ENVIRONMENTAL DETERMINANT OF RURAL HOUSEHOLDS' VULNERABILITY TO WATER SCARCITY IN SEMI-ARID NIGERIA

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ABSTRACT

Though water resource is an important natural endowment for the attainment of improved living conditions and sustainable development, man's consumptive demand for it continued to fall short of the supplies. This is especially in the rural communities of the semi-arid region of Nigeria, whose most water sources are unimproved and the supplies from which fall below the demand, resulting in water scarcity. The study assessed the environmental perspective of the rural households' susceptibility to water scarcity in Nigeria. The study employed multistage sampling, the mixed-method approach of data sourcing, and the data were analyzed with the basic descriptive and inferential statistical tools. The study findings show the continued practice of extended family system, characterized with low literacy rate and weak income levels, use of shared latrines, as well as defecation in the bushes and open spaces. It also demonstrated nine-in-ten households are vulnerable to the complex conditions of water scarcity, especially those in Kerri-Kerri Formation and the Fika Shale, as the Pearson correlation of the conditions revealed. The linear regression model of the correlated variables statistically proved to have accounted for more than 60% of the water crisis. However, the households' adaptation strategies to water scarcity were traditional and highly ineffective to the problem of water scarcity conditions of the area. This denotes that the environmental variability influences both water availability and vulnerability to scarcity. Therefore, the study recommends the mainstreaming of the physical environmental conditions into the rural water policy, in addition to upgrading and maintenance of the available water facilities.

1.   Introduction

Water is the most important natural resource for sustainable development and quality of human life, reiterated in the target 6.1 of the ambitious Sustainable Development Goals (SDGs) (United Nations, 2015). The provision and sustainable management of water are essential for the world's economy and improvement of public health and living standards as well as poverty alleviation (Balogun *et al.*, 2017). While the global use of the limited freshwater resource is increasing by a factor of six over the past ten decades (Wada, 2016; Huang & Yin, 2017), water is said to be unevenly distributed, resulting in its scarcity as one-fifth of the world population live in regions where water is scarce while one-quarter suffer from its scarcity (Fan *et al.*, 2013). However, the rate of water scarcity has been attributed to several factors. These include the population growth,

economic development and changing consumption patterns, climate change, technological advancement, and deficit in functional water infrastructure were identified as the factors projected to grow the rate of water scarcity by 1% annually (Ahiablame *et al.*, 2012; WWAP, 2018). The households' access to the potable water supply is measured by the number of people who have reasonable means of getting adequate (in terms of quantity and quality) amount of water that is safe for drinking, washing, and other essential household activities (Lukman *et al*, 2016). A study by Kithinji (2015) found that access to safe water supplies breaks down the barriers and contributes to poverty reduction, as it links the environment, development, and human health. The water scarcity is more prone in the developing regions of the world, due to reliance on unimproved water sources and surface water bodies. For instance, Connell (2017) highlighted that the lacked access to water supplies in sub-Saharan Africa is socio-economically costly and deadly as it claims more human lives each year than the combination of AIDs, breast cancer, terrorism, and all the world's political conflicts.

Moreover, in Nigeria, about 36% (90 million people) of the total population have no access to safe and improved water supplies whereas 51% of the total rural population suffers from water-related problems (Kithinji, 2015; UNICEF, 2015). The depressing water supply is evident as poor households continue to struggle with the challenge of water scarcity (Nwankwaola, 2011), especially among the poor rural settings. Despite her blessings of the estimated 226 billion cubic meters of surface water and about 40 billion cubic meters of groundwater, the rural populations of Nigeria are largely deprived of access to adequate water supplies (Adah & Abok, 2013). Abubakar (2019) demonstrated further that the water supply challenges revolve around the regional, demographic, and socioeconomic inequalities at various scales. These facts, in addition to the declining public water service level in the country, are clear, as the supplies in rural areas continue to fall below the demands. Also, the difference in the physical environmental characteristics is likely to influence the domestic water supply and has not been studied in the rural settings of the Yobe region of Nigeria. The domestic water scarcity in such an ecologically fragile environment constitutes a threat to living conditions and socio-economic development.

The extent of the rural households' vulnerability to water scarcity and the driving factors has not been sufficiently studied and documented in this study area. This is especially that water, sanitation and hygiene (WASH) services less than two-third of the total Nigerian population (NBS, 2016). Similarly, most studies on the domestic water supply in the country (Orounye *et al.,* 2012; Moruff, 2012; Ogunbode & Ifabiyi, 2014; Mohammed, 2016; Makwe & Ahmad, 2017; and Ahmad, 2017) were urban biased. Besides, available literature on the rural water supply (Inkani, 2015; Bukar & Daura, 2015; Inkani & Mashi, 2016; Chukwuma, 2017) also focused on climate change and variability, water infrastructure, and tariff, as well as the socio-economics of the households. These studies ignored the environmental perspective of the households' vulnerability to water scarcity, which led to limited knowledge of the problem, despite threatening the attainment of the target 6.1 of the SDGs, African Water Vision, and local relevant policies. Therefore, this study, which was prompted by the existence of differed geologic conditions in the area, examined the environmental determinant of the rural households' vulnerability to domestic water scarcity in the semi-arid region of Yobe State, Nigeria. The findings of this study would help in improving the local water policy, bridge the knowledge gaps, and enrich the campaigns for access to improved domestic water supply for all, regardless of geographic and socio-demographic considerations.

2. Conceptual Review

The study reviewed the concepts of vulnerability and water scarcity, which are the critical issues of the work, to appropriately base the investigations.

2.1   Concept of Vulnerability

The susceptibility of the people and their communities to water scarcity led Umar (2016) opined that the origin of vulnerability is deeply rooted in geography and natural sciences, which relates to the harm in the socio-ecological system as a result of environmental changes. The term vulnerability is conceptualized by the Intergovernmental Panel on Climate Change (IPCC) (2001) as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. To Cannon *et al*. (2003) as quoted by Umar (2016) is a set of characteristics that includes a person's initial well-being (nutritional status, physical and mental health) livelihood and resilience (assets and capitals, income, and qualifications) self-protection (capability and willingness to build a safe home, use a safe site) social protection (preparedness and mitigation measures) social and political networks and institutions (social capital and institutional environment). The International Development Research Council (IDRC) (2002) defined vulnerability as the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. In contrast, the United Nations Development Programme (UNDP) (2006) sees the concept as a human condition or process resulting from physical, social, economic, and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard. The dominance of hazard-oriented prediction strategies has been increasingly challenged by the alternative paradigm of using vulnerability as the starting point for risk reduction assessment (Inkani, 2015). Moreover, while these reviewed concepts of vulnerability encompass various conditions that have impacts on the susceptibility of a community or human population to stresses such as water scarcity, the environmental variability of this study area, as Umar, 2016 shows, may also connote the socio-economic and physical effects of the water crisis.

2.2   Concept of Water Scarcity

The concept of water scarcity, as the UNDP (2006) reported, water scarcity emerges from two distinct perspectives: first as a crisis arising from poor water services and, second as a crisis caused by the physical unavailability of the water resources. In the view of Rijsberman (2006) poor access to the safe and affordable water supply to meet up domestic demands within a significant time results in water scarcity. But FAO (2007) posited that water scarcity is the point at which the aggregate impact of all users impinges on the supply, or quality, of the water supply under prevailing institutional arrangements which leads to a shortfall in availability. As water occurs in a dynamic cycle of rain, runoff, and evaporation, with enormous Spatio-temporal variations in quality which governs its value Inkani (2015), water scarcity takes two dimensions: Firstly, the physical water scarcity corresponds with the absolute level of scarcity, where the water sources are limited by nature and water competition grows amongst the people, which commonly occur in both arid and semi-arid regions. Secondly, the socio-economic water scarcity which connotes the inability of a household or community to meet up basic water needs due to lack of labour and time, financial resources, poor maintenance culture of water facilities, inadequate technological innovations, or political insubordination. However, Table 1 as modified from Inkani (2015) shows that water scarcity could also be driven by the characteristics of the households and communities, which formed part of the science of investigation.

Table 1. Indicators of Vulnerability to Water Scarcity

S/N	Indicator	Variable Measures
1.	Local Knowledge	Extent of local knowledge available; Per capita knowledge of adjustment options; Per capita use of the knowledge available
2.	Household Practices	Cooking practices; Washing practices; Bathing practices; Domestic animal watering
3.	Water Supply Source	Alternation is supply source; Rainwater harvesting; Development of surface water treatment and conservation options
4.	Population Mobility	Seasonal migration; Permanent migration; Livestock relocation
5.	Livelihood Options	Alternation of livelihood sources; Permanent change in livelihood options; Movement to change livelihood source; Change in the character of livelihood type
6.	Institutional Options	Institutional arrangements available; Extent of per capita use of the options; Incentives and motivation to use the options

Source: Adapted from Inkani (2015)

3.   Materials and Methods

3.1   Study Area Setting

The study area, Fune Local Government Area is an extraction of the Yobe State landmass (45,502km²) that formed part of the semi-arid environment. As shown in Figures 1 and 2, it falls between longitude 11º 54'E to 11º 90'E and latitude 11º 53'N to 11º 88'N, which has a total landmass of 4,985km² and a population density of 78 persons/km² (NPC, 2017). Characterized with water supply challenges, the study area has hot and dry climatic conditions – the hottest months being March, April, and May, and the temperature ranges between 30C to 42C (Babagana *et al*., 2018). The soil of the area is mostly sandy in nature and loose in texture, highly erodible, though supports the cultivation of crops such as millet, sorghum, beans, and groundnut as well as livestock rearing. The area is geologically stratified into three distinct formations with related but different characteristics. The Chad Formation is the youngest of the three stratigraphic units, consisting of continental lacustrine and fluviatile deposits of fine to coarse-grained clays and sands of quaternary sedimentation linked to Pleistocene-age as shown in Table 2 (Makinde *et al*., 2010; Adegoke *et al*, 2014). Water occurs under table conditions, though depends on the prevailing hydrogeological situations (Oruenye, 2009), especially that the aquifers, upper and the middle, provides water for the wells and boreholes Offodile (2002). The depth of the aquifers in the area of flowing wells ranges from 240m to 380m, while the free-flowing yields have 21l/min to as high as 90m³/hr (Audu, 2017). The Kerri-Kerri Formation is a continental, lacustrine, and deltaic-type geologic unit of Paleocene age, consisting of thin and thick beds of sandstone, grits, and clay (Adegoke *et al*, 2014). With marked variation in the thickness, the groundwater in the aquifers of the formation occurs under water table condition but locally in confined or semi-confined aquifers, where the laterally extensive lenticular clays are inter-bedded with sands and chiefly recharge by precipitation (Okosun, 1995; Oruenye, 2009). Yusuf *et al*. (2018) added it is characterized by deep layer aquifer and much of the arenaceous beds are with little or no water. This makes the area to be unpredictable in terms of availability and depths of groundwater reserves. The Fika Formation, otherwise known as the Fika Shale, which conformably overlies the Gongila Formation comprises of blue-black, ammonite-rich, open marine shale, gypsiferous, and with intercalations of thin limestone beds (Okosun, 1995; Adegoke *et al*, 2014) as revealed in Table 2. It was reported by Okosun (1995) and

Nwankwoala (2015) that Fika Shale has a maximum thickness of 890m (Okosun, 1995) and the aquifers of Shale are limited in extent, confined to the fracture and weathered zones, resulting in poor water yields due to its argillaceous nature.

Table 2: Lithological Characteristics of the Geologic Formations of the Study Area

Geologic Age	Formation	Lithology and Environment of Deposition
Pleistocene	Chad Formation	Clays, sands, and gravels medium to coarse sands felspathic lacustrine in origin
Paleocene	Kerri-Kerri Formation	Laterite, oolitic sands, sandy clay, continental lacustrine/deltaic
Senonian	Fika Shale	Black and blue shales, poorly exposed with cotton soil characteristic feature and gypsiferous

Source: Offodile (2002) and Adegoke et al (2014)

3.2   Study Design

This study which explored the influence of the physical environmental conditions on domestic water scarcity led to the employment of mixed methods of research, both quantitative and qualitative. The approach has deepened the study findings with a comprehensive and detailed account of the issues under investigation while offsetting the shortcomings of the independent application of the methods (quantitative and qualitative).

3.3   Study Population and Sampling Design

The population targeted were the rural communities of the study area, which necessitated the employment of a multistage sampling approach. Firstly, researchers' observations show challenges in access to water supply in the area and helped in its purposive selection for the investigations. Secondly, the geologic map of Yobe State highlighted three respectively distinct stratigraphic divisions of the geology of the area into the Chad Formation, Kerri-Kerri Formation, and Fika Shale, which were adopted as study zones (see Table 3.) and three communities were purposively sampled from each zone. Thirdly, household heads (who served as respondents) were drawn using systematic random sampling, proportional to the size of the studied communities.

Table 3. Details of Sample Frame and Size of the Studied Communities

Study Zones	Communities	Longitudes	Latitudes	Households	Samples
Fika Shale	Daura	11.405567	11.553658	183	35
	Murba	11.504024	11.660501	243	47
	Ngelshengele	11.60465	11.550527	201	39
Kerri-Kerri Formation	Dadume	11.360187	11.839857	69	13
	Kafaje	11.251558	11.918324	99	18
	Kolere	11.286100	11.882700	165	32
Chad Formation	Dufuna	11.182238	12.257496	303	59
	Jajiburawa	11.148437	12.215455	165	32
	Gurungu	11.068409	12.13727	207	40
Total				1635	315

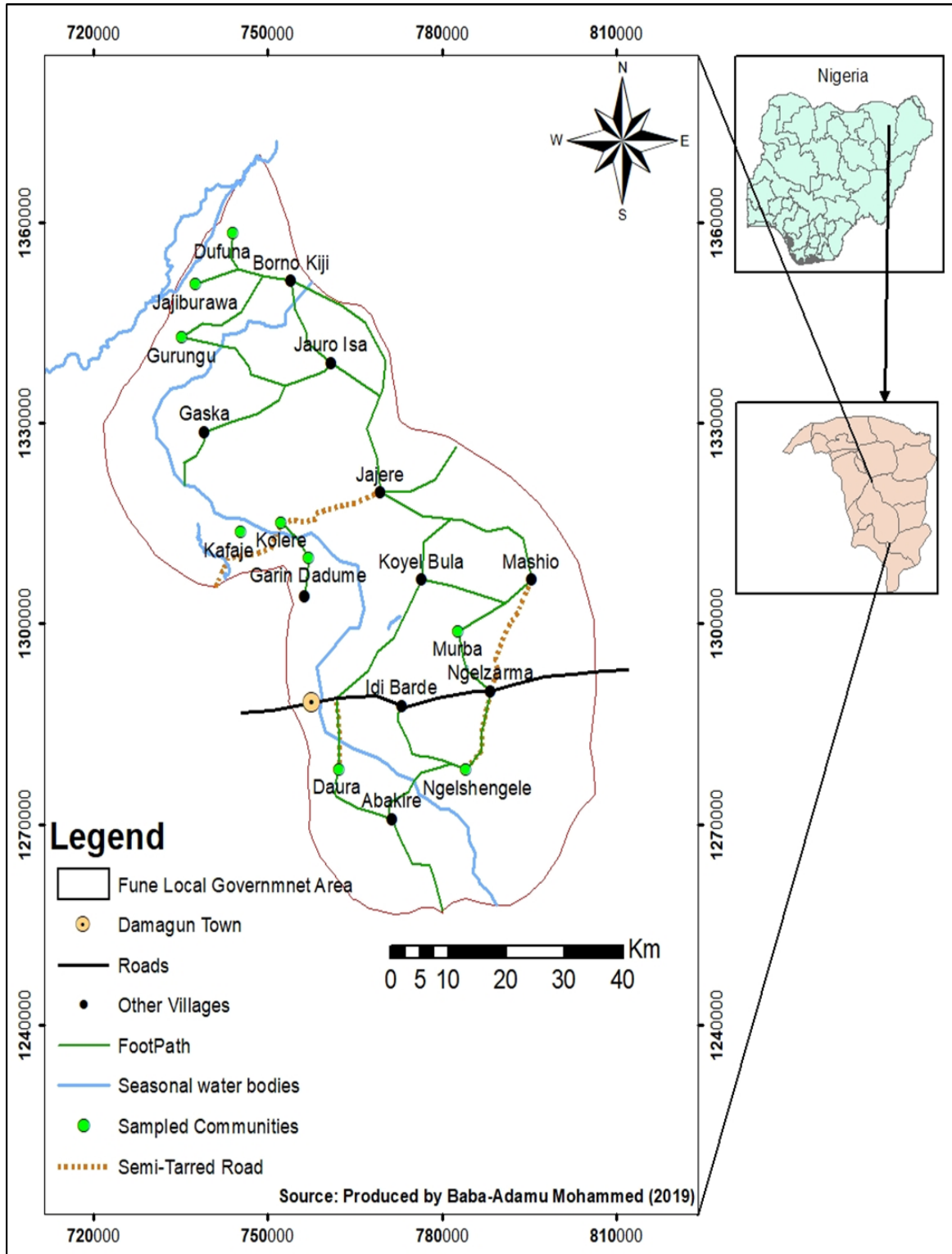*Source: Fieldwork, 2019*
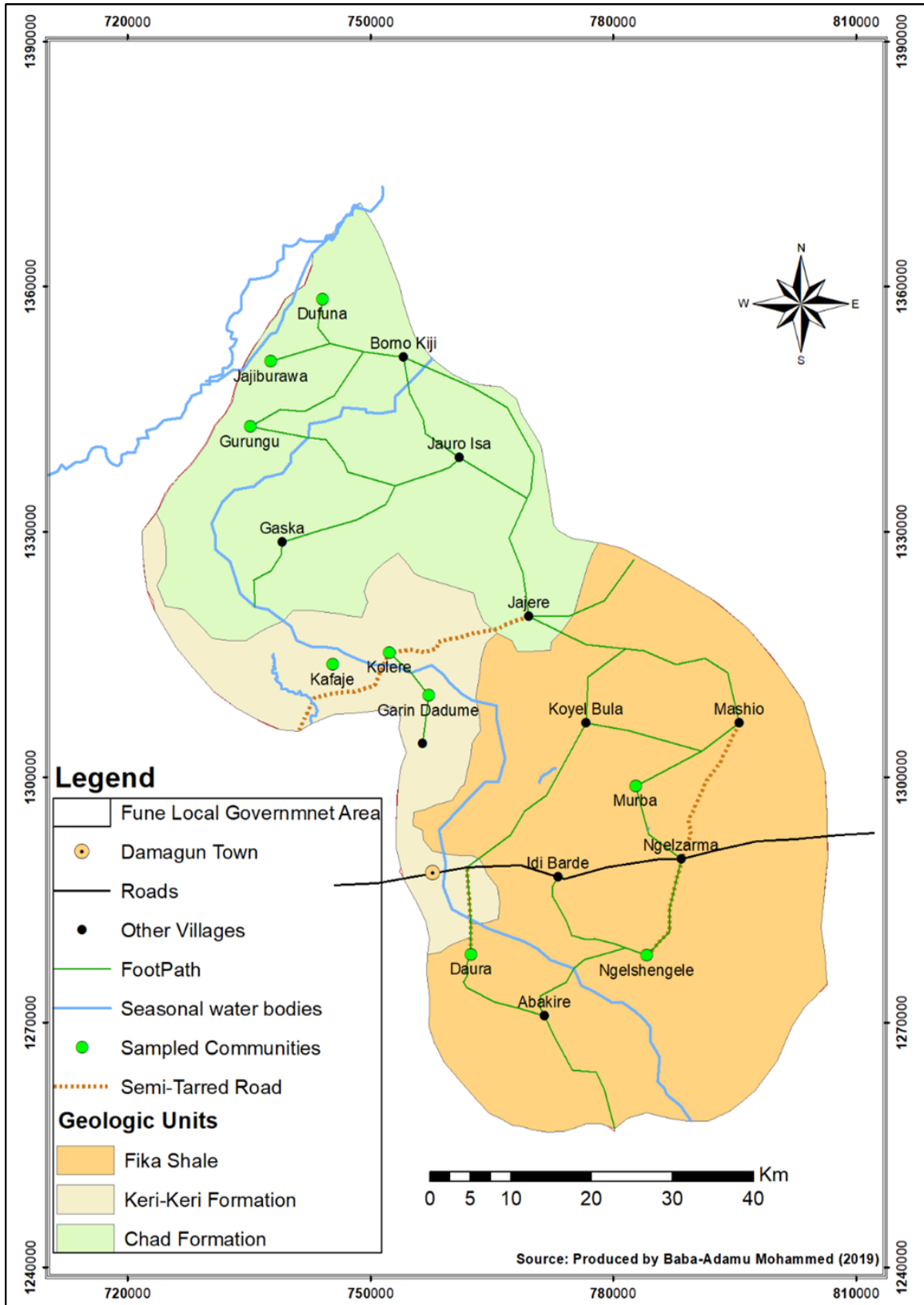
Figure 1. Study Area and its Communities

Figure 2. Study Zones and the Sampled Communities

3.4   Data Sources and Analyses

This study used both primary and secondary sources of data. The primary data was sourced through in-depth interviews conducted between May and July 2019; whereas the secondary data were sourced through the desk review of relevant kinds of literature. The data were analyzed with both the basic descriptive and inferential statistical tools, which include the charts, tabulations, and the linear correlation, t-test, and regression models. However, the overview of the research flow was given in Table 4. Another model called the Water Scarcity Vulnerability Index (WSVI) developed by Inkani (2015) was also used for the data of the problem, where the households' total water availability and demand were used for its computations. The model expresses vulnerability in percentage that ranges between 1 and 100 – the higher the percentage, the higher the corresponding susceptibility to the water scarcity and vice versa. For the interpretation of the extent of the vulnerability, Table 4 shows the definition of the problem. The model assumed that:

$$WSVI = 1 - \left(\frac{HWA}{HWD}\right) X\ 100 \qquad (1)$$

Where:
WSVI = Water Scarcity Vulnerability Index; HWA = Household Water Availability; HWD = Household Water Demand; 1 is the value of water sufficiency a household should have if all its water demands are met

Table 4. Interpretation Table of the Water Scarcity Vulnerability Index

Water Scarcity Vulnerability Class	Water Scarcity Vulnerability Index	Water Scarcity Definitions
I	0%	No Water Scarcity
II	0 – 5%	Low Water Scarcity
III	6 – 15%	Moderate Water Scarcity
IV	16 – 35%	High Water Scarcity
V	Above 35%	Acute Water Scarcity

Source: Adopted from Inkani (2015)

The water availability, demand, and vulnerability to scarcity, the independent variables of the study, in the study zones, Kerri-Kerri Formation, Chad Formation, and Fika Shale, which served as the dependent variables, were subjected to linear correlation analysis, to ascertain the extent of the problem. The assumptive validation of the simple linear correlation analysis states that:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - \sum(x)^2}\ \ \sqrt{n\sum y^2 - \sum(y)^2}} \qquad (2)$$

Where:
n = study population; x = independent variables (WA, WD, WSV); y = dependent variables (FKS, KKF, CDF)

The statistical t-test analysis of the differentials in the per capita water availability amongst the study zones was computed in SPSS, which assumed that:

$$(3)$$

$$t = \frac{x - \mu_o}{\frac{s}{\sqrt{n}}}$$

x = sample mean; μ$_o$ = population mean; s = sample standard deviation; n = sample size

The simple linear correlation analysis shows that two study zones have enough statistical evidence to prove the incidence of the water scarcity were regressed to establish the depth of the problem. The data assumption of the regression model has it that:

$$WSV = KKF + CDF \tag{4}$$

$$WSV = \beta_o + \beta^1 KKF + \beta^2 CDF \tag{5}$$

Where:
WSV = Water Scarcity Vulnerability; KKF = Kerri-Kerri Formation; CDF = Chad Formation

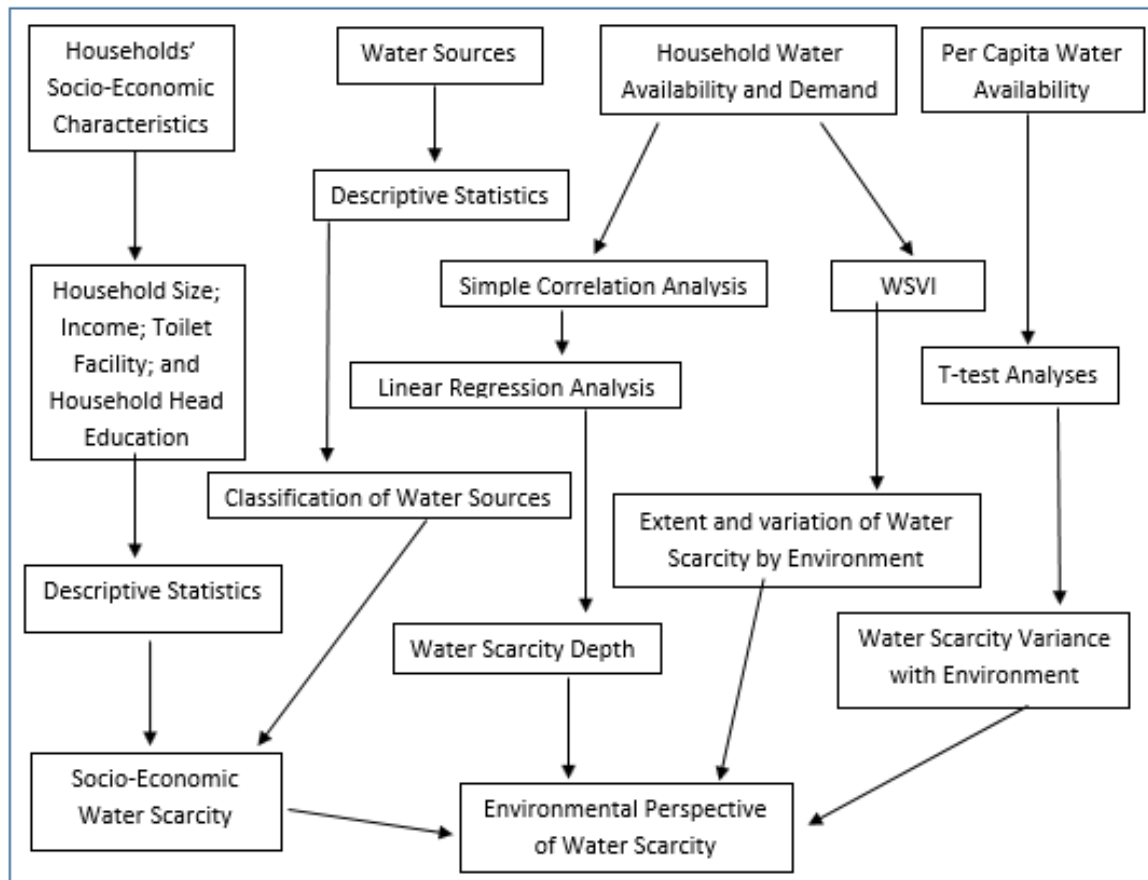Figure 3 summarizes the flow of the study and all the steps taken in completing the analysis.

Figure 3. Research methodological flow chart

4.   Findings of the Study

The findings of the study which expressed the situation of the issues under investigation are presented under various sub-headings below.

4.1   Households' characteristics

The study demonstrated that the extended family system in practice in the area since the mean household size, as shown in Table 5, is fourteen members in both Chad Formation and Kerri-Kerri Formation, whereas Fika Shale has ten members. The households' size is higher above the national average size of five members, which may be one of the reasons why the primary education was the mean attained by most of the population (see Table 5). The households' monetary income profile, as given in Table 5, shows that an average household generates ₦18,886 ($52.5), ₦10,035 ($27.9), and ₦12,982 ($36.1) per month in Fika Shale, Kerri-Kerri Formation, and Chad Formation, respectively (see Table 5). These revealed an alarming poverty level of the households, with potential implicate their purchasing power and consumption. However, the commonly used toilet facility (see Table 5) was the traditionally shred pit latrine, which is one of the conventionally classified unimproved facilities, polluting the environmental air quality and increasing exposure to diseases.

Table 5. Households characteristic variables

	Fika Shale				Kerri-Kerri Formation				Chad Formation			
	HS	HHE	HMI	HTF	HS	HHE	HMI	HTF	HS	HHE	HMI	HTF
Mean	14	Primary	18886	SPL	14	Primary	10035	SPL	10	Primary	12982	SPL
Max.	18	Tertiary	40000	SAS	18	Tertiary	40000	SAS	18	Tertiary	40000	SAS
Min.	3	None	5000	ODP	3	None	5000	ODP	3	None	5000	ODP

HS = Household Size; HHE = Household Head Education; HMI = Household Monthly Income; HTF = Household Toilet Facility; SPL = Shared Pit Latrine; SAS = Soak-Away System; ODP = Open Defecation Practice

4.2   Domestic water sources

The households' sources of water for daily supplies in the study area were the public boreholes (21.8%), hand-dug wells 50.8%) and surface water bodies (27.4%) (see Figure 4). It shows that the borehole facilities, being part of improved water sources, guarantees water quality and adequacy, was used only by about one-in-five of the total population, which is grossly inadequate for meeting the ambitious agenda of the SDG 6. However, the dug-wells and the surface waters, are unimproved water sources, but services the water needs of the greater share (78.2%) of the population, though remain potentially implicative to health and economy.
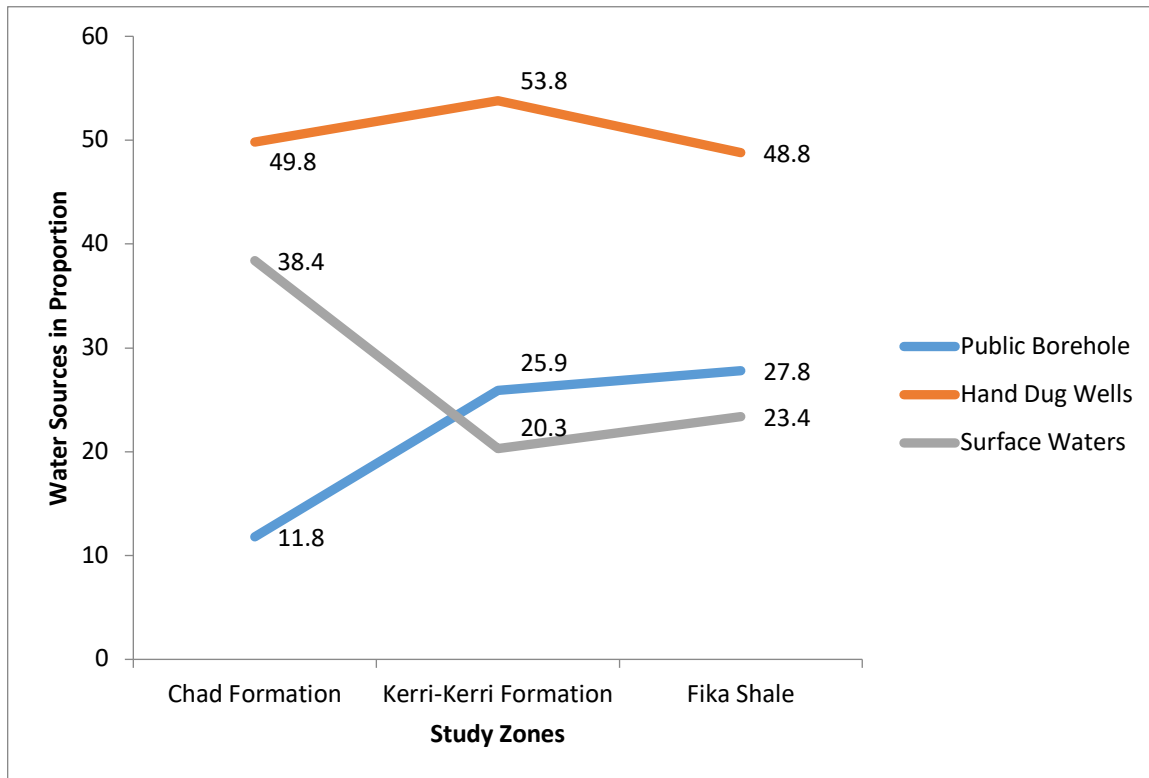
Figure 4. Proportion of Water Sources

4.3 Water Availability and Scarcity Vulnerability

The descriptive analyses as shown in Figure 5 revealed that an average household in Fika Shale access 190 litres of water supply – which stands to be the 40.5% of the demand (447 litres), indicates a deficiency of 257 litres daily, meanwhile the per capita water availability was 50% (19 litres) based on the UNDP standard of 38litre/person/day. Figure 5 further shows that in Kerri-Kerri Formation, 172 litres of water (50%) of expected daily water demand (344 litres) were available for an average household, and the only 16 litres (42.1%) were accessible by a person in the zone. In the same vein, the situation in the Chad Formation highlights that the daily water supply for an average household was about 171 litres, running short of 192 litres of their demand, and the per capita water accessibility was 24 litres (63.2%) relative to the demand (see Figure 5). However, the overall proportion of the population vulnerable to the incidence of scarcity closely relates to the outcome of the WSVI, the differences in the water availability, demand, and vulnerability to scarcity might be a reflection of the physical environmental conditions of the study area.
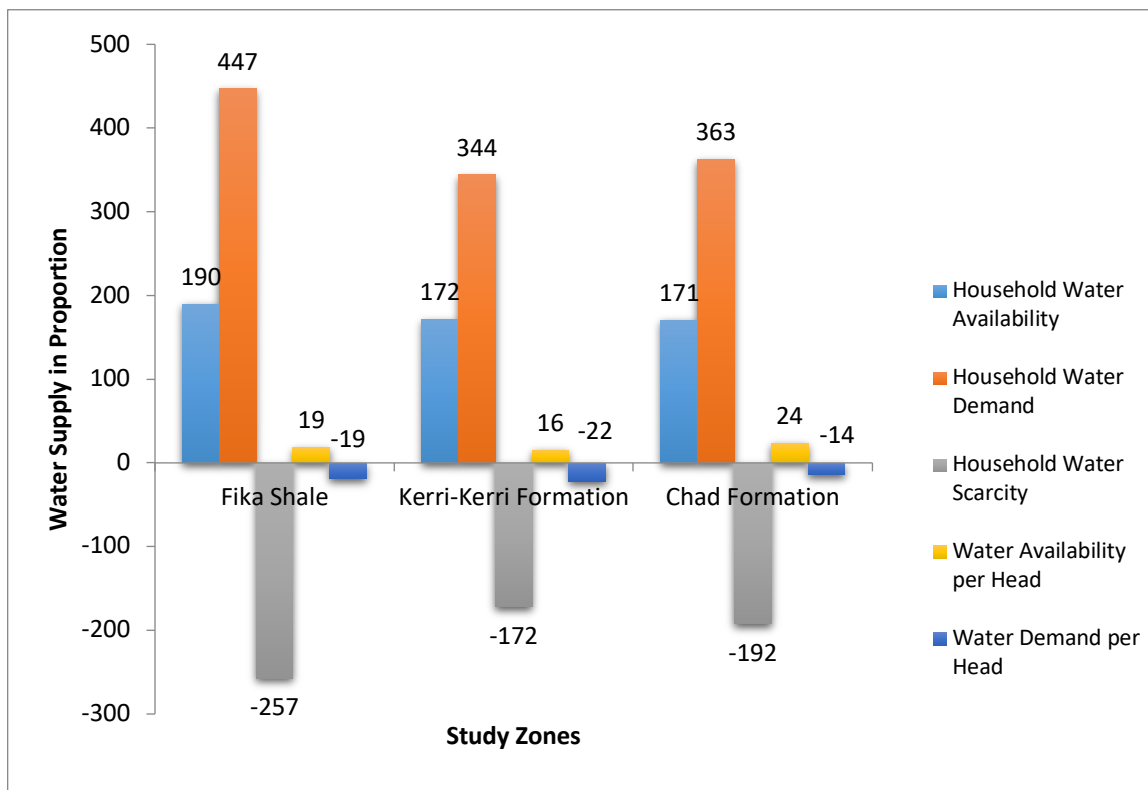
Figure 5. Average households water supply dynamics

4.4 Water Scarcity Computations using WSVI

The WSVI analyses in Table 6 demonstrated that 1.8%, 37.7%, and 58.7% (98.2%) of the studied households in Chad Formation, as shown in Table 6, have falls into the categories of the 'Moderate Water Scarcity', 'High Water Scarcity' and 'Acute Water Scarcity', respectively, while 1.8% experiences 'No Water Scarcity'. Table 6 maintained that in Kerri-Kerri Formation, 29.8% and 64.9% (94.7%) of the households were in the 'High Water Scarcity' and the 'Acute Water Scarcity' levels, as 5.3% demonstrated immunity to the problem. In the zone of Fika Shale, as highlighted in Table 6, 40.6% and 58.5% (99.1%) of the households were suffering from the 'High Water Scarcity' and the 'Acute Water Scarcity' respectively. These findings established that about 97.3% of the households in the study area were water deficient, which invariably suggests their vulnerability to diseases and other socio-economic challenges.

Table 6. WSVI model summary

Water Scarcity Vulnerability Index	Study Zones		
	Chad Formation	**Kerri-Kerri Formation**	**Fika Shale**
No Water Scarcity (0%)	1.8%	5.3%	0.9%
Low Water Scarcity (1 – 5%)	0%	0%	0%
Moderate Water Scarcity (6 – 15%)	1.8%	0%	0%
High Water Scarcity (16 – 35%)	37.7%	29.8%	40.6%
Acute Water Scarcity (36% - above)	58.7%	64.9%	58.5%

Source: Fieldwork, 2019

4.5 T-test analyses of the per capita vulnerability to water scarcity

The findings of the t-test analyses, shown in Table 7, revealed that there is a statistical difference of 12 litres of water per head between Kerri-Kerri Formation and Chad Formation; 5 litres between Keri-Kerri Formation and Fika Shale; another 5 litres between Chad Formation and Fika Shale (see Table 7). The variability in the per capita water availability is statistically large, especially between Kerri-Kerri Formation and Chad Formation - which stands to be about 32% of the expected daily water sufficiency per head.

Table 7. T-test results of the water per head difference

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Kerri-Kerri Formation – Chad Formation	11.54	39.12	5.18	-21.92	-1.16	-2.23	56	.03
Pair 2	Kerri-Kerri Formation – Fika Shale	5.19	29.69	3.93	-13.07	2.69	-1.32	56	.19
Pair 3	Fika Shale – Chad Formation	5.29	35.77	3.47	-1.59	12.19	1.53	105	.13

4.6 Linear correlations and regression of water scarcity variables

The water availability, demand, and exposure to scarcity were modelled using simple correlation analysis and presented in Table 8. It indicates that Chad Formation has a statistically insignificant relationship with the variables and lacked enough evidence to prove the presence of the problem. Kerri-Kerri Formation also revealed insignificant relationship with the water availability and susceptibility to scarcity, while the water demand was positively significantly related with Kerri-Kerri Formation at 95% confidence limit (n = 315, α = 0.05, p-value = .028, r = .132). The situation in Fika Shale, as shown in Table 8, revealed that the water availability was positive and significantly associated (n = 315, α = 0.01, p-value = .009, r = .157) at 99% level of confidence, while the vulnerability to water scarcity was positive and significantly influenced (n = 315, α = 0.05, p-value = .029, r = .131) at 95% confidence limit.

Table 8. Correlation Matrix

		Water Availability	Water Demand	Water Scarcity Vulnerability
Chad Formation	Pearson Correlation	-.073	-.033	-.024
	Sig. (2-tailed)	.224	.581	.686
	N	315	315	315
Kerri-Kerri Formation	Pearson Correlation	-.066	.132*	.034
	Sig. (2-tailed)	.271	.028	.574
	N	314	314	314
Fika Shale	Pearson Correlation	.157**	.080	.131*
	Sig. (2-tailed)	.009	.183	.029
	N	315	315	315

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

4.7   Linear regression model

Kerri-Kerri Formation and Fika Shale which were found to have statistically significant relationships with the dynamics of water supply were subjected to a linear regression model to ascertain the extent of the Correlations. The model highlighted that the variables accounted for 42% of the water supply problems in the study area (see Table 9) and statistically significant (see Table 10). This scientific basis establishes that water scarcity challenges were more profound in the two zones, which points to the environmental biasness of the problem.

Table 9. Linear Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.454[a]	.427	.421	17.7316652

a. Predictors: (Constant), Kerri-Kerri Formation; Fika Shale

Table 10. The ANOVA of the Linear Regression Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	64051.924	2	21350.641	67.907	.000[b]
	Residual	85834.463	313	314.412		
	Total	149886.387	315			

a. Dependent Variable: Households' Water Supply
b. Predictors: (Constant), Kerri-Kerri Formation, Fika Shale

4.8   Discussions of the study findings

The mean household size of the study area, 13 members, implied a 160% increment to the national average of 5-member household, and similarly affirmed the practice of the extended family system, which is usually driven by labour demands. The large-sized households could also lead to high demand for water, especially during the COVID-19 pandemic that advocates for more sanitary concerns. Studies by Irianti *et al* (2016), Abubakar (2019), Victor *et al*. (2019), and Simelane *et al*. (2020) found household size as a statistically significant determinant of domestic water consumption and increased water expenditures. Another study by Armah *et al.* (2018) concluded that households with small sizes are more likely to have access to adequate and improved drinking water sources than large-sized ones. These proved that the studied households are likely to have high water demands, shortage of which may constitute socio-economic implications. The primary education found to be level attained by an average household is less than the national basic literacy expected for all Nigerians, which formed part of human rights. This poor feat in education amongst the population threatens SDG 4 and could influence access to less water and management of resources might result in the competition. Though Simelane *et al*. (2020) found education as a statistically insignificant factor in household access to the improved drinking water sources, other studies by Kithinji (2015), Adams *et al*. (2016), and Abubakar (2019) reported the literacy level as a determinant of access to improved water supply, with statistically significant influence on the water consumption. Additionally, the high vulnerability of the households to poverty, with the grossly poor monetary income generation to the national poverty benchmark of ₦137,430/person/year, shows that the social and economic challenges of the studied people might be huge. This is because the poverty extent challenges the attainment of the SDG 1, though was projected by the United Nations (2020) to be hardly achieved. It is especially the COVID-19 ambush on the global health and development components that increases the poor population and weakens efforts toward its coverage by the year 2030 (Sumner *et al*., 2020). Moreover, the famous means of sanitation were found to be sharing of the unimproved pit latrine in the study area, which

negates the strides in SDG 6.2 and increases exposure to water contamination, diseases, and poor environmental conditions. The World Health Organization (WHO) (2010) as quoted by Inkani (2015) for instance reported 90% of rural households in Nigeria as vulnerable to water-related diseases and one-tenth of each person's productive time is sacrificed to the treatment of such diseases. Rajgire (2013) and Okullo *et al.* (2017) added that an estimated 80% of diseases and one-third of deaths in developing countries, which the study area is part of, are attributed to the consumption of contaminated water. Balogun *et al.* (2017) demonstrated further that improvements in water supply contribute to health equity by reducing the link between poverty and diseases, prevents approximately 2.4 million deaths annually, and averts 7% of the global burden of diseases and 19% of child mortality.

Furthermore, the study findings show that the overwhelming majority of the studied population depend on the unimproved water sources, which aligned with Sule *et al.* (2016), specifically open wells and surface waters, according to the classification of the WHO/UNICEF (2006) as quoted by Obeta & Chikwu (2013) as well as Bukar & Daura (2015). These water sources are not only prone to seasonal and climatic variations, but also the positive changes in the demographics of the area, in addition to health risks. A study by Toyobo & Taniowo (2011) highlighted that reliance on such unsafe water remains the most important cause of poor health, food insecurity, the low pace of socio-economic development and attributed the prevailing water crisis to poor sustainability of the infrastructure, paucity of funds, inadequate technology and lack of political will. Additional kinds of literature (Fair *et al.,* 1971; Tebbutt, 1991; Steel & McGhee, 1991; Metcalf & Eddy, 1991; John De Zuane, 1996 as quoted by Lukman *et al.,* 2016) described the detailed impurities in such water sources and need for prompt treatment before consumption. The prevalence of water-borne diseases such as diarrhoea, typhoid, and malaria fever could be linked to the nature of the water sources. It was further observed that the water provision from these sources involves distant trekking of more than a kilometre and about minutes are usually lost per round trip of the activity, which includes queuing and transportation. This contradicts the recommendations of the WHO (2010) as quoted by Inkani (2015). The annual loss of 40 billion productive hours and 443 million school days to fetching water in sub-Saharan Africa (UNDP, 2006) has the potential to magnify the decline in socio-economic productivity, growth, and development of the population, especially the neglected rural poor.

As the descriptive analyses have shown, only about 54.1% of the studied population expressed the inadequacy of the accessible amount for water in their households, whereas the WSVI highlighted more than 90% of the households into the water scarcity vulnerability scenario, as most water sources in the area fall into the category of the unimproved. Studies by Offodile (2002) and Makinde *et al.* (2010) demonstrated that despite the promising groundwater potentials in the Chad Basin, which this study area is part of water yields decrease away from the Lake Chad due to the climate change events. The groundwater in the zone occurs mainly under water table condition, locally in confined or semi-confined aquifers and chiefly recharge by precipitation (Okosun, 1995; Oruenye, 2009; Audu, 2017; Yusuf *et al.,* 2018) as studied have shown, which could also be prone to climatic variability. However, the levels of the problem in Fika Shale might not be unconnected with the water-bearing aquifers of the geologic formation, though the clayey characteristic of the area retains water in the rock fractures for various uses including domestic provision. This is because, the Fika Formation is reported to have limited aquifers in extent, confined to the fracture and weathered zones, resulting in poor water yields due to its argillaceous nature (Okosun, 1995; Ofodile, 2002). The general finding has affirmed the report of the WHO (2010) as quoted by Inkani (2015) that only 32% of the rural population in developing countries have access to safe drinking water supply, which might be associated with the overbearing dependency of the people on the unimproved water sources. It also threatens the attainment of the SDG 6, the African Water Vision as well as other local initiatives. However, the pattern of the water scarcity reflects the differentials in the physical environmental conditions, against the conclusion of Inkani & Mashi (2016) in the rural setting of Katsina State, Nigeria that water scarcity tends to decrease from the south to the

north in the reflection of the rainfall amounts. The extent of the water crisis was evaluated using inferential statistical models, which shows significant results.

The t-test analysis has established a difference in the water per head amongst the study zones, especially between the Kerri-Kerri Formation and Chad Formation, which is found to be 32% of the expected daily water sufficiency. While it asserts that the geologic condition of the area is a significant factor in water accessibility, such the difference may be due to the variability in aquifer characteristics. It also reflects the general geography of water availability in Africa with a tendency to have water scarcity increase with the distance away from the equator especially to the north. Studies by Fagoyinbo (2015) and Obeta & Nwankwo (2015) opined that the variation in the water yield of the aquifers is a function of geologic characteristics and the interplay between rock fractures in the aquifer - which provide storage and recharge to the bedrock. As such, the correlation analyses of the households' water supply dynamics and the study zones, computed using SPSS, revealed that the Chad Formation has insignificant relationships, while Kerri-Kerri Formation and Fika Shale have significant associations at certain levels. Thus, the significantly related variables were subjected to linear regression model analysis and indicate a significant relationship as 42% of the susceptibility to the water scarcity is accounted for by the variables.

5.   Conclusion and Recommendations

The household size, with thirteen members, remained large since it is 260% higher than the national average of five members and the water demand may increase. It also revealed that primary education was the mean attained by the average household heads, with implications on the overall livelihood system of the area, especially that domestic water sourcing and management are central. The ₦13,967 monthly income of the average-sized households in the study area is grossly inadequate to meet up the growing demands, as the COVID-19 pandemic has led to increase in water demand for complying with the safety measures. The study further demonstrated that boreholes, hand-dug wells, and surface water bodies were the water sources relied upon by households, and the high use of unimproved water sources was evident, despite its potential to contaminations and disease-prone conditions. However, the average household in Fika Shale, Kerri-Kerri Formation, and Chad Formation was managing to use 40.5%, 50%, and 47.1%, respectively, of their daily water needs. This conveyed that it is only in the Kerri-Kerri Formation that the MDGs' water target was met. The water scarcity findings of the WSVI analyses demonstrated that 98.2%, 94.7%, and 99.1% of the studied households in Chad Formation, Kerri-Kerri Formation, and Fika Shale, respectively vulnerable to the conditions.

Further analyses by linear correlation indicate that Kerri-Kerri Formation and Fika Shale have statistically significant relationships with the water consumption dynamics of the area. Besides, the regression model of the two study zones highlighted that the variables statistically accounted for more than 60% of the water supply problems in the study area. The study concluded that the emerged pattern of vulnerability to water scarcity in the study area was attributed to the spatial difference in the environmental conditions and the complex nature of human existence. Therefore, the mainstreaming of both the physical environmental conditions into the rural water policies would work towards addressing the problem. The community-managed improved water supply systems should be provided to meet up with the daily water demand, reduces vulnerability to disease, and the water users be regarded as stakeholders – in the initiation, implementation, and maintenance of the water sources. The indigenous strategies of coping with the water scarcity use by the locals should be strengthened by authorities through training and campaigns. There is also the need for relevant stakeholders to increase research funding in the area of domestic water supply and livelihoods, especially in rural places, to generate scientific data for proper planning and development activities.

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