Pathway

Based on our theory of development and anticipated outputs, there would be two major impact pathways (Figure 2). One would be through the creation of knowledge products of high scientific value with clear messages that will help pull the two most important levers required for desired change in groundwater management – namely, the indirect lever of policies outside the groundwater sector and direct lever of program implementation within sector.

The second will be through changes in the discourse surrounding the formal groundwater management agencies from their current mode of resource monitoring to a mode of natural resource management. The prime target audience will be key policy makers in the sector so that they can institute the required changes that would be needed to meeting our overarching goals of better groundwater governance for poverty alleviation and livelihoods security through groundwater development schemes.

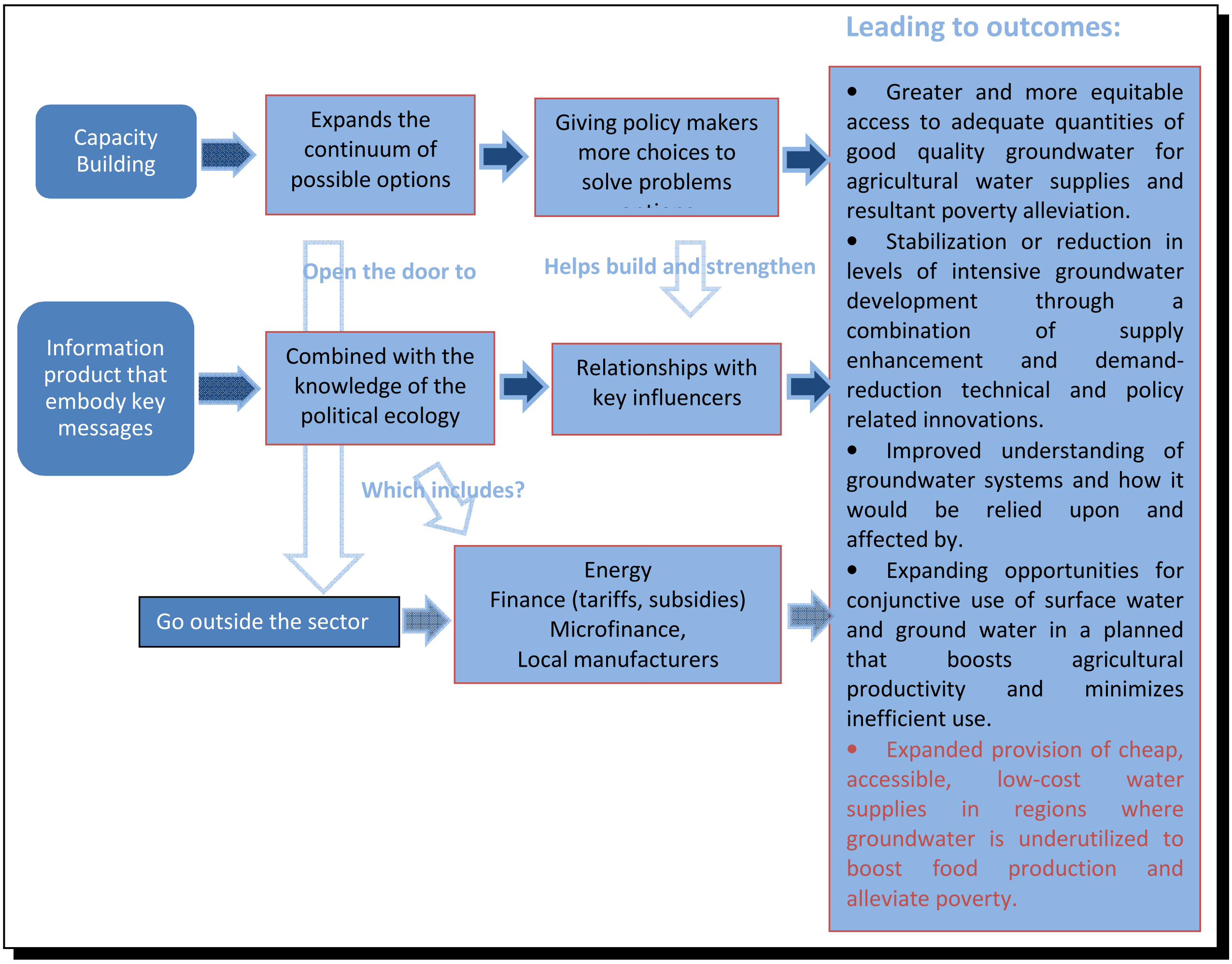

Figure 2. Impact Pathways for Sustainable Use of Groundwater
(Source: Best Bet: Groundwater, Groundwater governance for poverty alleviation and livelihoods security (page 90) **source details incomplete, please complete the cited reference**)

4.6 The leading Piece of Resource in the Fight against Poverty in Nigeria

There are no examples of communities that have eliminated poverty without first solving their scarce and contaminated water issues. By creating access to groundwater to literally millions of people, prosperity is enabled to take hold. Water makes every other humanitarian project better. In most developing regions there is not a lack of water only a lack of access. In Nigeria groundwater development is fast emerging the leading piece of resource in the fight against poverty. It has immensely contribute to agricultural development, thereby limiting food scarcity, also it has influenced the design and construction of many engineering facilities such as dams, roads, buildings and waste disposal sites. The knowledge of groundwater and its development in Nigeria has limited the rate unemployment in the country as many individual now source their livelihood from controlled groundwater assessment and management services, borehole drilling and several federal government groundwater schemes. In the last fifteen years, a remarkable increase in the number of privately owned. There has been an increase in the individually owned and operated boreholes within in many states because it is claimed that government owned boreholes breakdown too often. In Nigeria, groundwater has impact audibly the following areas

Empowerment: Groundwater development has created significant social and economic impact; empowering individuals and communities in Nigeria by providing a cost effective method of accessing clean water reserves. Although countless organizations work every day to bring clean water to those that need it, most do so at an incredibly high cost, why some are still affordable.

Creating Jobs and Businesses: Groundwater accessibility greatest feature is its ability to be owned, managed and maintained by local entrepreneurs. For example, Groundwater has led to the emergence of several borehole drilling organizations, in many states in the country; a drilling team is usually operated by about 8 people. This has proved to be the best tool to combine enough strength, simplicity and durability and enable individuals the ability to run a successful and profitable drilling business. The Low cost and robust nature of the drills has allowed entrepreneurs to create a viable drilling business that was nearly impossible with other manual drilling methods. Figure 3 shows the project states and areas where hand drilling is known to operate, it is estimated that of the 30,000 hand drilled wells in Nigeria, and approximately 20,000 were constructed for water supply in the major cities of the country. These are mostly in the southern cities of Lagos, Benin, Warri and Port Harcourt. In addition to the numerous locations for hand drilling shown, shallow alluvial aquifers also occur along the floodplains of major rivers which are exploited for both irrigation and water supply.

Economic Independence: Communities and individuals with access to groundwater now grow healthier crops, and their children can now go to school, and refrain from hours previously spent fetching water at the streams and other sources.

Improved Health and Standard of Living: In Nigeria Groundwater wells has proved advantageous over open water sources in the near elimination of malaria, typhoid and other water related diseases, because there is not a breeding ground for mosquitoes. Also gastrointestinal diseases and other water related diseases have been reduced to nearly zero in Nigeria.

Increases Farming Yields: With access to groundwater and irrigation there has been increase in farmland yields and also farmlands now have an additional growing season during the normally dry months. It is estimated that of the 30,000 manually drilled wells in Nigeria, over 10,000 have been constructed for irrigation. The presence of groundwater resources at shallow alluvial depths plays a key role. The aquifers are recharged annually with the onset of the rain and river flow.

Reduction in Water Borne Diseases: Quality groundwater access in Nigeria has helped to reduce water borne illness which includes cholera, dracunculiasis, hepatitis, typhoid and filariasi caused by various bacteria, virus, protozoa and pathogenic microorganisms and usually occurs as a result of poorly treated drinking water and wastewater or a natural disaster, like flooding and environmental pollutants common to surface waters. Thereby eradicating water borne and water related diseases in the rural areas, hence helping to raise a healthy and more productive people.

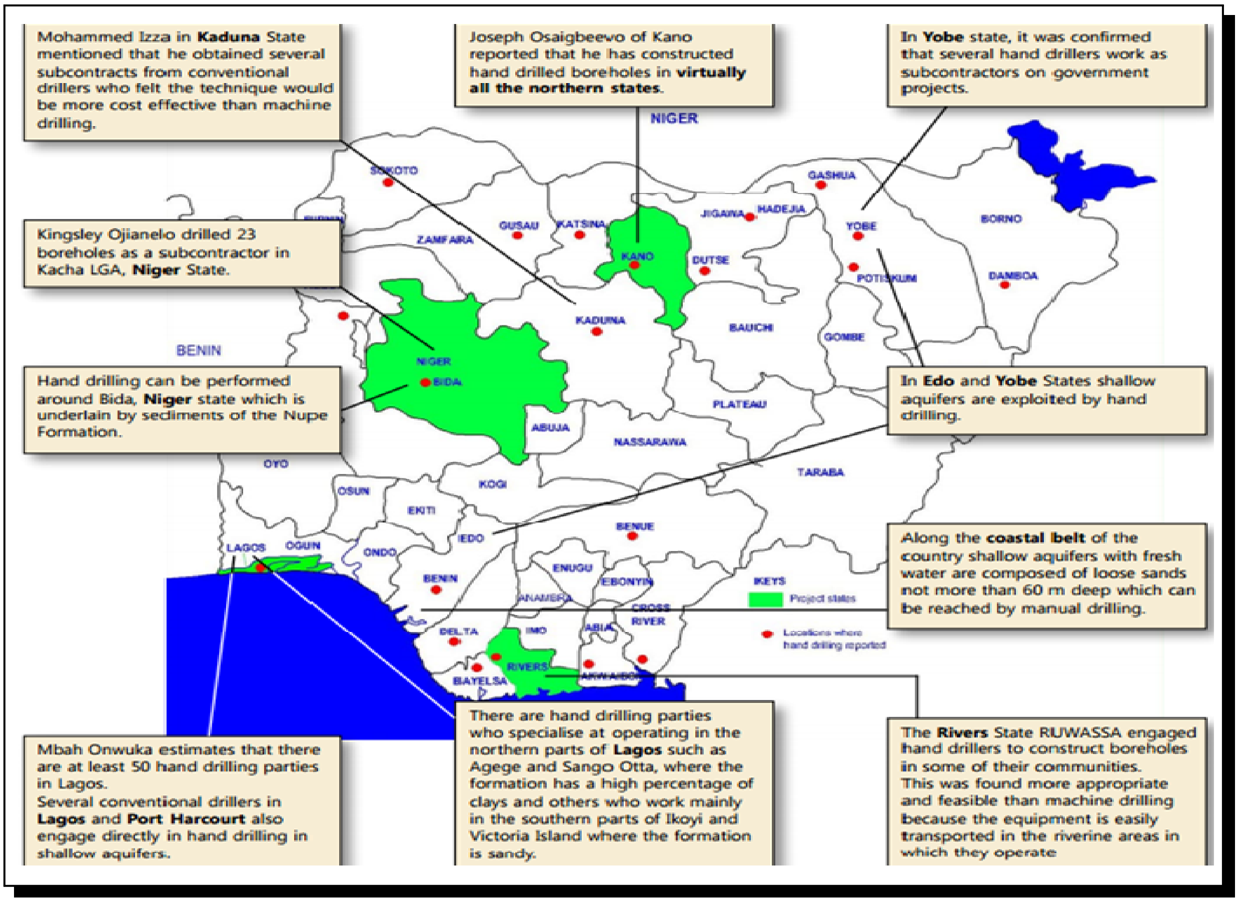

Figure 3. Project States and areas of hand drilling prevalence

Capacity Building: The Federal Government of Nigeria set up the National Water Resources Institute in 1977. The Institute is responsible for conducting training courses for all cadres of man power development for the water industry. Apart from regular programmes of the Institute the Institute conducts courses in groundwater related areas such as borehole sitting, drilling technology, construction and management, rehabilitation and development, and hand pump installation and maintenance

The Institute also runs outreach training courses which provide on the job training for staff of particular agencies at their location. The National Water Resources Institute is also carrying out a project on Standardization of Water Well Drilling Rig Fabrication including Development of Rig Fabrication Models. The project which is in line with the Reformation and vision 20/20 of the Federal Government, principally aimed at standardizing the design and processes for local water well drilling rigs fabrication; building indigenous capacities on fabrications of water well drilling rigs; and ensure availability of standardized spare parts for local fabrication of water well drilling rigs. These efforts of the government are in realization of tackling the enormous challenges of groundwater development

5. Conclusion and Recommendation

Groundwater supplies have being found to be very feasible and the most economic source of potable water for rising rural population, its impacts in Nigeria cannot be over-emphasized. The provision of groundwater supplies for agriculture and cottage industries has raised the rural standard of living and reduce poverty. It is a well-known fact that groundwater basins are difficult to govern and manage, partly because of poor information, and also because of poor visibility of the resource, the need for reliable data and accurate information and appropriate expertise in support of water resource planning is central to any strategy. To this end, there is a serious need to strengthen groundwater-related research and educational programs. Monitoring of groundwater resources of the country in quantity and quality should also be pursued as integral component of the various water resources development programs and projects.

The scale of Nigeria's social, economic and environmental reliance on groundwater to invest in strengthening efforts to improve scientific understanding and to develop governance systems and management institutions before substantial portions of the groundwater resource are degraded should be acknowledged. This is vital to assure and sustain the improvements in human livelihoods, food security and poverty alleviation/reduction and if further progress is to be made towards achieving water-dependent targets within the Millennium Development Goals. A functional sustainability of groundwater development requires better understanding of the renewable resources involved (i.e., groundwater recharge), improved construction supervision practices, and efficient maintenance, repair and rehabilitation arrangements for pumps and boreholes.

Poverty is understood to be more complex and multi-dimensional than simply a lack of income, reflecting both severity (depth below the absolute poverty line of #500 a day) and duration of poverty. The concept of Groundwater as a resource for poverty alleviation provides a helpful integrated conceptual frame work for understanding poverty. Poverty needs to be understood from the point of view of the poor. Groundwater's potential contribution to the enhancement of livelihoods and poverty reduction is great, although not without challenges and gaps in our existing understanding. One opportunity is the reduction of the costs of conventional (mechanized) drilling and a Second, development, promotion and uptake of very low-cost well construction techniques through indigenous small-scale private enterprise. This requires better knowledge of groundwater recharge, enhanced construction quality, and more effective maintenance procedures.

Quite unfortunately, in spite of the fundamental role groundwater plays in human well-being, as well as that of many ecosystems, it is yet to be fully appreciated and adequately managed and protected, both within the country and regionally. The government policy should be aimed at programmes and infrastructures that enhance basic and daily life needs of her citizens, it is often considered that top-down infrastructural programmes are not sustainable and begins to fold immediately after commissioned. If such are the reasons, the governments of the day need to be committed to the fundamental requirement thereby initiating dynamic bottom-up initiatives and approaches. Successive governments in Nigeria should continue to maintain and improve on the ongoing projects established by their predecessor. In this concept, Dun-Gwom, 1999 based good democratic governance of resources on management which deals with the effective care, prudent use of and conservation of resources to meet present and future needs of man in maintaining a good quality of life. The concept of partnerships as a model for planning and management of water resources in the 21st century is appropriate and advocated. Poverty causes lack of regard for constituted authority as it breeds hunger, social rejection and dejection, and at the extreme case, armed robbery. The issue of poverty alleviation should be taken with all amounts of seriousness it deserves and not ordinarily paying lip-service to it. Therefore, the suggestions advocated in this paper, if sincerely implemented, have the potential of reducing poverty in Nigeria. More importantly, special attention should be given to improving knowledge and assessing the total benefits and costs of using groundwater in poverty alleviation.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

References

[1] D. Adekile and O. Olabode, *Study of Public and Private Borehole Drilling in Nigeria*, `http://rwsn.ch/documentation/skatdocumentation.2017-05-16.3173940374` (2009).

[2] S.M.A. Adelana, P.I. Olasehinde and P. Vrbka, Groundwater recharge in the Cretaceous and Tertiary sediment aquifers of northwestern Nigeria, using hydrochemical and isotopic techniques, in E. Bocanegra, D. Martinez and H. Massone (eds.), *Groundwater and Human Development*, Mar de Plata, Argentina, pp. 907 – 915 (2002).

[3] S.M.A. Adelana, P.I. Olasehinde and P. Vrbka, A quantitative estimation of groundwater recharge in parts of Sokoto Basin, Nigeria, *Journal Environmental Hydrology* **14** (5) (2006), 1 – 17.

[4] S.M.A. Adelana, P.I. Olasehinde and P. Vrbka, Identification of groundwater recharge conditions in crystalline basement rock aquifers of the southwestern Nigeria, in *Special UNESCO Volume: Recharge systems for protecting and enhancing groundwater resources*, IHP-VI, Series on Groundwater No. **13**, 649-655, UNESCO, Paris (2006).

[5] S.M.A. Adelana, P.I. Olasehinde, R.B. Bale, P. Vrbka, A.E. Edet and I.B. Goni, An overview of the geology and hydrogeology of Nigeria, in S.M.A. Adelana and A.M. MacDonald (eds.), *Applied Groundwater Studies in Africa*, IAH Selected Papers in Hydrogeology, Vol. **13**, 171 – 197, CRC Press/Balkema, London (2008).

[6] W.A. Abderrahman, Should intensive use of non-renewable groundwater resources always be rejected? in R. Llamas and E. Custodio (eds.), *Intensive Use of Groundwater: Challenges and Opportunities*, Balkema, Rotterdam, The Netherlands, pp. 191 – 203 (2003).

[7] C.O. Ajayi and M. Hassan, The delineation of the aquifer overlying the basement complex in western part of the Kubanni Basin of Zaria (Nigeria), *Journal of Mining and Geology* **26** (1) (1990), 117 – 125.

[8] O. Ajayi and O.O. Abegunrin, Borehole failures in crystalline rocks of south-western Nigeria, *Geojournal* **34** (1994), 397 – 405.

[9] C.N. Akujieze, S.J.L. Coker and G.E. Oteze, Groundwater in Nigeria-a millennium experience, distribution, practice, problems and solutions, *Hydrogeol. J.* **11** (2003), 259 – 274.

[10] An integrated approach to sustainable groundwater development and management in Nigeria (PDF Download Available), available from: `https://www.researchgate.net/publication/228410802_An_integrated_approach_to_sustainable_groundwater_development_and_management_in_Nigeria` [accessed May 23, 2017].

[11] British Geological Survey, *Reay. Sheet 115E* (Scotland), Bedrock and Superficial Deposits, 1:50 000 Geology Series (Keyworth, Nottingham: British Geological Survey) (2003).

[12] J.Y. Dun Gwom, Partnerships in Planning and Environmental Management in Nigeria, *Journal of Environmental Sciences* (1999), p. 3.

[13] A.E. Edet, *Hydrogeology of parts of Cross River State, Nigeria: Evidence from Aero-Geological and Surface Resistivity Studies*, PhD Dissertation, University of Calabar, Calabar, Nigeria, p. 316 (1992).

[14] A.E. Edet, C.S. Okereke, S.C. Teme and E.O. Esu, Application of remote sensing data to groundwater exploration: A case study of Cross River State, south-eastern Nigeria, *Hydrogeol. J.* **6** (1998), 394 – 404.

[15] A.E. Edet and C.S. Okereke, Assessment of hydrogeological conditions in basement aquifers of Precambrian Oban massif, south-eastern Nigeria, *J. Appl. Geophy.* **36** (1997), 195 – 204.

[16] L.K. Fellows and M.J. Farah, Ventromedial frontal cortex mediates affective shifting in humans: evidence from a reversal learning paradigm, *Brain.* **126** (2003), 1830 – 1837.

[17] P.H. Gleick, Global freshwater resources: Soft path solutions for the 21st century, *Science* **302** (2003), (1524).

[18] N.P. Iloeje, *A New Geography of Nigeria*, Longman, Nigeria, p. 201 (1981).

[19] S. Janakarajan and M. Moench, Are wells a potential threat to farmers' well-being? Case of deteriorating Groundwater Irrigation in Tamil Nadu, *Economic and Political Weekly* **16** (September 2006), 3977 – 3987 .

[20] JICA, *The project for review and update of Nigeria national water resources master plan*, Vol. *2*, Japan International Cooperation Agency: Yachiyo Engineering Co., Ltd.; CTI Engineering International Co., Ltd.; Sanyu Consultants Inc. [JICA report PDF] (2014).

[21] Ministry of Water Resources, *National Water Resources Master Plan* (2013).

[22] M. Moench, Groundwater and Poverty: Exploring the Connections, in: Llamas MR (2003).

[23] S. Menon, Groundwater management: need for sustainable approach, in *Proceedings of the seminar on Artificial Recharge of Groundwater*, December, 1998, Central Groundwater Board, Ministry of Water Resources, New Delhi (1998), www.wikipedia.org.

[24] A.N. Ndem, *Poverty to Sustainable Development (A Community-based Approach)*, University of Calabar Printing Press, Calabar, Nigeria (2008).

[25] H.O. Nwankwoala and P.C. Mmom, Groundwater utilization versus millennium development goals: Implications for sustainable development, *Journal of Nigerian Environmental Society* **4** (2008), 34 – 42.

[26] M.E. Offodile, *Groundwater Study and Development in Nigeria*, Mecon Services Ltd, Jos, Nigeria (2002).

[27] C.S. Okereke, E.O. Esu and A.E. Edet, Determination of potential groundwater sites using geological and geophysical techniques in the Cross River State, southern Nigeria, *J. Afr. Earth Sci.* **27** (1) (1998), 149 – 163.

[28] M.O. Olorunfemi, The hydrogeological implication of topographic variation with overburden thickness in basement area of S.W. Nigeria, *J. Min. Geol.* **26** (1) (1990), 145 – 152,

[29] M.E. Offodile, *An Approach to Groundwater Study in Nigeria*, Mecon Services Ltd., Jos, Nigeria, p. 247 (1992).

[30] G.E. Oteze, Management approaches for Nigeria's water resources, *J. Min. Geol.* **42** (1) (2006), 15 – 20.

[31] O.E. Oteze, Management approaches for Nigeria's water resources, *Nigeria J. Mineral Geol.* **42** (2006), 21 – 30.

[32] L. Oyebande, Power generation and development in the Nigeria's power sector, *Int. J. Hydropower Dams* **6** (2004), 213 – 219.

[33] U.C. Okoye and E.O. Onyukwu, Sustaining poverty reduction efforts through inter-agency collaboration in Nigeria, in K. Omeje (Ed.), *State, Society Relations in Nigeria: Democratic Consolidation, Conflicts and Reforms*, pp. 49 – 66, London (2007).

[34] M.O. Oyawoye, The Basement complex of Nigeria, in T.F.G. Dessauvagie and A.J. Whiteman (eds.), *African Geology, University of Ibadan Press*, Ibadan, pp. 67 – 99 (1970).

[35] S.W. Petters, Central West African Cretaceous – Tertiary benthic Foraminifera and stratigraphy, *Paloeontographica A.* **179** (1982), 1 – 104.

[36] K. Rijswlk, Small community water supplies, *IRC Technical Paper Series*, No. 18, The Netherlands (1981).

[37] P. Sanyal and S. Babu, Policy benchmarking and tracking the Agricultural Policy Environment in Nigeria, Nigeria Strategy Support Program (NSSP), *Report No. NSSP* 005, p. 23 (2010).

[38] UN-DESA, *World economic situation and prospects 2011: update as of mid-2012*, New York: United Nations (2012).

[39] UN/WWAP (United Nations/ World Water Assessment Programme), *UN World Water Development Report: Water for people, water for life*, UNESCO (United Nations Educational, Scientific and Cultural Organization) and Berghahn Books, Paris, New York and Oxford (2003).

[40] UNICEF/WHO, *Joint Monitoring Programme for Water Supply and Sanitation, Water for life: Making it happen*, World Health Organization and United Nations International Children Education Fund, `http://www.wssinfo.org` (2005).

[41] K.O. Uma and K.M. Onuoha, Groundwater resources of the Lower Benue Trough, Southern Nigeria, in C. Ofoegbu (ed.), *The Evolution of the Benue Basin* (1990), pp. 115 – 134, Consultants, 1985.

[42] P. Webb and M. Iskandarani, *Water Insecurity and the Poor: Issues and Research Needs*, Discussion Papers on Development Policy No. 2, Bonn, Germany: Center for Development Research (1998).