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CLIMATE CHANGE ADAPTATION IN GORONYO LOCAL GOVERNMENT AREA, SOKOTO STATE, NIGERIA: THE CASE OF RURAL WATER SUPPLY IN A SEMI ARID REGION

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ABSTRACTS
The impact of climate change on sustainable rural water supply is discernable in Sokoto state and indeed, Goronyo area. This present study examines climate change adaptation to rural water supply. The required data were collected using a structured questionnaire. Systematic random sampling approach was used in data collection. A total of 165 questionnaires were administered in the study area. A double stage reduced model was employed; factor-multiple and factor-stepwise regression methods were used in establishing relationships between components. The results of factor-multiple regression and factor stepwise regression analysis showed an explanation of 84% and 82% respectively. The paper identified that climate change adaptation to rural water supply in Goronyo area is underlie by: water reliability, household size, water conservation, water accessibility and water storage indices.

Keywords: climate change, adaptation, rural, water supply, Goronyo, factor regression,

INTRODUCTION

Climate change is a long-term change in the statistical distribution of weather pattern over periods of time that range from decades to millions of years. Climate has been recognized as a major environmental problem facing the earth. The impact of climate change on water resources is topical in view of its importance to the earth's hydrological cycle(an unending transport of water)which is being driven by solar energy.For example, higher levels of solar energy trapped in the atmosphere normally lead to an intensification of the cycle, resulting in changes in precipitation pattern such as dryer dry seasons and wetter rainy seasons, and sometimes occurrence of drought. Such intensification can further results in melting of glaciers, exacerbation of flood risk during the rainy season and reduction in dry season water supplies; all these can be felt globally.

Water acquires most of its geochemical and biological substances during its cycle from cloud, to rivers, through the biosphere and geological layers. Consequently, changes in the amount and pattern of precipitation will change route and residence time of water in the watershed and inadvertently its quality. In addition, in areas of high water table or areas under intensive irrigation, increased evaporation due to temperature rise will raise concentration of dissolved salts. Also, increasing flood events could raise water table to a point where agrochemicals and industries wastes from soil will leach into the groundwater body. Moreover, sea water incursion into the aquifer can be experienced with increasing in sea level.

The impact of climate change on water resources is recorded to be rapidly intensifying.For example, according to the Stockholm Environmental Institute estimates which is based on moderate climate change,by 2025 the population of the world living in countries of significant water stress has been increasing rapidly.Furthermore, large catchments such as Lake Chad and river Senegal water have decreased by 40-60%. Also, there are evidences that desertification has been aggravated lower than average annual rainfall, runoff and soil moisture, especially in northern, southern and western Africa (UNFCC, 2003). These have produced smaller flows in rivers and it has lowered groundwater levels.

According to Eboh (2009) the impacts of climate change cannot be felt equally across the world. For example, countries in sub Saharan Africa are likely to suffer the devastating impact of climate change more; because of their geographical location, low income, low technological and institutional capacity to adapt, reliance on climate–sensitive renewable natural resources (such as water and agriculture). In the same vein, Anyadike (2009) also observed that African countries are more susceptible to climate change in view of the fact that Africa is exposed to the dangers of desertification, declining runoff of river catchment, declining soil fertility, dependency on subsistence agriculture, prevalence of AIDS and vector borne diseases, inadequate government mechanisms and rapid population growth.

The effect of climate change on water will also affect human health. For example,presently, over 300 million die across the world each year from avoidable water borne related illnesses. This therefore suggest that, there will be increase in water borne, water washed, water based, water related and water dispersed diseases. More importantly, there will be conflicts over water because existing water sources will be overstretched (Smith, 2006). Climate change has intensified water conflicts all over the world (Wolf, 2001; Postel and Wolf, 2001). A study of climate change impact on rural water supply is therefore desirable.

EVIDENCES OF CLIMATE CHANGE IN NIGERIA

Nigeria is vulnerable to climate change in view of its geographical location to the Atlantic Ocean (Olaniran, 2002; Ayoade, 2003; Odjugo, 2007).Three major areas of Nigeria are mostly affected by climate change. They are: coastal areas, Niger delta and Sudan–sahelian zone of Nigeria. Several ecological challenges are already been linked with climate change in nigeria (Adebayo, 1998;Odjugo, 2010 and Ikhuoria, 2003; West 2003; Chindu and Nyelong, 2005; Odjugo 2005;Adefolalu, et al 2007).

Evidences of climate change in Nigeria can be broadly classified into 3. First, studies of the thermal characteristics (Bello and Isiguiso, 1999;Adefolalu, 2005). Second, studies on the moisture characteristics (Adefolalu, 1986; Oguntoyinbo, 1986;Oladipo, 1990; Olaniran, 1988; Bello, 1998; Olaniran, 2002). Lastly are studies of the aerodynamic characteristics (Adebayo, 1980; Omotosho, 1990) of climate in Nigeria.Evidences of climate change abound in Nigeria. For example, heavy precipitation that is associatedwith the on-going tropical sea surface temperature change has been found to be consistent with IPCC predictions where 40% of Nigeriawere recentlyaffected by devastating flood.

Odjugo (2010) used a 105 year data to assess temperature trend in Nigeria, he reported a steady increase in air temperature since the 1970s and he discovered that in 63% of the period of study (1971-2005) temperature were above normal. He also confirmed that the rate of temperature increase is higher in semi-arid region than what obtains in the coastal areas of Nigeria, for the 105 years of his study. Odjugo (2010) reported an average increase of 1.7^{o}C over temperature for in Nigeria, 1.2 ^{o}C for Niger delta area and 2^{o}C for Sudan- Sahel zone of Nigeria.

In addition, Ahmad and Ahmad (2000), IPCC (2001), NEST (2003), and Hangaveled et al (2005) all reported increasing temperature, increasing evapotranspiration, decreasing rainfall amount in continental interiors, increasing rainfall in the coast, increasing intensity of weather related disaster such as thunderstorm, lightening, landslides, floods, droughts, bush fire, unpredictable rainfall pattern, sea level rise, increase desertification, and land degradation, drying up of rivers and lakes and constant loss of forest cover and biodiversity.

Also, Increasing frequency and intensity of unusual or extreme weather related events such as erratic rainfall pattern floods and sea level rise have also been reported (Odjugo, 2005; 2009, Molega, 2006; Nnodu et al; Umoh, 2007).

Political conflicts induced by climate change on sustainable water resources have been in the downstream half of river Niger between Nigeria and Niger, southern part of lake chad between Cameroun and Nigeria, in Yobe, Bornu and Jigawa state (Saliu,et al 2011, Niasse,2005)

The above evidences pointed to the fact that every part of Nigeria, particularly the sudano-sahelian part is already living with climate change, this call for papers on how the rural people of marginal environments adapts to climate anomalies. This present study will examine adaptation strategies of rural communities to climate change in Goronyo area, Sokoto, Nigeria.

STUDY AREA

Goronyo local government of Sokoto state is located between latitude 11^o 00` and 14$^o$ 00`N and longitude 3^o 50` to 8$^o$ 00` E. Average annual rainfall is about 740mm. Rainfall is highlyseasonal and controlled bythe movement of the inter tropical discontinuity (ITD). Most rainfall is experienced during the relatively short but intense localized thunderstorm covering small areas. Diurnal concentration of rain shows occurrence mainly in the afternoon and early morning. In some years rainfall is evenly dispersed throughout, in some other, it may occur irregularly but in large amount. There is a prominent seasonal variation in temperature and diurnal range of temperature. Daily maximum temperature is about 36^{o}C. During the harmattan season, daily minimum temperature falls below 17^{o}C. Between February and April which are the peak of heat, temperature reaches the highest of 44^{o}C Range of temperature is generally high. Indeed, Goronyo is one of the few areas fingered for having more acute climate change effects in Nigeria.

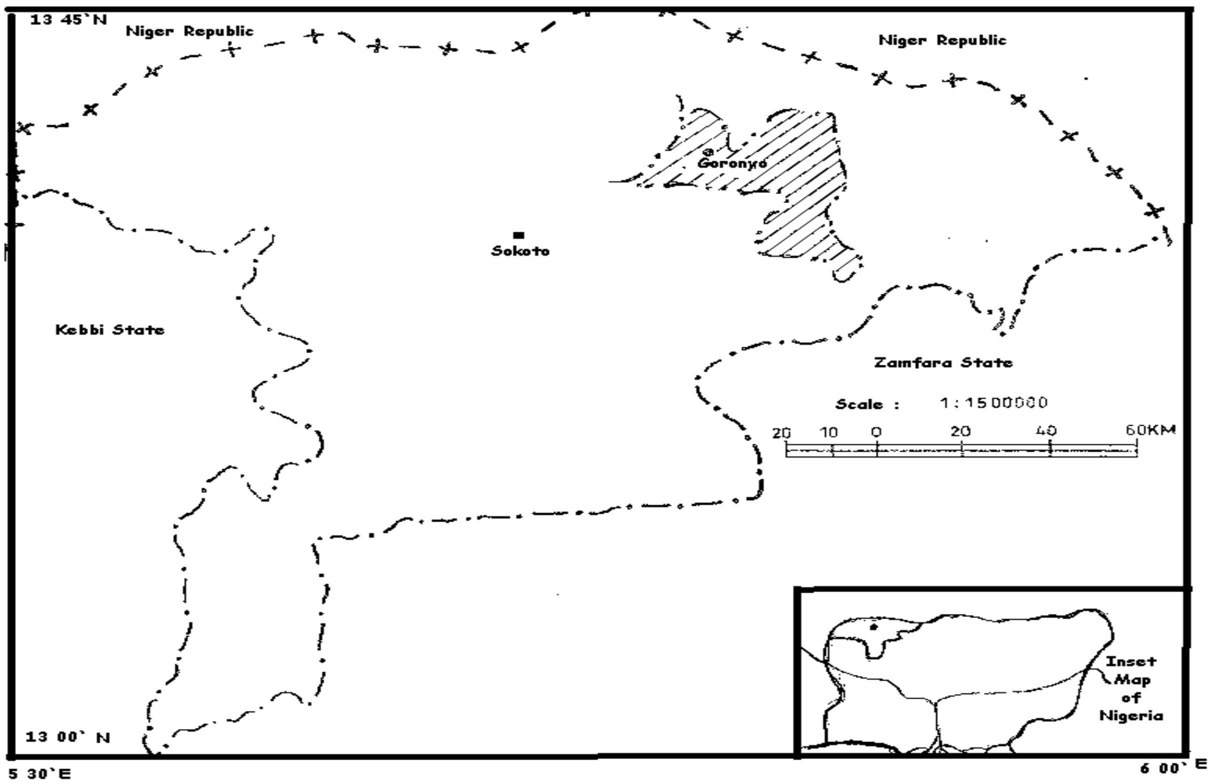

Fig. 1: Map of Sokoto State showing Goronyo Local Government Area

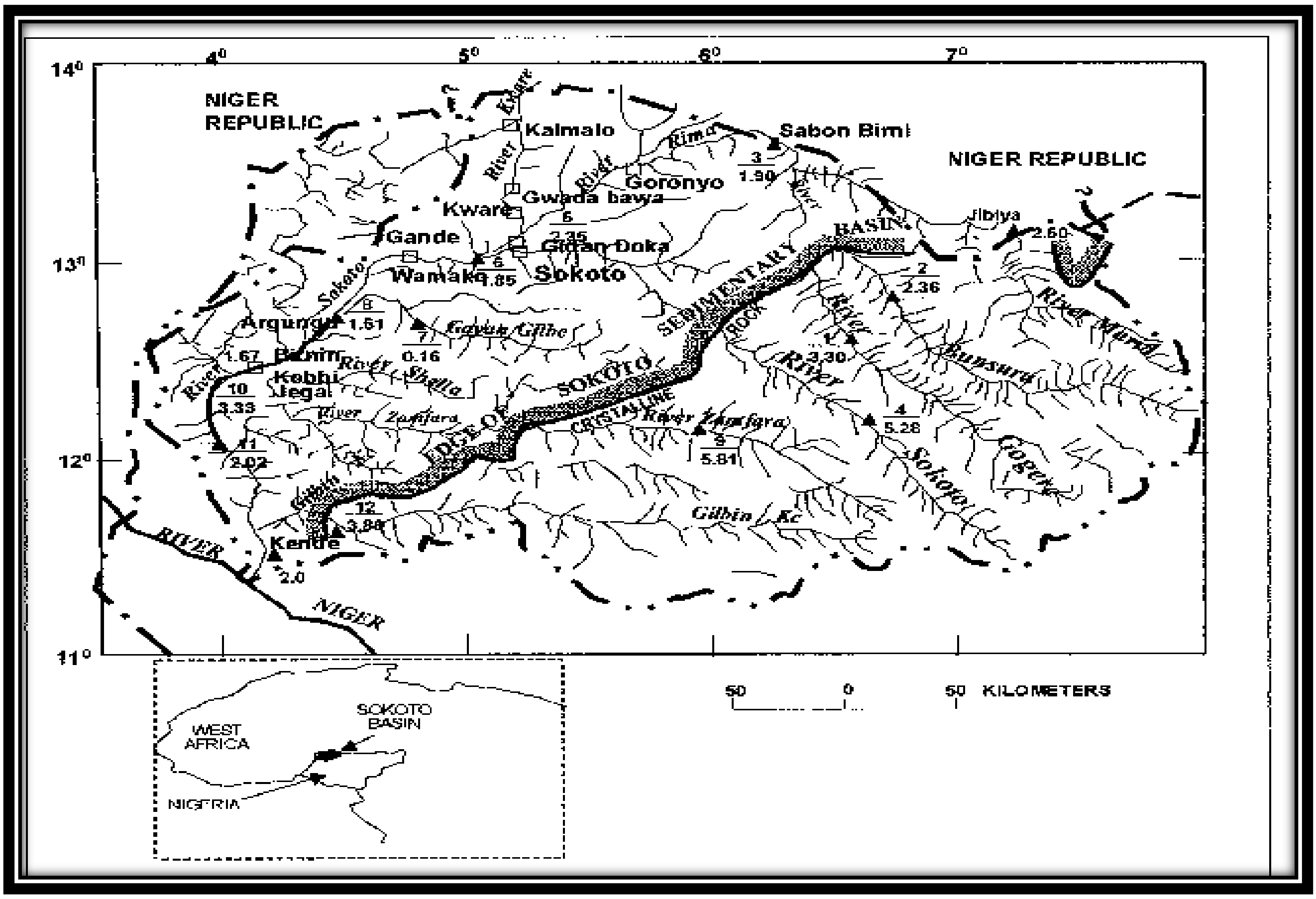

Fig 2: Hydrographic map of Sokoto basin showing Goronyo and other settlements.

Goronyo is located on the Sokoto plains, where heights range from 366 to 1,200 metres above sea level. It is located on monotonous lowland derived from softer sedimentary rocks with an average height of 300metres. The monotony is interrupted by isolated hills of laterite capped mesa resulting from resistant limestone rocks. The Sokoto plains merged into areas of flood plain which stretches for 8km in some places comprising of stream channels, swamps, lagoons, terraces, etc.

Goronyo is located on the marine sediments of the Rima and Sokoto groups. This deposit is collectively termed Taloka, Dukumaje and Worno formations consisting of fine grained sandstones, mudstones and siltstones. In Goronyo, there is loss of water due to high level of infiltration and seepage into the sedimentary formations. Gradient is gentle and drainage is not dense. Runoff coefficient is low. The rivers flow on flat plains where low runoff velocity has led to the deposition of large quantities of sediment. Rivers are wide and shallow; large flood plains and fadama are extensive within the local government. Runoff from upper catchment usually overflowson the flood plain. Annual flood is a common occurrence in the local government. A recent study by Odjugo (2010) shows that temperature of the study area has increased by about 2% in the last one century. Goronyo has an extensive flood plain that is witnessing increasing flooding in recent years; the 2010 flood is unprecedented.

The Sokoto caliphate where Goronyo is located hasa long history of buoyant economy particularly dating to centuries. Evidences from the work of Clapperton and Barth showed centuries of intensive irrigation farming and commerce. The major industries are craft, bridle, bags and leather cushions cottage industries. There is also a long distance trading involving goods such as kolanuts, dates, salt, cloth, leather, rice, onions, garlic, pepper and spices, fishes, etc, up to North Africa countries of Libya, Morocco, etc and to the southern parts of Nigeria. Dry season migration to south western Nigeria, which is occasioned by drought, is a very important phenomenon in Goronyo. Indeed, dry season migration is becoming popular by the phenomenon of climate change.

METHODOLOGY

The data required in this study are mainly information on water use characteristics of the rural people, people's perception on climate change, and on the adaptation strategies of the local people. This information were solicited with the use of structured questionnaire. The questionnaire used in this study was divided into 4 sections. Section A focused on primary information, Section B on water use characteristics, section C climate change perception and section D focused on response and adaption strategies in the local government area.

A total of 58 variables were generated from the administered questionnaire. These variables can be classified into 4 categories. These are: primary attributes, water use components, climate change perception and climate change response strategies.

Questionnaire administration was done through systematic random sampling. Hence, all the 11 wards of the study area were covered. 15 questionnaires were administered in each ward. These make a total of 165 questionnaires in the whole of the study area.

In view of the size of these variables a Double Stage Reduced Model (DSRM) involving both factor analysis (FA) and principal component analyses (PCA) were used to remove redundancy from the variables. Factor analytical technique was first used to identify significant variables out of the 58 generated in this study. The result of this first stage of reduction showed that 17 factors were generated with a total of 30 highly significantly loaded variables (Table 1). The percentage of explanation in this case was 88%. Principal component analysis on the other hand, was used in the second stage reduction whichinvolved the selection of the identified 30 variables into the principal component model. The result of the second stage showed that 10 components were responsible for the explanation with a total cumulative explanation of 80% to the variance (Table 2). These 10 components are the underlying factors of climate change and sustainable water resources in Goronyo L.G.A. of Sokoto state Nigeria.

COMPONENTS OF WATER USE, CLIMATE CHANGE AND ADAPTION.

a. **Component I:** This factor is tagged household time**; it** is also strongly loaded on maintenance of water source. This factor contributes 15.2% to the explanation of the variance. The amount of time spent per head in collecting water is a signal to water accessibility. In the study area, water sources are almost 100% from groundwater. Hence, it is available at the point of need, it is maintained by individual. Hence, shorter time is spent collecting water. This component is an **index of waiting time**.

b.

c. **Component II** is tagged access to water. It has high loadings on 3 variables. These are access to water, reduction in agricultural output, and impact on cottage industries. The factor defining variable is access to water, contributed 12.1% explanation. This component is an **index of water accessibility.** Accessibility to water will affect water use in the agricultural sector and the cottage industries.

d. **Component III** is known as **reduction in water use** is an adaptive strategy due to water scarcity induced climate change. This factor has significant loadings on beast of burden, water conservation, and reduction in water use.It is an **index of water use conservation**. It has contribution of 9.70% to the total explanation. Reduction in water use and water conservation coupled with the usage of donkeys in fetching water are ways by which the Goronyo people adapt to water shortage due to climate change. Donkey is a beast of burden that has capacities to carry about 120litres of water at a time. Hence the use of donkeys to collect water reduces the numbers of trips to water points and it is also more convenient compared to head portage system of fetching water. This has proofed as a wonderful adaption mechanism for fetching water in the study area.

e. **Component IV** has high loadings on water borne diseases, sources of water, and distances to available water points. This factor has contribution of 9.13%. It is an **index of water sourcing**. The source of water is a signal to the level of water contamination. However, water contamination, particularly as referred to spread of water borne disease is not common phenomenon as the major source of water in Goronyo local governmentarea is mainly hand dug wells and boreholes, more importantly, distances to water are generally short. This is expected in view of the fact that undergroundwater is available at close to the source of supply; consequently, individual households have hand dug wells in their homes and compound.

f. **Component V** is contributes 7.30% explanation to the variance; it has high loadings on family size and total time spent by the household in collecting water. This factor is an index of demography. The higher the number of people in the household, the longer the time spent in collecting water by these households.

g. **Component VI** has a contribution of 7.20% to the total variance; it has high loadings on uses of water and drying water sources. It is tagged **index of water availability**. Drying water sources will affect water availability and uses of water. This is because the quantity of availablewater will determine the uses of water.

h. **Component VII** has significant loadings on 4 variables, namely: regularity of water source, water borne diseases, volume of water collected, and people awareness of climate change. It is tagged water source reliability. This factor has a contribution of 6.60%, it is described as an **index of water reliability.**The source of water in Goronyo local government area **is**relatively regular, because it is mainly from deep wells and deep hand dug wells. Water in most of these wells last till march, however, by May many of the wells would have dried up due to lowering water table caused excessive drawdown by over exploitation, evapotranspiration, lack of recharge in the long dry season.

i. **Component VIII** is tagged water storage; it has high loadings on 2 variables which are water storage and volume of water collected. This factor has 4.90% contribution. It is tagged index **of water storage.** The storage capacities at individual households will no doubt determine the amount of water collected.

j. **Factor IX** is an **index of household occupation**. This factor has a significant loading; householdoccupationtypes. It has a contribution of 4.28% to the total explanation. The people occupation has a direct relationship with individual water use habit. For example, occupation is predetermined by the nature and types of education, skill acquisition, access to information, civilization, etc. all these surrogates will affect level of hygiene and the amount of water use.

k. **Factor X** has the least contribution to the variance (3.61%) in the explanation. Two variables (increasing dust and increasing frequency of rainstorms) have significant loadings on this factor. This factor could be regarded as **index of climate change impact**. Indeed, a cursory look at the study area showed that these are among the dominantimpacts of climate change on Goronyo people. The increasing rainstorms of the past 2 years have affected agriculture remarkably in this area. The annual rainfall of 2010 caused large scale flooding in the LGA where some settlements including Sabon Geri Dole were completely washed away, and many acres of onion, garlic, pepper, tobacco, etc were washed away. A condition which has affected food in security. Nigeria.

Table 1: Principal component analysis of sustainable water use, climate change and adaptation in Goronyo

Variables		Components									
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
1	Number Per Household	-.22	-.12	.26	-.15	.73	.07	.00	.05	.28	.02
2	Occupation	-.16	.21	-.06	.09	.08	.12	.16	-.09	.81	.07
3	Number Of Children Under 7 Years	-.27	.06	.02	.31	.62	.04	.03	.01	-.04	-.28
4	Sources Of Water	.05	.10	.12	-.88	-.09	-.12	-.11	.12	-.21	.04
5	Distances To Water Points	.50	.02	.29	.70	-.19	.15	.18	.03	.15	.07
6	Average Time Spent Collecting Water	-.18	-.21	.08	-.06	-.65	-.04	.26	.13	.18	.04
7	OwnershipOf Water Source	-.60	.08	-.40	-04	.01	.40	.21	-.20	-.40	.20
8	MaintenanceOf Water Source	-.70	.08	-.34	.16	-.05	.50	-.01	.02	-.15	-.01
9	RegularityOf Water Supply	.10	.28	-.06	.14	.16	-.07	.84	-.04	.05	.20
10	SufficiencyOf Water Supply	.50	.64	.02	.12	.22	.15	.20	.15	.04	-.05
11	AccessibilityTo Water	.43	.80	-.04	.10	.34	.16	-.03	.09	-.01	-.04
12	Water Borne Diseases	.11	-.07	-.41	.12	.23	.01	.70	.12	.26	-.02
13	PaymentFor Water	-.30	.20	-.02	.80	.11	-.23	.00	.04	-.23	.12
14	UsesOf Water	-.20	.01	.07	.13	.21	.84	-.12	-.07	-.04	.22
15	Climate ChangePerception	.09	.24	.31	.02	.32	-.02	-.74	-.15	.02	.05
16	Water Source Drying Up	.21	.05	.21	-.11	.06	-.86	.06	.17	.13	-.13
17	Increasing Dusty Wind	.20	-.10	.09	.10	-.15	.18	.02	-.23	-.24	.80
18	Increasing Rain Storms	.01	-.03	-.12	-.00	-.03	-.06	.10	.21	.19	.81
19	Larger Water Storage	.20	.23	-.09	-.07	-.06	.09	.13	.80	.01	-.08
20	Beast Of Burden	.18	.11	.70	-.21	-.35	-.03	.03	-.23	-.09	-.10
21	Water Conservation Habits	-.12	.19	.80	.19	.12	.08	.10	-.07	-.05	.27
22	Reduction In Water Use	.03	-.08	.80	-.04	.20	.15	.12	.18	-.00	-.21
23	Unclassified Mode Of Responses	.44	.30	-.14	-.05	-.30	-.27	.13	.02	.40	-.17
24	Total Household Time	.94	.13	-.04	-.04	-.10	.07	.03	.10	-.13	.11
25	Queue In Water Points	.93	-.01	-.11	-.04	-.10	.08	.04	.10	-.16	.12

26	Water Collected/Day	-.02	-.30	.16	-.09	.05	.08	-.03	.70	-.40	.16
27	Water Wash Diseases	.16	-.38	-.06	.16	-.05	-.11	.30	.51	.34	.03
28	Conflicts At Water Points	.10	-.60	-.09	.35	.21	.11	-.22	.06	.04	.06
29	Reduction In Agricultural Activities	.06	-.82	.00	-.04	.16	.18	.20	.08	-.23	.07
30	Cottage Industries	.05	-.81	-.08	-.04	-.01	-..10	.01	.05	-.06	-.02
Component Description		Index of Waiting Time	Index of Water access	Index of Water Conservation	Index of Water sourcing	Index of Demography	Index of water availability	Index of water Reliability	Index of water storage	Index of household occupation	Index of Climate change
		IWTIM	**IWACC**	**IWCON**	**IWSOC**	**IHSIZ**	**IWAVL**	**IWREL**	**IWSTO**	**HOCCP**	**ICCAD**
a	**Eigen Value**	**4.58**	**3.62**	**3.00**	**2.74**	**2.18**	**2.16**	**1.97**	**1.47**	**1.28**	**1.08**
b	**Percentage Variance Explained**	**15.2**	**12.1**	**9.70**	**9.13**	**7.28**	**7.20**	**6.56**	**4.90**	**4.27**	**3.61**
c	**Cumulative percentage Variance Explained**	**15.2**	**27.3**	**37.0**	**46.1**	**53.4**	**60.6**	**67.1**	**72.1**	**76.3**	**80.0**

Relationship between climate change and water use characteristics

The results of the factor regression analyses are presented in Table 2 and 3. These show that the various components offered 84% to the discussion of climate change adaptation and water use in Goronyo. This relationship can be explained further by equation 1

Y= 2.955+029IWTIM+0.072IWACC-0.092IWCON+.007IWSOU+.097 IHSIZ – .008IWAVL +.007IWREL -.045 IWSTO +.005 HOCCP +.016 IC…………. (Eq 1)

(R^2=84%; SE=0.021)

Table 2: Factor- multiple regression equation of climate change adaption components in Goronyo

Components	Coefficients	t	Standard Error	Percentage Explanation (%)
Constant	2.955	141.8	0.021	84
1.IWTIM(index of waiting time)	.029	1.355		
2. IWACC(Index of water accessibility)	.072	3.399		
3. IWCON(Index of water conservation)	-.092	-4.386		
4. IWSOU(index of water sourcing)	.007	.338		
5. IHSIZ(index of household size)	.097	4.586		
6. IWAVL(index of water availability)	-.008	-.361		
7. IWREL(Index of water reliability)	.007	-10.598		
8. IWSTO(index of water storage)	-.045	-2.151		
9. HOCCP(index of household occupation)	.005	.257		
10. ICCAD(Index of climate change and climate change adaption)	.016	.771		

Factor- stepwise regression was also used to rewrite equation 1 with the intention of arriving at the best fitted model. The result is presented in Table 3 and equation 2.

Table 3: Factor- stepwise regression equation of climate change adaption components in Goronyo

Variables	Coefficients	t	Standard Error	Cumulative variance	% Variance	% Total Variance
Constant	2.955	146.17	0.020			
1. IWREL (Index of water reliability)	-.223	-10.93		55.0	55.0	82.5
2. IHSIZ (index of household size)	.097	4.729		65.2	10.2	
3. IWCON (Index of water conservation)	-.092	-4.523		74.6	9.60	
4. IWACC (Index of water accessibility)	.072	3.51		80.3	5.70	
5. IWSTO (index of water storage)	-.045	-2.218		82.5	2.20	

This shows water-source reliability as the most important component contributing 55% to the explanation, this followed by size of household which is large determinant of water use in the area (10%). Others include water conservation methods such as reduction in water use and the use of beast of burden to carry water (9.60 %). Water accessibility is also important which comprises limited uses of water in both agriculture and cottage industries (5.70%). And lastly water storage component which is relevant to climate change as families now uses larger containers (2.20%) to store water for their uses. This suggest that sustainable water use in Goronyo is guided by a network of adaptation and resilience strategies surrounding five issues, namely: water reliability which is factored on the deep groundwater reservoir, of the Sokoto basin, household size, water conservation, accessibility and water storage (Figure 3a,b,c).

The above can be modelled by equation 2

Y=2.955-.223IWREL +.097IHSIZ -.092IWCON +072IWACC -.045IWSTO

(R^2=82.5%; SE=0.020)

DISCUSSION OF RESULTS

The underlying factors of climate change adaption to sustainable rural water supply can be explained in the context of the above discussion.

Goronyo local government area is located on the Rima group of sedimentary formation, it is underlain by cretaceous sediment, a highly porous and permeable material. Water table and well depth are equally deep, drainage density and runoff coefficient are low. Hence, major sources of water are therefore hand dug wells and deep boreholes which are owned by individual households and government; almost all compound or householdis having a well in some parts of the study area such as in Taloka and Goronyo townships. Two types of hand dug wells are found namely: local government authority wells and individual hand dug wells, which are maintained by individual and the communities. In view of this,time spent in collecting water is comparatively short. Availability of water and good maintenance of water sources partly explain the short time spent in collecting water. For example, Admassu, et al. (2003) in a study in Ethiopia observed that duration of waiting time needed to collect water at the water point positively associates with respondent complaints about functionality of water points. Meanwhile, UNICEF (1995), FGN (1991; 2000), permissible waiting time of 30 minutes (0.5hrs) , the acceptable time allowed for fetching water. It should be noted that at the height of dry season (April and May) of this water points dry up and time spent in collecting water will be greater than the threshold values. .

Access to water in the study area is affected by climate change as years of unpredictable rainfall and weather has affected water usage, particularly in the agricultural and cottage industries. For example, before the 2010 flood and high rainfall disaster, irrigation agriculture was actually facing lots of challenges for example, water conflicts due to climate change was reported in the sahelian zone of Nigeria (Niasse, 2005). Cottage industries such as local brick industries, pot making *dadawa* were affected by water uses. The irregularities in rainfall was brought on a sharper focus in 2010 September where several farmland particularly in the low lying *fadama* farmland of onions, garlic, pepper, and other settlements such as Sabon-Gari Dole and host of other settlements were flooded. These explain the current scarcity and high prices of onions particular in this year 2011. Hence, reduction in agricultural output, and impacts on cottage activities are some of the negative impacts of climate change that had been previously pointed out (;IPCC,2001; Odjugo,2010, Bello,2010).

In view of the unpredictability of rainfallin Goronyo and northern Nigeria water sources are found to be drying up (UNPCC,2003). Reduction in stream flow has also been noticed in hydrological data in the sudano-sahelian region

(Olanian, 2010; Wiasse, 2005; Odjugo 2010; Dami, 2008). Three methods of adaptation are common: these are: use of beast of burden to fetch water, adoption of water conservation method in the household, and reduction in water usage. The use of donkeys is a common sight in Goronyo; about 1out of 5 people have a donkey. According to field information, a donkey can carry 120liters of water at time, but could carry double of this, while pulling a cart. Also, Carmel carry about 300 litres at time, where a trawler is attached these beasts of burden would carry much more load. This will reduce the numbers of trips, reduced stress, etc. Indeed, these 3 water conservation methods are the major adaptation mechanism, during the height of dry season (April/May), when the piezometric level further drop and manywells would have dried up, and household now fetched water in the fadama wells, where water levels are closer to the surface.

Groundwater remains the major source of water in Goronyo, in view of the geological advantage. Both hand dug wells and boreholes are relatively deep. Hence, the issue of faecalcontamination is not common as soak awaypit are not common in community.This explain the few cases of water borne diseases in the study area. The major water quality challenge is bad taste, condition which is expected in limestone formations such as Goronyo. Further, in view of the advantage of point availability of underground water points are within the house or compound or in short distances close to respondent houses. This explains reasons for the short distances to water points in Goronyo, except in the peak of dry season around March, April and May when the fadamawell are patronized due to drying up of some water points. At this season donkeys and camel are used for transporting water in 30 litres Jeri can in Goronyo. Hirji (2001; 2002) has also observed the role of safe water sources to public health in the rural areas of southern Africa.

Goronyo area has a culture of large family size, with an average family size of 8-10 people, due to the prominence of Islamic religion. Therefore, the relatively large size of the household has lengthened the time spent at the household level in collecting water. This agrees with the findings of Ifabiyi, et al. (2010).Groundwater is the major source of water in the study area. This affect the uses of water in the study are, the dominant uses of water in Goronyo are mainly for domestic and livestock watering and dry season farming, watering of cattle at well sites and fadama tube wells are common sights in Goronyo .

The potable water supply in Goronyo can be said to be fairly regular, reliable and sustainable. This the case for most part of the year except for the months of April to early June in few localities where wells dried up due to drop in the piezometric level. This was reported in few locations in Goronyo area and in habitants had to result to fadama wells when the well in the village dries up, and villagers had to trek long distances to water. The relative regularity of water has no doubt reduced outbreak of diseases. The people of the study are generally exhibited sufficient awareness of climate change.

In view of the nature of water supply all respondents store water and as part of mechanisms for adjusting to climate change, they all have fairly large water containers. The volume of water collected will depend on the size of the storage facilities. Many of the respondents are farmers and they also combine it with some fishing, but many of them are farmers, farming onions and garlics, while almost all of the farmers are into cattle rearing, particularly for settlement along river Rima some combine arable farming with cattle rearing. A few civil servants were also found. The study revealed that occupation willdetermine water use. This is expected because of the impact of the level of education and other social factors which are products of occupation.

CONCLUSION

Evidence of climate change is manifested in the scarcity and increasing pressure on available water resources in Goronyo. A double stage reduced model used in selecting the most important variables that best underlie the explanations in the variance showed that depict in the 1st stage of reduction that 17 factors and 30 significantly loaded variables best explained climate change adaptation to sustainable rural water supply. These together have 88% explanation to the variance. The second stage of reduction resulted in producing 10 orthogonal components and 26 significantly loaded variables which together explained 80% explanation in the variance. The results of factor-multiple regression and factor stepwise regression analysis showed an explanation of 84% and 82% respectively. The paper identified that climate change adaptation to rural water supply in Goronyo area is underlie by: water reliability, household size, water conservation, water accessibility and water storage indices. The result of factor-multiple regression further suggest that sustainable water use in Goronyo is guided by a network of adaptation and resilience strategies bordering on five issues, namely: water reliability which is factored on the deep groundwater reservoir of the Sokoto basin, household size, water conservation, accessibility and water storage. Hence, adaptation to climate change in Goronyo is hinged on these five factors.

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Fig. 3a: A donkey with120 litres of water

Fig 3b: A donkey carrying 180 litres of water

Figure 3c: Fetching of water using beast of burden is a common practice in Goronyo. The advantage of this is to reduce numbers of trips to water points and to overcome the problem of distance to water point.